Clash Characterization and Matrix Analysis Between Building Systems in BIM-Based Construction Projects

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DOI: https://doi.org/10.30880/ijscet.2025.16.02.004

Abstract

Clashes in construction projects are among the key factors that reduce the efficiency of project delivery. In traditional 2D-based design, these clashes are difficult to detect because architectural, engineering, and construction (AEC) systems are not integrated within a unified platform. In contrast, Building Information Modeling (BIM) enables effective clash detection through specialized tools such as Revit and Navisworks. This study evaluates the effectiveness of clash detection by comparing the BIM process with conventional 2D drawings and identifies the main factors contributing to clashes in AEC models. Furthermore, it examines the interrelationships of clashes among different models within the BIM environment and develops a clash analysis diagram to facilitate their identification. Finally, the study proposes several solutions aimed at minimizing clashes during the design phase of construction projects when applying BIM.

1. Introduction

Building Information Modeling (BIM) is an effective process in the construction industry today. It provides a digital copy and integrates information about structure, form and and potential solutions to support the completion of construction projects [1] . According to ISO 19650 standard, the coordination between disciplines, rationalization of data management and optimization in construction projects, in which the coordination between the three systems of architecture, engineering and construction (AEC) has created a complete BIM data for the project [2] . However, the coordination between different fields and human resources often leads to clashes in the BIM process [3] . The core of clashes in the BIM is the multi-disciplinary coordination on the same data platform [4] [5] . This clash reduces performance of the construction project and if this clash is not detected early, errors will appear during construction and construction process may occur.

The project's Common Data Environment (CDE) serves as the central repository for all project-related information and data, where AEC disciplines collaborate. It also facilitates coordination with contractors and facility managers [2]. In Vietnam, CDE guidelines have been issued [6] , with guidelines for using CDE for projects.

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However, in the current context of applying BIM, effective coordination on the shared data platform (CDE) remains a challenge [7].

Currently, asynchronous cooperation between the fields of architectural engineering, structural engineering, and mechanical, electrical, plumbing (MEP) engineering frequently occurs [8] [9] , particularly during the design stage. Recently, the clash analysis in the BIM has received increasing attention, with various solutions proposed to solve the clash problem. In which, the clash analysis software in BIM [10] is commonly used such as Revit, NavisWorks or Dynamo, etc. When analyzing clashes, each field of AEC can quickly analyze the clashes and list the details [11] . However, when architectural, structural, and water supply and drainage models are integrated into a BIM project, the identification of clashes becomes more complex [12] . This complexity arises from persistent challenges in the coordination and management of BIM projects.

In the BIM standards of ISO 19650 [2] and IFC (Industry Foundation Classes)[13], the BIM models are established and work together in a model to handle arising problems. In this context, the benefits of BIM are evident in the early detection of clashes, which ensures effective use of the CDE and strengthens data management. Additionally, the CDE is a clearly defined basis for coordination in planning, enhancing teamwork and quality control [2] [6]. The application of IFC in clash detection is established based on ISO standards (ISO 19650:2018, ISO 10303:1994, the buildingSMART - 2020) and algorithmic solutions have shown good results in the clash detection [14]. The IFC data for BIM has helped in establishing automatic code checking systems, such as CS (Corenet System) or SMC (Solibri Model Checker), etc., which have helped in defining clash detection in the BIM [15].

In addition, the application of Machine Learning algorithms in BIM clash detection has also been mentioned a lot, such as the application of Modified Extreme Gradient Boosting (MXGBoost) algorithm [16] , which improves the performance of clash detection in BIM. Algorithms such as Decision Tree (DT), Random Forest (RF), Support Vector Machine (SVM) and K-Nearest Neighbors (KNN) have been also integrated to increase the performance based on clash reporting with an accuracy of 80% [17]. Another survey showed that the clash detection accuracy was 84% when applying artificial neural networks [18]. In some reviews, Machine Learning Algorithms have been integrated into BIM for collision detection, the clash detection results are very promising and the sensitivity in the clash detection is high [19] [20] [21] [22] .

In parallel, the application of Augmented Reality (AR) techniques to the BIM process to simulate construction has been studied in many roles, such as building energy testing [23] and building facility management [24]. In addition, the application of Blockchain in the BIM process has also been considered. Such as the application in construction design information management [25], or decentralization of data storage and minimizing risks from construction operation errors [26], or considering Blockchain as a solution to automate the entire construction process and improve construction industry productivity [27]. Integrating the internet of things (IoT) into BIM to control information, improve construction efficiency and enhance operational management [28]. Furthermore, Industry 4.0 technologies applied in construction promote automation across the stages of design, management, construction, and operation [27].

As seen, clashes in construction are critical factors that automation processes must address and analyze from the design stage. In practice, clash resolution is often slow [16] , especially with 2D technology, the clash will be difficult to detect [29] and 2D technology will increase construction costs when clashes occur. The automation of clash resolution is also very complicated, in which, the databases used to analyze clashes are difficult to fully establish for each type of construction project [13] .

Thus, clashes in a construction project represent a major challenge that must be identified at the design stage. Identifying clashes also contributes to minimizing project risks and reducing construction costs [30] [31]. In addition, applying BIM or integrating Machine Learning algorithms into the BIM provides effective solutions for detecting and resolving clashes [11], but the development of a comprehensive clash database remains a key factor in ensuring accurate identification [32]. Therefore, this study will collect data on models in the BIM process and analyze the construction fields (architecture, structure and MEP), potential clashes of models in the BIM and finally propose a database to detect clashes according to the BIM process for construction projects.

2. Method of Studying

The study of identifying clashes in BIM was conducted based on the principle of analyzing the structures of architectural, structural and MEP models, thereby identifying potential clash factors in each field. The next step was to identify potential clashes when the disciplines were integrated in the BIM process. The identification of potential clash factors will serve as a database for the clash analysis (manual methods, work experience), the clash prediction (by machine learning methods) and recommendations for improving coordination in the BIM process of construction projects.

The research was carried out with the steps as follows (Fig. 1):

- Step 1. Collecting documents on the causes of conflicts and methods for detecting clashes in BIM. In this step, analyzing the steps of implementing construction projects using the traditional method and the method of applying the BIM process. Then, determining the effectiveness of the BIM in the construction and the factors influencing the BIM process.
- Step 2. Study of the factors that significantly affect the BIM process, thereby identifying the factors that cause clashes in the BIM process. In which, analyzing of the mandatory application of BIM in Vietnam from 2025, evaluating the characteristics of conflicts in implementing construction projects using traditional methods and BIM procedures. In addition, analyzing the actual effectiveness of applying BIM to construction projects.
- Step 3. Reviewing internal clashes in each system (architecture, structure, MEP), then identifying potential clash factors between the systems.
- Step 4. Assessment of the importance of each type of the clash and the clashes between construction systems, the study analyzed the conflict matrix and identified the factors that could change if conflicts occur.
- Step 5. Analyzing and evaluating the limitations of the clash detection and establishing the clash mitigation solutions. The mitigation solutions are analyzed for each cause of the clash, establishing the clash warning table between the parties and the clash prevention solution diagram.
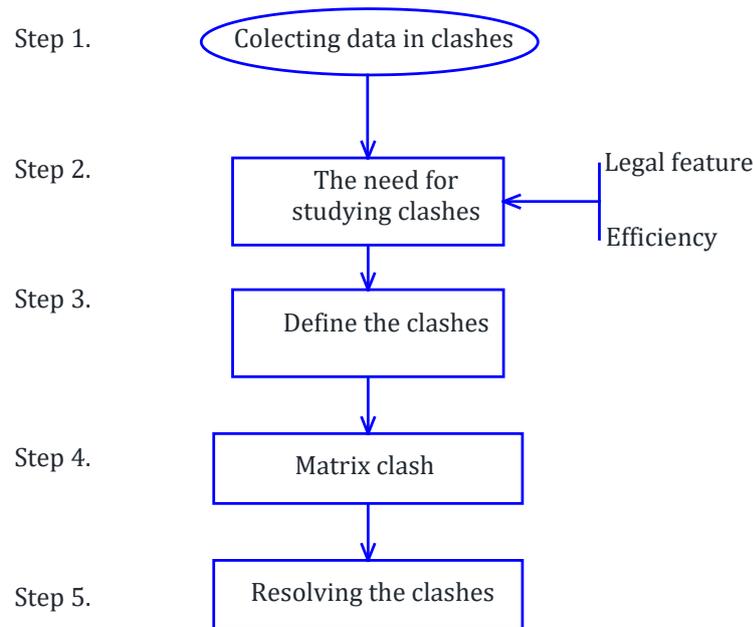

Fig. 1 *Plan for identifying potential clashes in the BIM process*

The research focuses on identifying clashes, to help the design phase be more complete. So that investors, design units and contractors have a clearer view of clashes. At the same time, in the process of integrating automatic tools for the clash detection (Machine Learning algorithms), there will be a basis for collecting influential data fields and target data in the research.

3. Research Basis

3.1 Legal Basis in Vietnam

BIM application in Vietnam started in 2017. The Government decided to establish a National BIM Steering Committee (Decision 203/QD-BXD [33]) to deploy BIM application and development activities. Through many stages of BIM development, the facilities and conditions for applying BIM in Vietnam have made progress, especially the number of BIM application projects has increased over time (According to the National Online Bidding System, in 2022, there was only one BIM application construction project proposed in the Bidding Documents. But by 2024, there were 64 projects requiring BIM in bidding)[1].

Construction solutions with BIM processes have become popular due to the strong direction of the government. In particular, Decision 258/QD-TTg (April 2, 2021) requires projects from level 2 to apply BIM (according to project classification standards in Vietnam) [34].

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Currently, BIM has become a process that is mentioned a lot in construction projects in Vietnam, the process of applying BIM has been supported and promoted by the Government to each locality. However, the application of BIM in practice still has many difficulties, especially the problem of human resources in the BIM. Therefore, analyzing the effectiveness of the BIM plays an important role. Among these factors, clashes in construction projects according to the BIM process are one of the factors that play a practical and effective role in project design.

3.2 Analyzing of the Clash Characterization According to a Traditional Technology and the BIM

To have a clearer assessment of the effectiveness of clash detection according to the BIM process, the study surveyed the actual assessment and workflow, some of the problems in the construction project conflict are analyzed and listed, this process is compared between 2 forms of work processing: work processing by the conventional method with 2D drawings and the BIM process [35].

Considering an example of a water pipe design running under a beam. If the water pipe runs under the bottom of the beam, there will be no clash, but if the pipe runs under the floor, there will be a clash with the beam. Analyzing between the traditional method and BIM, some impacts shown in Table 1 as follows.

Table 1 *Characteristics of clash in construction*

Basic features	Detecting clashes in construction works	
	Traditional method according to 2D drawing	Application Method by BIM Process
Methods of determining clashes	Manual detection by eye, experience and during construction. E.g., Impossible to visualize whether the pipe will cross the beam, because the elevation between the members is not clear on the 2D drawing.	Automatic detection by software: Autodesk Navisworks; Autodesk Revit; Autodesk Construction Cloud; Autodesk BIM 360; Solibri Model Checker and BIMcollab. E.g., Using Revit software for simulation, the clashes can be located immediately on the model.
How to handle clashes	Most clashes are identified during the construction phase, making it difficult to correct or find a way to legalize the clash. E.g., Pipe clashes with beam, then the opinion of the parties needs to be consulted to drill the beam or route the pipe around the beam.	The clashes can be handled during the design phase. E.g., Clash handling at the design stage, pipe elevation correction so that the pipe runs under the beam right from the design stage and no clashes occur during construction.
Cost Impact	The cost of resolving clashes increases project costs, wastes materials, and extends construction time. E.g., When drilling beams, or bending pipes under beams, additional costs are added: Labor costs and material costs. When water pipes operate at curved angles, hydraulic losses are caused.	It reduces rework costs and it can change the construction process through early clash resolution. E.g., When the pipe is designed with the appropriate elevation, the pipe runs under the beam, without any clash. Then there is no cost for processing at the location where the pipe runs through the beam.
Construction schedule	It can often be delayed due to unexpected issues that arise on site. E.g., When a clash occurs with a pipeline cutting though a beam, the project must be stopped to revise the design, submit it to the investor and design unit for approval, and then construct according to the revised plan.	Faster project implementation through well-coordinated activities. E.g., The clashes are resolved early in the design process, construction progress is not interrupted due to pipeline design modifications.

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Coordination at work	Building systems work separately, without coordination on the 3D model system, it will lead to uncontrollable clashes. E.g., The fields of architecture and plumbing are not connected, they are mostly separated in design. These clashes are not foreseen in the design, but will appear in the construction stage.	Synchronizing work between work groups, the models in the BIM must be set up through the CDE system. E.g., When working together on a model in Revit, the parties (AEC) will interact with each other, and method editing will take place immediately if the clashes occur.
Accuracy of components	When the structure of the systems in the building is not visible, so the geometrical structures of buildings are difficult to determine precisely. E.g., When designing the pipes, the clashes cannot be predicted, leading to changes in the geometric dimensions of the pipes during construction (such as the pipes being bent many times).	The 3D model in the BIM process has absolute accuracy for components. It increases the accuracy in installation and project drawings. E.g., The pipes will be properly identified, not reworked on site.
Risk and Safety Management	The risks of project are difficult to identify accurately. In fact, it introduces unexpected factors. E.g., if the construction encounters clash between the water pipe and the beam, and the method of drilling beam is used, then the drilling position and beam processing technique will be complicated, and more seriously, it can reduce the bearing capacity of the beam and cause instability to the construction.	Controlling risks, analyze clashes and resolve them early. Reducing waste and increase investment efficiency for the project. E.g., During the plumbing construction phase, the integrity of the components will be controlled, with no impact on the structure and water supply system.
Decisions	The response reactions are often slow to be implemented, must follow a long process and through many steps, many units for approval and editing. There are clashes causing the suspension of the project. Sometimes, the funding process for the project must be redone. E.g., A decision on clash resolution will not be made, because the clash between the beam and the pipe is not detected.	The conflict issues are resolved right from the design, between partners in the project, with the initiative to respond to information: investors, design consultants and construction contractors. Main decision is on cost and solutions to change works if clashes appear, there is no need for administrative procedures and direct conferences between partners in a project. E.g., Immediate decision making on treatment options. Pipes that bend around beams or change pipe elevation. The clashes do not appear during construction.

From Table 1, it shows that the BIM process makes more accurate decisions for the project, the change of the project decreases and the exact cost of the project can be determined. The clash in the project plays an important role in completing a construction project.

3.3 Practical Basis for Conflict Detection Efficiency

Clash detection is an important and highly effective process in project design that applies the BIM process. Research shows that clash detection has helped the project gain some advantages as follows:

- *Saving investment costs:* When clashes are detected, these clashes are checked and corrected right from the design stage.

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In Vietnam, the Vietinbank Tower project detected and resolved over 1,500 clashes during the project's design[36]; Controlling the volume during construction time achieved an accuracy of over 95% compared to the design at the Tan Son Nhat Airport Domestic Terminal Parking Project, Ho Chi Minh City. Some other studies show that, for example, the investor saved $135,000 with only a $4,000 investment in BIM tools [37]. Baseline analysis shows up to 33% cost reduction when detecting clashes in BIM compared to traditional design methods (using 2D drawings) [38].

- *Shorten construction progress:* Detecting clashes helps the project avoid maximum project suspension during construction due to conflict factors.
  In other words, the project's delay time is reduced and the work is carried out faster, saving the project time. For example, in Vietnam, the Park Hill 6 project has shortened the progress by about 10%, reduced 8% of rework and about 40% of change processing time during the project's construction [36]. Or in a 3-storey housing project in the Khulna area of Bangladesh, more than 100 clashes were detected, which could save 3 weeks and 400,000Tk (equivalent to 3,273.3 USD) [11]. Evaluating a single rework element also shows the time saved. For example, ss can be seen in Figure 2, re-piping will waste project time and materials.
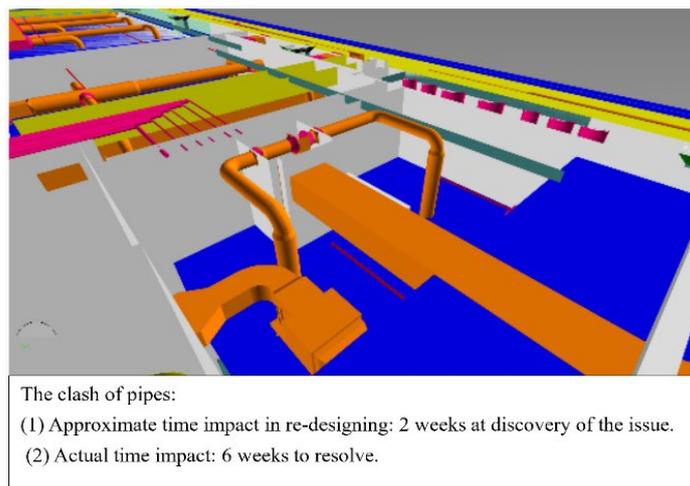

The clash of pipes:
(1) Approximate time impact in re-designing: 2 weeks at discovery of the issue.
(2) Actual time impact: 6 weeks to resolve.

Fig. 2 *Waste caused by clashes between electrical, water and structural systems when integrated on the same model [46]*

- *Enhance collaboration between partners:* The project applies the BIM process to help the project implementation from the design stage with the collaboration of all parties. The owner, investor and design unit (architecture, structure and MEP fields) also participate in a working environment (CDE). Decisions and solutions will be carried out quickly and intuitively with 3D models and online discussions (Fig. 3). Especially the application of cloud solutions for the BIM process.
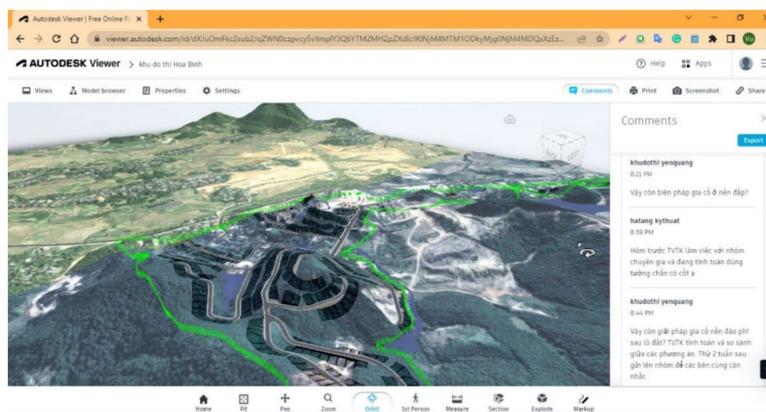

Fig. 3 *Discussion between parties on infrastructure design of Yen Quang urban project (in Hoa Binh pro., Vietnam [1]*

- *Ensure the accuracy of the project:* Early detection of clashes, components will ensure accuracy right from the design stage, to the construction stage, the components will be installed accurately. Especially important for projects using prefabricated components.
- *Minimize project risks:* Detecting clashes, make the project run smoothly, work items will be carried out step by step, dangerous factors will be warned from the design stage. In particular, the work schedule is not interrupted or surprised by a certain stage. For example, the delivery of materials is not on time, such as delivering cement right at the start of the project, leading to a long storage time and difficult storage, which can easily lead to the expiration of the cement or the deterioration of the cement.

Thus, the clashes play an important role in reducing project risk. Identifying and categorizing clashes will help in gaining a clearer understanding of these clashes. The study will classify and list the clashes, as well as their causes.

4. Types of Clash in BIM

4.1 Clash Classification

BIM has been a cutting-edge process in the construction industry for a long time and continues to be one. One of its most important processes is clash detection. A simple example: mechanical ducts clash with beams, or electrical conduits cross plumbing, or structural elements block HVAC access. Such clashes will not only delay the project but also increase the initial cost.

The clash in the construction design is a type of waste. Surveying of the clash classification, it can be divided into the Hard clash, Soft lash and Time conflict [20] , or the Soft, Medium and Hard clash (The description of the clashes is shown in Fig. 4) [37], or Hard, Soft, 4D clashes and Animated clashes [38], or as dividing into Hard clashes, Duplicate clashes and Clearance clashes [39]. However, assessments have shown that the classification of the clashes based on 3 forms of the Hard clash, Soft clash and Workflow or Data clashes is the most complete representation [40] [41].
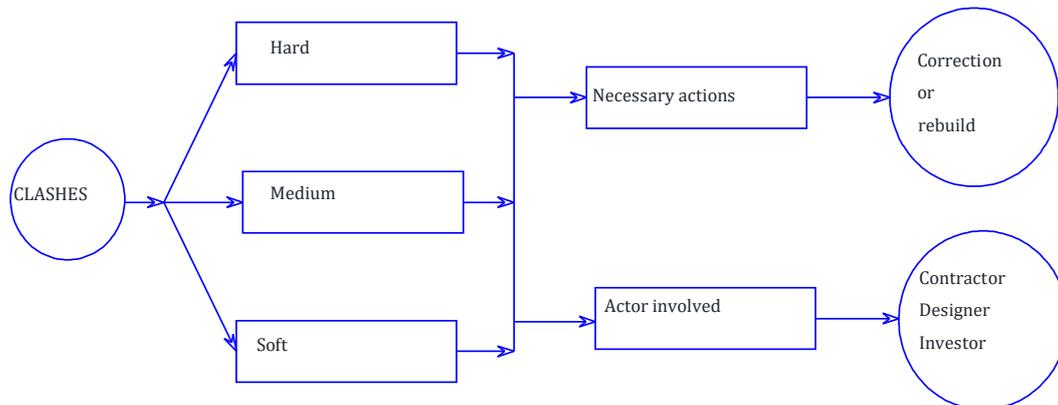

Fig. 4 *Types of clashes divided into soft, medium and hard [37]*

There are three main types of clash:
- **Hard Clash:** The physical conflict of factors, such as water pipes with beams (as shown in figure 5, some clash types between column/beam and pipe with handling method in BIM are shown)[42]. This type of clash is common when elements in the same space and it does not know their coordinates. This clash is often defined in the software of the BIM process.
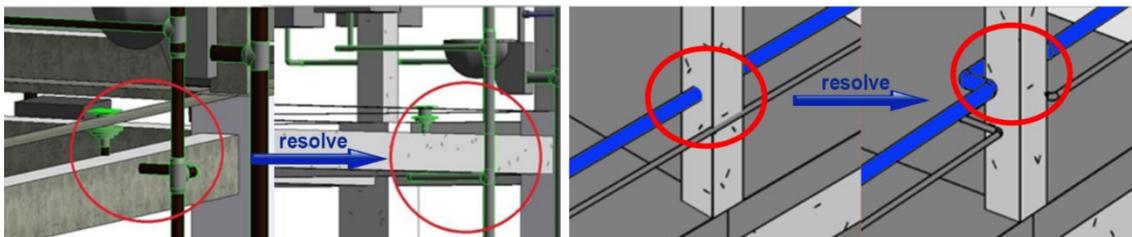-

Fig. 5 *Clash of pipe and beam component [42]*

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- **Soft clash**: This is a type of conflict without intersection between components, which geometric space of inappropriate factors (e.g., the soft clash of the pipeline with the architecture is illustrated in Fig. 6). For example, the water pipe of the toilet has a small distance (Fig.7) [43] or the distance between the toilet and the wall is too small (Fig. 8), so repairs and installations will become more difficult. This type of the clash needs to be resolved early to facilitate later processes.
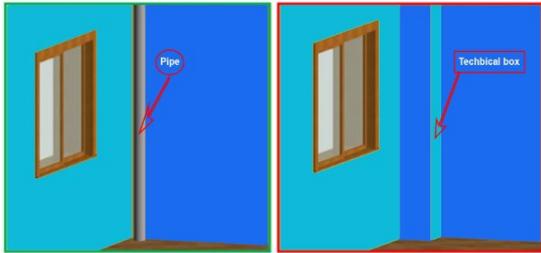
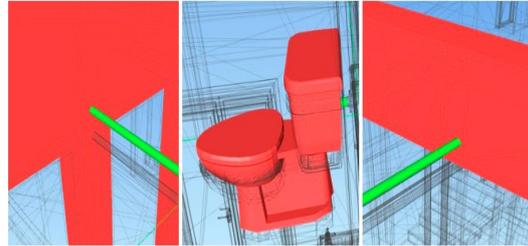**Fig. 6** *Soft clash with pipe is not in the technical box*   **Fig. 7** *The pipe is too short for construction [43]*

- **Workflow or data Clashes:** The type of conflict when the process of operating asynchronous tasks, between areas with interruptions and does not follow the common work process. This type conflict has an impact on many industries and it can make the work delay. For example, the delivery of cement according to the schedule does not match the casting of concrete components.

In the study here, the analysis and evaluation based on the 3D model in the BIM process, the analysis goes into the two basic factors: Hard and Soft clashes. From these clashes, it helps to set data and input conditions for conflict detection processes (manual processes, using machine learning in the clash detection, etc.).
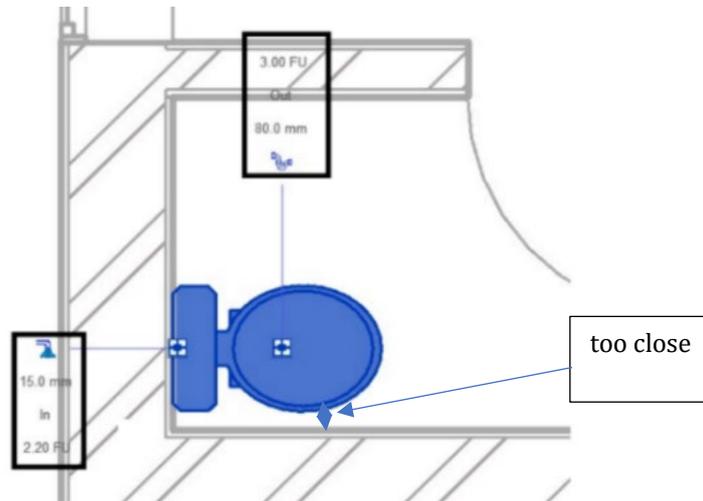
Fig. 8 *The toilet is too close to the wall, making it difficult to construct or use*

The clashes are implemented in each field as follows:

a. Architecture

Setting up a model in BIM based on the architectural structure of the building. A wireframe system is set up and coordinates are determined, then parameters and objects representing architectural components will be included in the model. The software used for the BIM process, the library system has pre-set basic components, if not pre-set, it can be set up additionally. For example, the Family in Revit about iron doors, it will not be available, then it will be set up to be included in the model. The Families in Revit can include walls, doors, windows, floors, etc. These Families will be included in the model to simulate the architectural structure. After setting up, the databases of objects in the architecture have been set up, the geometric structures and materials have been set up.

At this point, architectural clashes will be checked for correction and pinpointed, possible clashes include in Table 2:

Table 2 *Some internal clashes in the architectural model*

Clash name	Description	Correction
Wall and door	Clash caused by doors being inserted into the wall without removing the overlap.	Cutting out the wall with the door
	Clash due to unequal size of wall and door openings	Keeping the door intact, edit the missing or extra wall part.
Partitions and walls in the bathroom	Arrangement of overlapping partitions and walls.	Removing overlapping walls
Location of sanitary equipment	The space of sanitary equipment is not enough or is placed too close together, too close to the wall or partition (Fig. 8).	Adjusting the location of sanitary equipment accordingly
Arranging the stairs and walls	The stairs overlap the wall.	Adjust the wall so that there is no overlap.
Furniture size	Furniture that is not the right size to affect the design layout of the space.	Checking to make sure the furniture is the correct size.

Table 2 describes some internal clashes in the architectural model. These clashes are considered within the architectural system, and the design process must carefully consider the objects to avoid clashes and the structure of the project.

b. Structures

Designing the structure of the building in the BIM also needs to be done in order. First, set up the grid and coordinates, which must match the grid and coordinates in the architectural section. The components of the structure are set up in turn as columns, beams, floors and foundations. Similar to the architectural model, if the Revit software is used and the Family libraries are not enough or have the wrong size and shape, set up new Family. After setting up, simulate the building using the structural components, in which the geometric structures and materials are also set up, these data will be detailed statistics to serve the work of determining the project estimate.

Components of the structural model: Structural floor; Bracing; Structural column; Concrete Stair; Structural Framing; Structural Wall; Structural Foundation.

Internal clashes are shown in the Table 3:

Table 3 *Some internal clashes in the structural model*

Clash name	Description	Correction
Columns and beams	Overlap between columns and beams due to the initial geometrical dimensions of the members.	Removing the overlap of columns with beams.
Floors and columns Floors and beams Floors and technical cells. Concrete walls and columns	Overlap is caused by the geometric dimensions of the components.	Checking each object in detail and removing the appropriate overlap.

Table 3 describes some internal clashes of the structural system, from which these clashes can be clearly seen in the design, to ensure the accurate dimensions of the components and statistics.

c. MEP (mechanical, electrical, and plumbing)

MEP includes HVAC systems, water supply and drainage systems, electrical systems, etc. Setting up the MEP systems also require a grid and coordinate system that is suitable for the architectural and structural systems. The components of the building system must also be set up, including libraries of different types of buildings. For example, Revit software, the libraries also ensure completeness for each type of building, and there are many shared libraries on the internet system.

The basic components of the MEP system include: Pipes (normal), Electrical ducts, HVAC Ducts, Ducts for electrical lines.

Some clashes in the MEP systems are shown in Table 4:

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Table 4 *Some internal clashes in the MEP system*

Clash name	Description	Correction
Toilet with partition or wall	Placed the toilet too close to the wall or partition. It causes difficulty in use and disadvantage in installation and repair.	Re-determining the reasonable distance to place sanitary equipment.
The water pipe for the toilet is too short	The location of the water pipe for the toilet is too short and too close, making it difficult to install.	Re-determining the water supply location for the toilet to be far enough away and easy to install.
Hot water pipes and chilled-water lines are too close together or overlap	Designed the pipes too close together, construction and repair are difficult, affecting the stability of water temperature.	Re-position the hot water pipe conveniently and at a distance from the chilled-water piping, and without overlap.
Ventilation pipe is not placed in the right position	Ventilation pipe is placed low, high or out of position.	Adjusting according to the structure of the building
Overlapping the wiring system	The wiring system has a complex structure, so cross-over is easy to occur, difficult to handle during repair and installation.	Moving and rearranging the wiring system
Overlapping water, sewer and fire pipes	Because of the variety of pipes, overlapping and covering often occurs.	Classifying areas to route appropriate pipes

Table 4 shows some basic clashes of MEP systems, which can be avoided when these factors are carefully considered during the design process and combined with the spatial structure.
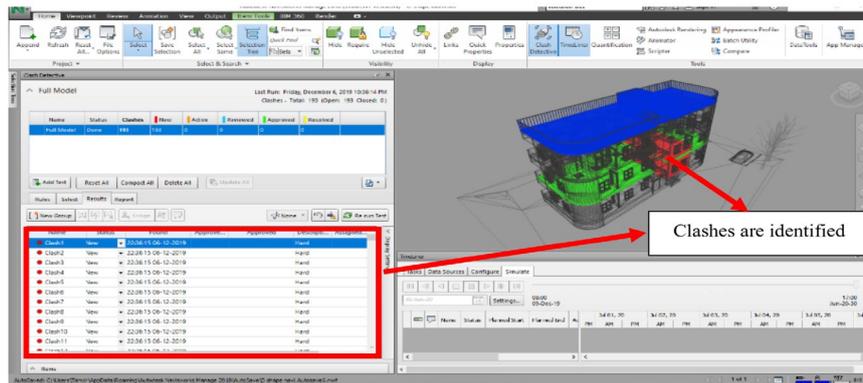

Fig. 9 *Analyzing the model-wide clash in the Revit software [11]*

4.2 Clash Matrix Between Systems in BIM

As the components of a construction project are integrated together in the BIM process, then clashes between disciplines begin to rise. At the end of the clash analysis process, the clashes will be listed and marked on the model (e.g., showing in the description in Fig. 9) [11] . The differences in coordinates, locations, geometrical and spatial dimensions, which that have led to different types of clashes, the clashes between systems come in many different forms, some of which can be seen in Fig.10 [44].

The study found that the order of priority in identifying conflict types is represented in the matrix form in Table 5 as follows:

Table 5 *Conflict matrix between models in the BIM [45]*

	Architectural	Structural	HVAC	Plumbing	Electrical
Architectural	1	3	5	10	12
Structural		2	6	8	13
HVAC			4	9	14
Plumbing				7	15
Electrical					11

In Table 5, the order number indicates the priority for determining clashes in the BIM process for construction works. The clash analysis process will proceed in order of priority from small to large. In which, determining priority number 1 is to determine the internal conflict of an architectural model, in which the structure of the architectural model will determine the placement of other construction systems. The next is determining the internal conflict of the structural model, this is the model that determines the stability and solidity of the construction, so the priority of determining the structure of the construction plays an important role. Then, clashes between the architectural and structural models will be identified, this determination determines the permanent shaping of the construction work.
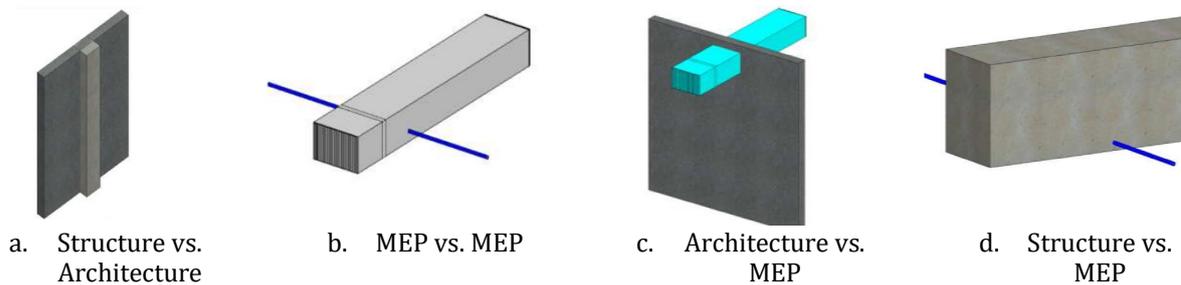

a. Structure vs. Architecture	b. MEP vs. MEP	c. Architecture vs. MEP	d. Structure vs. MEP

Fig. 10 *Clashes between objects in the BIM [44]*

In fact, if there is the clash between the architectural model and the structural model, then these clashes are a priority and must be handled right from the design stage. If the water supply system is compared with the structure of the structural model, the pipes and equipment of the water supply system can be adjusted conveniently without affecting the function and quality of the construction. Therefore, adjusting the water supply system in the clash with the structural model is convenient. In the matrix of Table 5, the 8th position is appropriate for the clash classification. For example, the clash between structure and MEP in Fig. 11 and 12, if adjusting the MEP system will be more convenient than editing the structural model [18] .
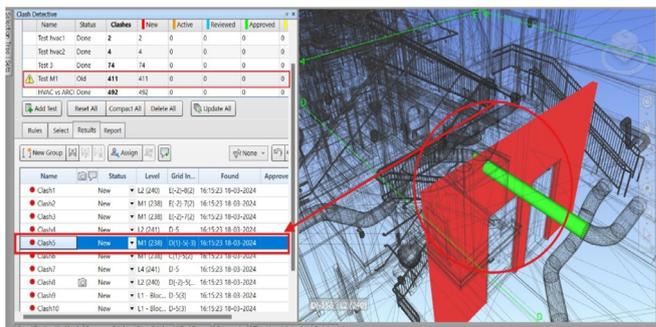

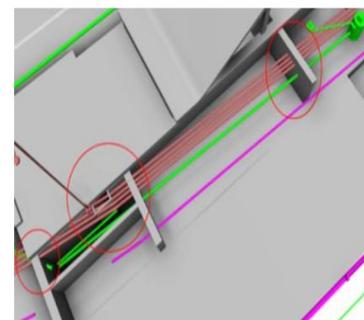**Fig. 11** *Clash between structure and MEP system [17]*

Fig. 12 *Clash between wall (structure) and plumbing (MEP) [20]*

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A detailed analysis of the clash between the elements is shown in Fig. 13:
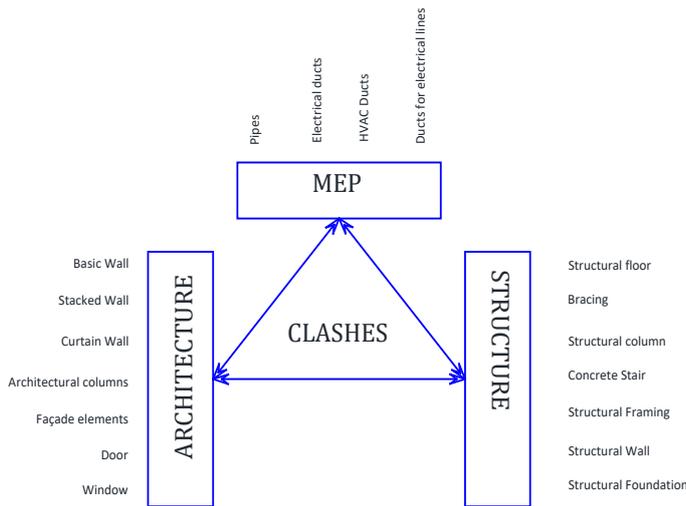
Fig. 13 *Clash diagram between objects in the BIM process*
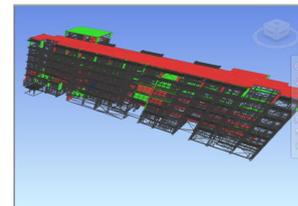
Fig. 14 *Clash between MEP system and architecture model [10]*

From Fig. 13, which describes the interactions between elements in each model system, the elements of the architecture will interact with the elements of the MEP model and vice versa. For example, the clash between walls and pipes. These conflicts will be analyzed and listed for each pair (e.g., the statistical results of the clashes between the models are illustrated in Fig. 14).

Thus, establishing a conflict matrix between systems (architecture, structure and MEP) plays an important role. Especially in the design phase, these clashes reduce design costs, save time and human resources for the project. The data system on conflicting elements and the linkage of conflicting elements in the systems of the BIM process have demonstrated the systematic and well-controlled work data.

5. Solutions to Reduce Clashes in Construction

5.1 Some Limitations in the Clash Detection

Looking at the overall clashes, it can be seen that clashes occur between all fields, such as between architecture and MEP; architecture and structure and structure and MEP (Fig. 14)[10] . Several studies have identified the causes of clashes as the independent work of professionals in a project [47], the complexity of the design [48], and the lack of expertise [49]. The lack of comprehensive training on clash detection and coordination for construction professionals has demonstrated a significant gap in skills development in areas such as design innovation, clash detection, and management. Closing this training gap is critical to improving the effectiveness of clash detection processes in BIM projects [50]. The survey also revealed some issues that cause conflicts in BIM as shown in Table 6.

Table 6 *Some limitations causing clashes in the construction projects*

Limitations in BIM	Clash characterization	Clash avoidance strategies
Using a low LOD (Level of Development).	Lack of data to identify clashes.	Using LOD level 350 or higher, to ensure full detail of structural components in terms of geometry, materials and connections in the construction.
		In the bidding system, clearly specify the level of BIM that must be applied.
The rulesets of the clash are not guaranteed.	Incomplete identification of clashes.	Detailed the Rulesets are required and regularly revised and updated. Compliance with ISO 19650 and IFC standards is required.
		Establishing integration and improving clash detection algorithms in the BIM.
Differences in geometric dimensions of components between systems in the building.	Geometric clashes between dimensions of components (especially the precast concrete member). Failure to install equipment due to lack of space.	Cross-checking between systems and communication of potential conflict locations between AEC systems is required.
Specialists work independently according to their own models.	Clashes occur between systems without timely detection.	Coordination is required in design, Architectural, structural and MEP systems must be deployed on the same CDE.
Complexity of the project.	Not fully controlling the structure of the project, easily leading to overlapping systems or not enough space for design.	There needs to be a division of labor, decentralization in design and management experts trained appropriately for each design level.
Lack of time to complete the project.	The design process of the project without re-checking. Errors in geometrical clashes of components and equipment locations.	Resources and materials must be ensured adequately during the design phase.
		In addition, the report must be completed and given sufficient time for review before formal submission.
Using files with different formats.	Making information errors, it can't read data from systems or read insufficient data. Then clashes in the project are not detected.	Clearly define file formats and CDE systems for each project.
Incorrect naming of elements in the BIM.	Data synchronization is not guaranteed and clashes are not fully recognized.	Naming rules in BIM must be consistent throughout the construction project.
Lack of experts who meet the required standards of the BIM.	Coordination of BIM processes for projects is not guaranteed. Easily causing clashes in workflow or data clashes.	The BIM human resource training system must be strong enough, from university level must be trained and applied BIM. Minimize design according to 2D drawings.
The skill of the staff is not high.	The design of the project does not meet the requirements, leading to unforeseen clashes due to incorrect designs or lack of information.	There needs to be an assessment and classification of the quality of the staff on a yearly basis or in smaller cycles. Assigning tasks according to the ability and meet the job position.

From Table 6, it can be seen that clashes occur in many different ways, so the clashes are difficult to predict in advance without connecting models in BIM. Research shows that MEP systems in the BIM process are very complex [41], as this system includes various types of works (Mechanical, Electrical, and Plumbing), each with its own characteristics. However, the design space for these works is limited (due to architectural space characteristics and the dimensions of structural system components), making conflicts between the MEP system

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and other systems very apparent. Standardising and designing a set of design libraries, along with a dataset on conflicts between systems, plays a crucial role in determining the quality of the project.

In addition, the lack of comprehensive training on clash detection and coordination for construction professionals has demonstrated a significant gap in skills development in areas such as design innovation, clash detection, and management. Closing this training gap is critical to improving the effectiveness of clash detection processes in BIM projects [34] . Therefore, developing a comprehensive and formal BIM training plan is one of the effective solutions for project management according to the BIM process.

5.2 Some Solutions to Prevent Clashes

Preventing and resolving clashes, different construction system models in BIM need to address internal clashes. Then, establishing the clash check between the models and setting up checks for these clashes is carried out in the clash detection model. The clashes between models need to be established (Fig.15) and analyzed this clash to handle them in the design phase (Fig. 16). It can also be seen that the most important cause of clash is the human factor.

Some surveys found that, MEP systems have complex and complex simulations in BIM, often clashes occur within the MEP system or the MEP system with architectural and structural models [51]. Some basic clashes can be seen, they are listed in Table 7:

Table 7 *Overview some of the main clashes*

Clashing factor	Clashing factor
HVAC duct	Beam
electrical equipment	
Stair	Water pipes
Wall	Pipe
Ventilation duct	Electrical conduit/trough
Door and Window	Wall

Considering Fig. 13 and Table 7, the analysis of the clash issues must be carried out synchronously, the objects that can be edited after the conflict are the elements that have little influence on the structure. In which, columns and beams are fixed elements in the clashes.
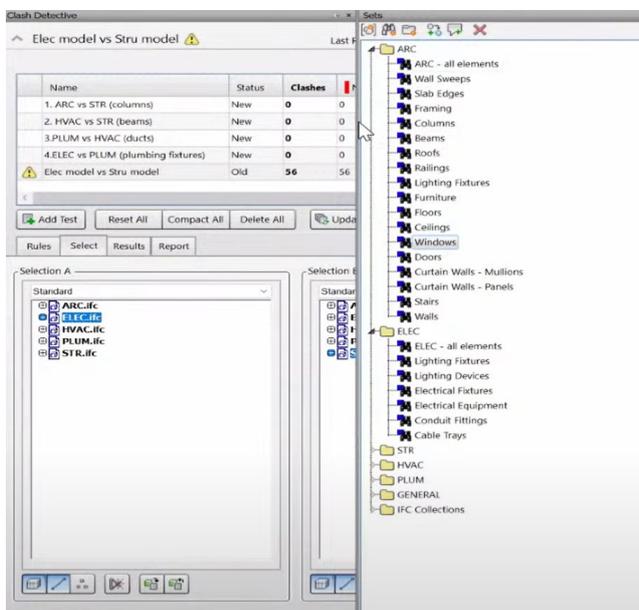

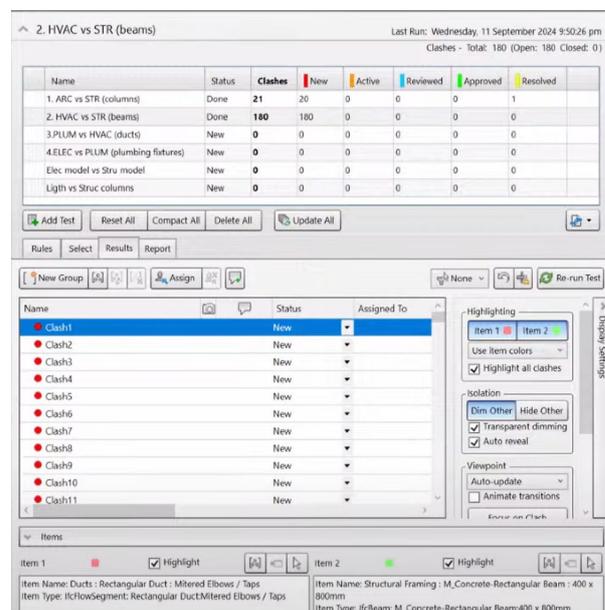**Fig. 15** *Setting up clash information between systems*

Fig. 16 *Statistics and marking of clashes*

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Commonly used tools to promote clash avoidance in the BIM process are Autodesk Navisworks and Autodesk Revit, which are used for clash detection analysis of BIM models. These tools allow for early identification of clashes between architectural, structural and MEP principles, minimizing miscommunication and misunderstandings during the construction phase. By integrating models in BIM and conducting clash detection analysis, clashes can be resolved before construction begins, resulting in improved project efficiency and cost effectiveness [46]. Using the Common Data Environment (CDE) will also enhance coordination and better management of clashes, which will help ensure higher quality projects by reducing delays and upfront costs. ISO 19650 and IFC standards, combined with integrated algorithms on the BIM platform, especially Machine Learning algorithms, will detect collisions more actively early, minimizing clashes caused by inappropriate design rules.
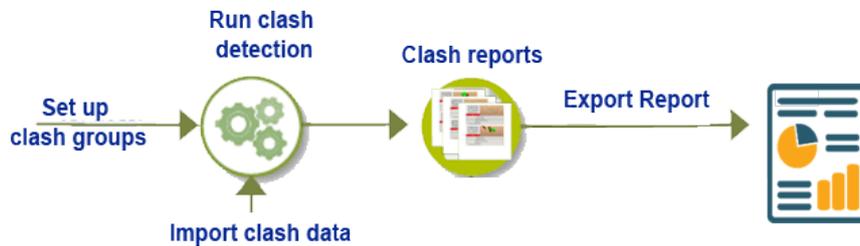
Fig. 1 *General structure for resolving the clashes in the BIM process*
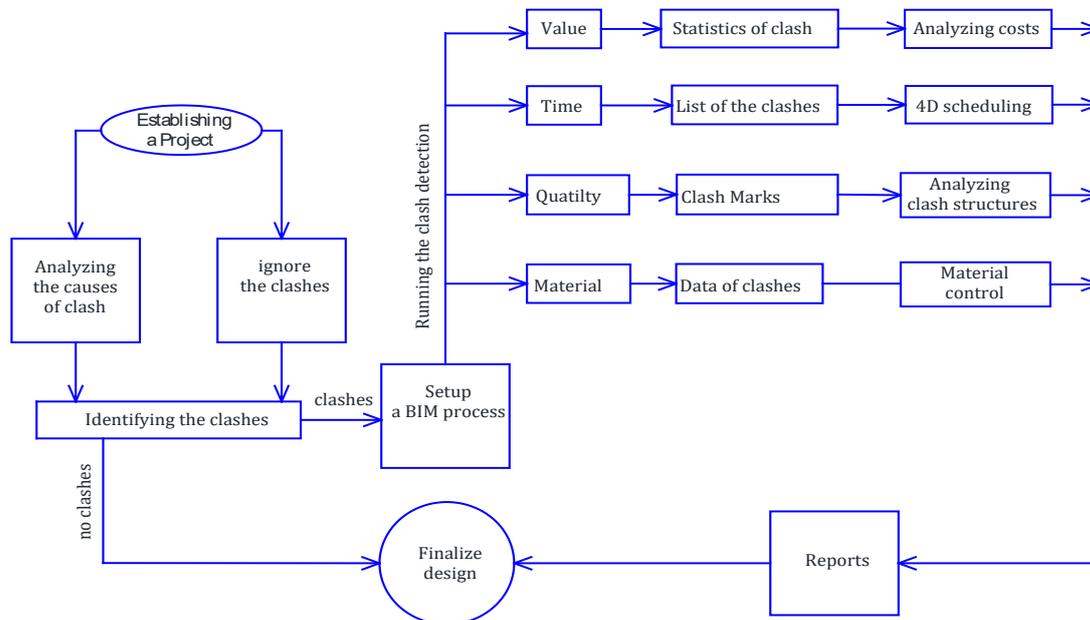
Fig. 18 *Flowchart for making a decision in checking the project clashes*

Conflict analysis and resolution should be established according to general structures (Fig.17), in which the establishment of clashes and analysis based on conditions should be listed in detail in steps. The decision-making framework for conflict analysis should clearly analyze the objectives, in which the interaction between the models plays an important role (Fig.18). For a construction project, the problem of determining costs is an important issue and the BIM process helps to perfect the structure and cost of the project at the best level. As an example, in Fig. 19, the diagram describes the process of applying Revit software and IFC standards to serve the purpose of detecting clashes using Solibri software. The output of the process is to determine an accurate data set to quantify the cost of the project, this data serves the bidding, management and construction work.
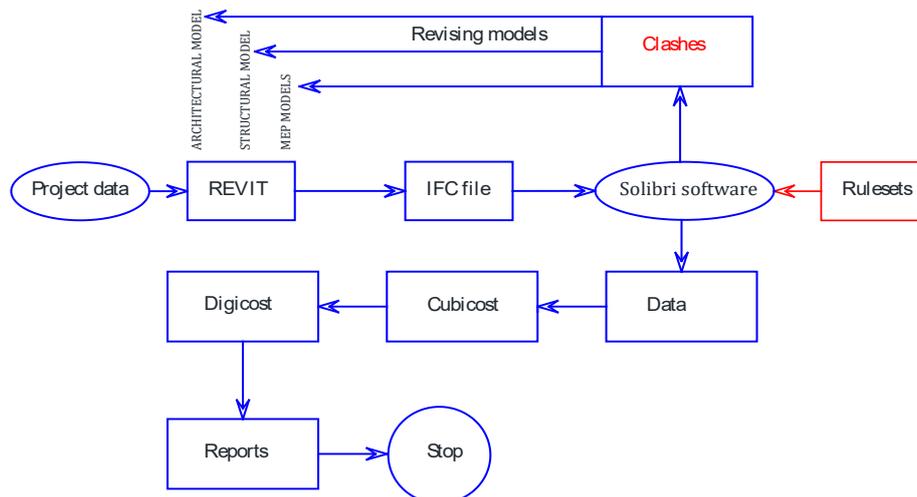
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Fig. 19 *Diagram of analyzing the project cost with considering clash resolution using software*

Thus, the solution to handle clashes for projects according to the BIM process is considered in the following aspects:

- Training human resources to meet the requirements of the BIM process. This issue has been considered in many studies, but the actual manpower problems are very difficult to determine. Currently, teaching about BIM is only a subject at the university level, and usually, those knowledgeable about BIM have to self-train through external programs outside the University. To address this problem, BIM majors must be established and formally trained in universities in Vietnam.
- The CDE must be uniformly regulated according to each type of project (for example: CDE for transportation projects; civil construction projects; urban planning projects, etc.). The issue of CDE regulations in Vietnam has not yet reached a consensus, and only guidelines for the use of CDE systems have been issued (Decision No. 348/QD-BXD was signed on April 2, 2021). Meanwhile, each design unit chooses a separate CDE to use. This limits the consistency and scalability of data for BIM projects.
- Developing the Rulesets according to international standards (meeting ISO 19650 and IFC standards). The establishment and standardization of BIM rules in Vietnam are still limited. These rules still lack specific guidelines and need to be incorporated into the legal framework regarding standards for establishing projects in BIM and meeting the expansion of applying the BIM.
- Developing a specific BIM process with the clash detection software for the project at each stage and publish BIM data for bidding activities. The clashes need to be given more attention in the regulations and guidelines for the application of BIM in Vietnam. The Revit and Tekla software are becoming popular in Vietnam, so the anomaly detection toolkits need to be diversified and made more accessible. Especially, establishing guidelines for applying Machine learning algorithms in conflict detection.

Thus, the clash is a factor that plays an important role in the implementation of construction projects. Clearly identifying the datasets on the clashes and their causes, the design phases of the project will become more favorable and avoid risks during the construction implementation.

6. Conclusions

Clashes in construction projects play an important role in reducing risks for construction projects. Studies show that clash detection reduces construction investment costs, ensures project safety and progress. The study has surveyed, evaluated and analyzed clashes in construction projects according to the BIM process. Some notable results are as follows:

- Survey on the clash issues and application of clash identification solutions in BIM, building a foundation for research on BIM and conflict issues in construction. In which, the effectiveness of conflict detection according to BIM process is evaluated compared to traditional methods using 2D drawings and the actual effectiveness of conflict detection.
- Analyzing internal clashes of individual construction models (architectural, structural and MEP models).
- Describing the database that identifies clashes when coordinating between models according to the BIM process, and at the same time point out the basic structure when identifying clashes between systems in a construction project according to the BIM process.

- Proposing some solutions to support experience in conflict analysis, thereby reducing basic clashes when designing individual construction models and minimizing clashes when integrating these models according to the BIM process.

Thus, the BIM process helps to improve the efficiency of construction design, minimize clashes and costs of rework during construction. However, further research is needed on the integration and application of Machine Learning technologies in analyzing and identifying clashes.

The study is only the initial step in identifying clashes, underlying causes, and some solutions to mitigate conflicts early in the project. The studies need to be further expanded to comprehensively supplement the clash dataset and establish the rules for identifying project conflicts. In the Industry 4.0 era in Vietnam, priority should be given to researching the integration and application of machine learning technology in clash detection.

Acknowledgement

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

Study conception and design: *Nguyen Minh Ngoc, Pham Van Duong;* ***Data collection:*** *Nguyen Minh Ngoc, Hoang Van Bien, Sendavanh PHONEXAYKHAM;* ***Analysis and interpretation of results:*** *Pham Van Duong, Tran Ngoc Thang;* ***Draft manuscript preparation:*** *Nguyen Minh Ngoc, Pham Van Duong. All authors reviewed the results and approved the final version of the manuscript.*

References

[1] Pham, V. D., Ta, V. P., Nguyen, M. N., Nguyen, V. V., & Mai, V. (2024). The Important Roles of BIM in the Construction Industry in Vietnam: A Multi-approach Analysis. *International Journal of Sustainable Construction Engineering and Technology*, 15(4), 176 - 187. https://publisher.uthm.edu.my/ojs/index.php/IJSCET/article/view/19939

[2] ISO 19650:2018. *Organization and Digitization of Information about Buildings and Civil Engineering Works, Including Building Information Modelling (BIM)-Information Management Using Building Information Modelling.* BSI: London, UK, 2018. Available online: https://www.iso.org/standard/68078.html (accessed on 18 October 2022).

[3] Izzudin, A., & Widiasanti, I. (2024). Pengaruh Clash Detection Pada Proses Perencanaan Biaya Pada Laboratorium PUT. *Jurnal Talenta Sipil*, 7(1), 301. https://doi.org/10.33087/talentasipil.v7i1.466

[4] Lopez, R., & Love, P. E. D. (2012). Design Error Costs in Construction Projects. *Journal of Construction Engineering and Management*, 138(5), 585–593, https://doi.org/10.1061/(ASCE)CO.1943-7862.0000454

[5] Fang, Y., Gao, S., Jiang, Y., & Li, S. (2023). BIM and lean construction in prefabricated housing construction in China. *International Journal of Lean Six Sigma*, 14(7), 1329–1353, https://doi.org/10.1108/IJLSS-03-2022-0059

[6] *Decision No. 348/QD-BXD (April 2, 2021) on publishing General Guidelines for applying BIM.* https://luatvietnam.vn/xay-dung/quyet-dinh-348-qd-bxd-huong-dan-ap-dung-mo-hinh-thong-tin-cong-trinh-200636-d1.html

[7] Arrotéia, A. V., Freitas, R. C., & Melhado, S. B. (2021). Barriers to BIM Adoption in Brazil. *Frontiers in Built Environment*, 7, 520154, https://doi.org/10.3389/fbuil.2021.520154

[8] Alreshidi, E., Mourshed, M., & Rezgui, Y. (2017). Factors for effective BIM governance. *Journal of Building Engineering*, 10, 89–101. https://doi.org/10.1016/j.jobe.2017.02.006

[9] Fang, Y., Gao, S., Jiang, Y., & Li, S. (2023). BIM and lean construction in prefabricated housing construction in China. *International Journal of Lean Six Sigma*, 14(7), 1329–1353. https://doi.org/10.1108/IJLSS-03-2022-0059

[10] Poojitha and P. Thamilselvi (2021). Clash detection in a multistorey building using BIM application. *International Journal of Multidisciplinary Education Research*,110 (5), 36 – 48, http://s3-ap-southeast-1.amazonaws.com/ijmer/pdf/volume10/volume10-issue5(1)/71.pdf

Int. J. of Sustainable Construction Engineering and Tech. Vol. 16 No. 2 (2025) p. 58-77

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[11] Datta, S.D., Sobuz, M.H.R., Mim, N.J. and Nath, A.D. (2023). Effectiveness of using building information modeling (BIM) tools in the project management: a case study. *Revista de la Construcción. Journal of Construction*, 22(2), 306-320. https://doi.org/10.7764/RDLC.22.2.306

[12] Yuye Jiang (2024). *Automatic BIM Conflict Resolution Using a Reinforcement Learning Approach*. Master Thesis, Technical University of Munich, page 78, https://mediatum.ub.tum.de/doc/1753824/8r9cm3k6u9y7owspuw2b7g224.Redacted_Automatic%20BIM%20Conflict%20Resolution%20Using%20a%20Reinforcement%20Learning%20Approach.pdf

[13] ISO 16739 : 2024 *Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries*. https://www.iso.org/standard/84123.html

[14] Juszczyk, M., Wieczorek, D., Pacyno, H., & Dzienniak, A. (2022). *Clash detection based on IFC/BIM models – case studies and process parameterization*. In I. Završki, A. Cerić, M. Vukomanović, M. Huemann, R. D. Golomejić Vlahov, & Z. Sigmund (Eds.), 15th International Conference Organization, Technology and Management in Construction and 6th International Project Management Association SENET Conference, Cavtat (Dubrovnik), September 21-24, 2022. https://cris.pk.edu.pl/info/article/CUT2786472727264a5598eb5532082a88bd/

[15] Bayram Ali Temel , Hasan Basri Başağa (2020). Investigation of IFC file format for BIM based automated code compliance checking. *Journal of Construction Engineering, Management & Innovation*, 3(2),113-130, https://doi.org/10.31462/jcemi.2020.02113130

[16] Ali Shehadeh, Odey Alshboul, Madhar M. Taamneh, Aiman Q. Jaradat, Ahmad H. Alomari (2024). Enhanced clash detection in building information modeling: Leveraging modified extreme gradient boosting for predictive analytics. *Results in Engineering*, 24, 103439, https://doi.org/10.1016/j.rineng.2024.103439

[17] Ibironke Regina Adegun (2024). *BIM Clash Report Analysis Using Machine Learning Algorithms*. Master of thesis. 125 Pages. University of Alberta. https://era.library.ualberta.ca/items/f2ec803c-d2db-4462-8b6c-10aa708daee2/view/cbd7a879-cbcc-45cf-ab89-bfbefb22b80b/Adegun_Ibironke_202408_MSc.pdf

[18] Harode, A., Thabet, W., & Gao, X. (2024). Developing a Machine-Learning Model to Predict Clash Resolution Options. *Journal of Computing in Civil Engineering*, 38(2), 04024005, https://doi.org/10.1061/JCCEE5.CPENG-5548

[19] Esmaeili, I., Martins, J. P., & Castro, J. M. (2024). *Quality check of BIM models using Machine learning*. In Conference: The 5th Portuguese Conference in Building Information Modelling, At: Lisbon, https://doi.org/10.21814/uminho.ed.164.2

[20] Chahrour, R., Hafeez, M. A., Ahmad, A. M., Sulieman, H. I., Dawood, H., Rodriguez-Trejo, S., Kassem, M., Naji, K. K., & Dawood, N. (2021). Cost-benefit analysis of BIM-enabled design clash detection and resolution. *Construction Management and Economics*, 39(1), 55–72. https://doi.org/10.1080/01446193.2020.1802768

[21] Okereke, R. ., Muhammed, U. ., & Eze, E. (2021). Potential Benefits of Implementing Building Information Modelling (BIM) in the Nigerian Construction Industry . *Journal of Technology Management and Business*, *8*(2), 1-15, https://publisher.uthm.edu.my/ojs/index.php/jtmb/article/view/9731

[22] Huang, Y.-H., & Lin, W. Y. (2019). Automatic Classification of Design Conflicts Using Rule-based Reasoning and Machine Learning—An Example of Structural Clashes Against the MEP Model. Proceedings of the 36th ISARC, Banff, Canada, pages 324-331, https://doi.org/10.22260/ISARC2019/0044

[23] Avani P. and Bhavana B. (2022). *Building Information Modelling and Augmented Reality for building energy systems visualisation.* IOP Conf. Series: Materials Science and Engineering, 1255, 012009, https://doi.org/10.1088/1757-899X/1255/1/012009

[24] Khan, S., Panuwatwanich, K. and Usanavasin, S. (2024). Integrating building information modeling with augmented reality: application and empirical assessment in building facility management. *Engineering, Construction and Architectural Management*, 31 (7),2809-2828. https://doi.org/10.1108/ECAM-12-2021-1146

[25] Liu, Z., Jiang, L., Osmani, M., & Demian, P. (2019). Building Information Management (BIM) and Blockchain (BC) for Sustainable Building Design Information Management Framework. *Electronics*, 8(7), 724. https://doi.org/10.3390/electronics8070724

[26] Tongrui Zhang, Dat Tien Doan, Jing Kang (2023). Application of building information modeling-blockchain integration in the Architecture, Engineering, and Construction / Facilities Management industry: A review. *Journal of Building Engineering*, 77, 107551, https://doi.org/10.1016/j.jobe.2023.107551

76

Int. J. of Sustainable Construction Engineering and Tech. Vol. 16 No. 2 (2025) p. 58-77

[27] Faraji, A., Homayoon Arya, S., Ghasemi, E., Rahnamayiezekavat, P., & Perera, S. (2024). Building Information Modeling (BIM), Blockchain, and LiDAR Applications in Construction Lifecycle: Bibliometric, and Network Analysis. *Buildings*, 14(4), 919. https://doi.org/10.3390/buildings14040919

[28] Shu Tang, Dennis R. Shelden, Charles M. Eastman, Pardis Pishdad-Bozorgi, Ray Gao (2019). A review of building information modeling (BIM) and the internet of things (IoT) devices integration: Present status and future trends. *Automation in Construction*, 101(66),127-139. https://doi.org/10.1016/j.autcon.2019.01.020

[29] Akponeware, A., & Adamu, Z. (2017). Clash Detection or Clash Avoidance? An Investigation into Coordination Problems in 3D BIM. *Buildings*, 7(3), 75, https://doi.org/10.3390/buildings7030075

[30] Alaloul, W. S., Qureshi, A. H., En, Y. P., Khan, S. A., Musarat, M. A., Alzubi, K. M., & Salaheen, M. Al. (2023). Survey Evaluation of Building Information Modelling (BIM) for Health and Safety in Building Construction Projects in Malaysia. *Sustainability*, 15(6), 4899, https://doi.org/10.3390/su15064899

[31] Malsane, S., Merin, M.J., Gokul, G.J., Nithin Dev, P., Babu, S.T. (2022). *Management of High-Volume Clashes During Clash Detection*. In: Srivastava, P., Thakur, S.S., Oros, G.I., AlJarrah, A.A., Laohakosol, V. (eds) Mathematical, Computational Intelligence and Engineering Approaches for Tourism, Agriculture and Healthcare . Lecture Notes in Networks and Systems, vol 214. Springer, Singapore. https://doi.org/10.1007/978-981-16-3807-7_23

[32] Hu, Y., Castro-Lacouture, D., Eastman, C. M., & Navathe, S. B. (2020). Automatic clash correction sequence optimization using a clash dependency network. *Automation in Construction*, 115, 103205, https://doi.org/10.1016/j.autcon.2020.103205

[33] Minister of Construction (March 21, 2017). *Decision 203/QD-BXD on the establishment of the Steering Committee for the implementation of the Project on applying Building Information Modeling (BIM) in construction activities and construction management and operation*. https://moc.gov.vn/vn/tintuc/1176/20995/thanh-lap-ban-chi-dao-thuc-hien-de-an-ap-dung-mo-hinh-thong-tin-cong-trinhbim.aspx

[34] Decision No. 258/QD-TTg of the Prime Minister: *Approving the Roadmap for applying Building Information Modeling (BIM) in construction activities*. https://vanban.chinhphu.vn/?pageid=27160&docid=207592

[35] Akas Patel (2025). Traditional vs Digital BIM Clash Detection: A Complete (accessed on June 1, 2025). https://www.united-bim.com/traditional-vs-bim-clash-detection/#:~:text=3D%20Contextual%20Visualization%20of%20Conflicts,in%2Ddepth%20blog%20post%20here

[36] Nguyen Viet Hung & Ta Ngoc Binh (2014). *Overview of Building Information Modeling (BIM) and the need to develop a roadmap for BIM application in the Vietnamese construction industry*, Hanoi (hardcoppy.

[37] Daszczyński, T., Ostapowski, M., & Szerner, A. (2022). Clash Cost Analysis in Electrical Installations Based on BIM Technologies. *Energies*, 15(5), 1679, https://doi.org/10.3390/en15051679

[38] Matejka, P.; Sabart, D. (2018). *Categorization of clashes and their impacts on Construction projects*. In Proceedings of the 17th International Scientific Conference Engineering for Rural Development, Jelgava, Latvia, pp. 827-835, https://doi.org/10.22616/ERDev2018.17.N102

[39] Braa F. Abdalhameed, Sepanta Naim (2023). Based BIM techniques to clash detection for construction projects. *Periodicals of Engineering and Natural Sciences*, 11 (1), 239-245, https://doi.org/10.21533/pen.v11.i1.93

[40] Harika Singh (2014). 3 Types of 3D BIM Clash Detection and their Importance. (accessed on June 2, 2025). https://www.hitechcaddservices.com/news/3-types-of-3d-clash-detection-have-their-own-importance/

[41] Quan T. Nguyen, Phuong Q. Luu, and Yen V. Ngo (2020). *Application of BIM in design conflict detection: a case study of Vietnam*. IOP Conf. Series: Materials Science and Engineering, 869, 022038, https://doi.org/10.1088/1757-899X/869/2/022038

[42] Abubakkar Sidiq, P.Thamilselvi (2018). Study On Implementation Of Clash Detection Tool In Housing Project Using BIM. *International Journal of advance research in science and engineering*, 7 (6), 215-225, https://ijarse.com/images/fullpdf/1530177054_J1164ijarse.pdf

[43] Alcinia Zita Sampaio, Nuno Gomes, Augusto Gomes (2024). BIM design coordination: conflict analysis and construction simulation. *Procedia Computer Science*, 239, 49 – 57, https://doi.org/10.1016/j.procs.2024.06.145

Int. J. of Sustainable Construction Engineering and Tech. Vol. 16 No. 2 (2025) p. 58-77

77

[44] Yi-Chun Lin, Shin-Hsun Chou, I-Chen Wu (2013). *Conflict Impact Assessment between Objects in a BIM System*. Proceedings of the 30th ISARC, Montréal, Canada, p. 337-344, https://doi.org/10.22260/ISARC2013/0037

[45] Ignacy Lozinski (2021). System Hierarchy and Clash matrix in BIM Coordination. https://bimcorner.com/system-hierarchy-and-clash-matrix-in-bim-coordination/

[46] Sarmad Mehrbod, Sheryl Staub-French, Narges Mahyar, Melanie Tory (2019). Beyond the clash: investigating BIM-based building design coordination issue representation and resolution. *Journal of Information Technology in Construction (ITcon)*, 24, 33-57, http://www.itcon.org/2019/3

[47] Froese, T.M (2010). *The impact of emerging information technology on project management for construction*. Autom. Constr., 19, 531–538. https://doi.org/10.1016/j.autcon.2009.11.004

[48] Tommelein, I.D.; Gholami, S. (2012). *Root causes of clashes in building information models*. Proceedings of IGLC20: 20th Annual Conference of the International Group on Lean Construction, San Diego, CA, USA, 18–20 July 2012.

[49] Leite, F. (2014). *Capturing Expert Knowledge in Design Coordination to Train Novice Designers*. Available online: http://ascelibrary.org/doi/pdf/10.1061/9780784413517.003 (accessed on 14 April 2025)

[50] Oyewole, E. O., & Dada, J. O. (2019). Training gaps in the adoption of building information modelling by Nigerian construction professionals. *Built Environment Project and Asset Management*, 9(3), 399–411, https://doi.org/10.1108/BEPAM-10- 2017-0090

[51] Riley, D.R.; Varadan, P.; James, J.S.; Thomas, H.R (2005). Benefit-Cost Metrics for Design Coordination of Mechanical, Electrical, and Plumbing Systems in Multistory. *Journal of Construction Engineering and Management*, 131(8), 877–889. https://doi.org/10.1061/(ASCE)0733-9364(2005)131:8(877)