Implementation of Building Information Modeling for Construction Clash Detection Process in the Design Stage: A Case Study of Malaysian Police Headquarter Building

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Abstract. The Malaysian government motivates constructor companies to use Building Information Modeling (BIM) on their projects because it can dominate problems such as design error, delay, and construction-overrun costs. This research also assesses the effect of BIM in the design phase of the construction process and how this technology can detect all existing clash in construction plans during the design phase. The research was carried out through a case study that contains an architectural, structural, and Mechanical, Electrical and Plumbing (MEP) BIM models and their following clash detection. The current study implemented Autodesk Revit and Autodesk Navisworks Manage as BIM tools to develop features to simplify and automatically clash detection process. The result from the case study analysis revealed that BIM is an appropriate tool for detecting clashes among the building elements. Therefore, constructability issues can be determined earlier during the design phase before the construction phase begins, controlling project cost, time, and having a seamless design to produce a better building.

1. Introduction

The construction industry is one of the most information-dependent sectors and relies heavily on the traditional method of communication, such as paperwork. Omissions and errors in paper documentation and exchange of drawings often cause unanticipated field costs and delays during the project delivery [1]. Furthermore, cross-disciplinary communication between the various professionals of the construction sector is, however, very problematic and can be seen to be a significant contributing factor in poor performance of project productivity [2]. Lack of integration in the traditional working process leads to errors, unstructured, and non-collaborative in the document transfer process between the parties [1].

There is a need for systems that work more efficiently to better coordinate and communicate between project team members, and also express the same project idea to all stakeholders involved in the project's life cycle [3]. Building information modeling (BIM) technology furnishes users with correct and reliable building information, accommodates the functions required to model the building, and provides a virtual view of the building model before the actual building is constructed [4]. BIM

increases the speed of construction delivery. It also supplies better coordination and less error, which reduces costs and improves productivity with higher work quality [5-7].

Conflict analysis is an essential and vital part of the evolution process of a 3D BIM model. In the clash detection test, the geometric conflicts among various elements (architectural, structural, and MEP systems) within 3D Building Information Model will be detected, checked, and modified early in the design phase before actual construction starts [8,9].

Therefore, Coordination between different organizations is improved, and errors are significantly decreased, thereby accelerating the construction process, reducing costs, minimizing the risk of legal disputation, and shortening the construction phase. There are three main kinds of clashes that clash detection looks out for 1) Hard Clashes; refers to a building component that penetrates another building component physically. 2) Soft/clearance Clashes; Refers to components closer to each other more than a certain distance. 3) Time/4D Clashes might include the contractor's schedule, the equipment and materials delivery, and general timeline conflicts [10]. The aim of this research is assessing the effect of BIM in the design phase of the construction process and how this technology can detect all existing clash in construction plans during the design phase.

2. Research methodology

In this project, relevant data are gathered and organized for intensive analysis of the details of construction. These data include architectural, structural, electrical, and mechanical 2D drawing plans. A case study is selected and built upon BIM to determine the BIM ability for clash detection in the design phase. The study has selected the one police headquarters office building located in Kota Tinggi. The research is measuring the ability of BIM for clash detection that utilizes Autodesk software such as AutoCAD, Autodesk Revit, and Autodesk Navisworks Manage for modeling, analyzing, and testing through the process stated as following sections.

3. Modeling process

3.1. Creating 2D CAD Details

AutoCAD is a general software application for 2D and 3D computer-aided design (CAD) and drafting Autodesk. Auto CAD produces detailed drawings in the 2D plan is drown by Auto Cad in the base of the initial sketch plan. The 2D plan format is in the format of DWG. DWG (drawing) is an AutoCAD native file format and a basic CAD data interoperability standard.

3.2. Generating the Architectural BIM models

Autodesk Revit Architecture allows architects and building professionals to capture and analyze the concepts and maintain vision through the design, documentation, and construction phases [11]. In this section, smart objects such as walls, doors, windows, stairs, and floors were created according to their specifications, as shown in figures 1, 2, and 3.
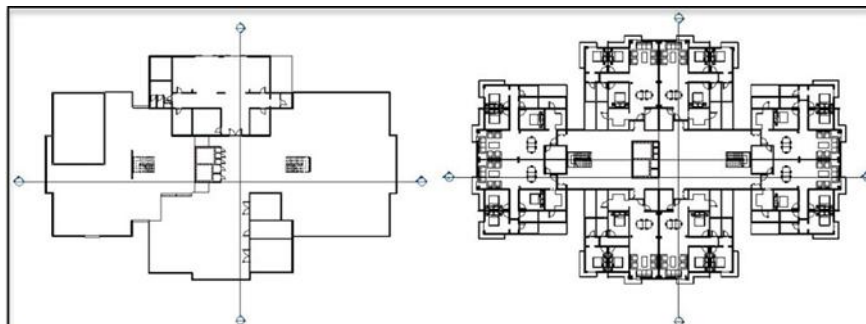

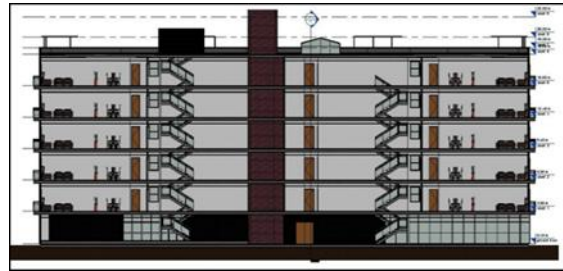**Figure 1.** Architectural floor plans which are created using revit.

Figure 2. Revit 3D view of the architecture.   **Figure 3.** Revit section of the architecture modeling.

3.3. Generating the structural BIM model

Revit Structure is for structural systems design and documentation. Once the architectural model has been imported to Revit structure, each architectural view is displayed correctly in 2D and 3D structural views. The position of beams, slabs, columns, pilling, foundation rebar, and other structural elements were added to the 3D structural model (see Figure 4).
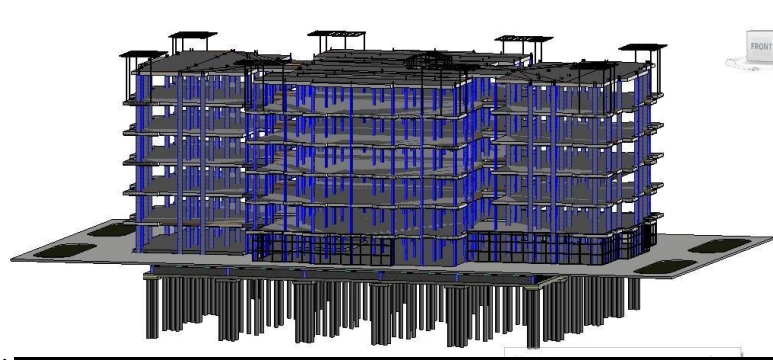

Figure 4. Revit structure 3D view of the structure modelling.

3.4. Generating the Mechanical, Electrical and Plumbing BIM Model

Revit MEP is for professionals who engage in MEP engineering. MEP stands for mechanical, electrical, and plumbing, which are the three engineering disciplines that are addressed by Revit MEP. In the third step of 3D modeling in Revit, plumbing, and electrical drawings were implemented based on 2D Cad information (see Figure 5).
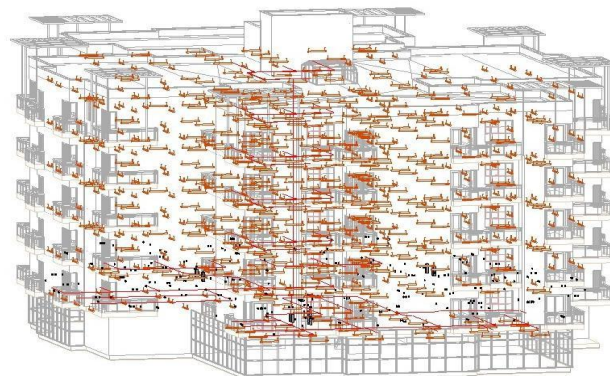

Figure 5.   3D view of the electrical modelling created by revit MEP.The plumbing model is a combination of a plumbing fixture, sanitary pipe, and pipefitting. For the electrical model, only lighting and electricity plug data were available based on 2D documents.

4. Clash Detection Process

There is several BIM software available in the market, which is beneficial for designers and professionals to enhance project productivity. The purpose of utilizing Navisworks software is to detect clashes and check interference among model elements by testing across the whole composite model or by checking particular subsets of the model elements. This BIM tool allows the user to set the rules, recognize clashes, Produce Reports, Trace Clashes, Status Clashes, Manage Clashes, Custom Clash tests, Clearance Tests, time-based clashes [8]. Therefore, Navisworks manages work through streamlined workflow across the organization and teams, promoting to reduce waste, raise efficiency, and eliminate change orders. In Navisworks, skill in navigating the model, aggregating clashes, and searching the model are essential to running a practical coordination project, and Navisworks gives powerful tools to succeed in these tasks.

After the creation of 3D models (Architectural, Structural, and MEP) by Auto Desk Revit, it is necessary to import the 3D model into Navisworks Manage in order to clash detection. In the next step, all native Revit format (rvt files) should be converted into Navisworks file format by file exporter (available in Autodesk Revit 2018). There are three native file formats for Autodesk Navisworks, such as; NWD, NWF, and NWC. NWC files are smaller than the original files and speed up end-user access to regularly used files. Setting up and running a clash test requires the following steps:

4.1. Group Selection and create folders for each group

The Select tab of the Clash Detective control bar enables the designer to refine the clash test by just testing sets of objects at a time, rather than the entire model against itself. This procedure will provide faster and more tangible results.

4.2. Set the rules for the test

Clash Rules can allow the user to ignore clashes that he is not currently interested in, are not real clashes, or are issues with 'unfinished' work which person will review later.

4.3. Set the items required in the test and select the test type preferences

This tab contains two same panels called Selection A and Selection B. These panels include two sets of different model elements that enable users to select these items in each time for testing against each other through the clash test. Clash tests may involve the interference of surfaces, lines, and points of the selected items. After choosing the elements, it is necessary to define the type of clash (Hard, Clearance, and Duplicates).

4.4. Produce a clash report

When the choice is made for the items in selection A and B, and also type and tolerance of the clash are set, it needs to start the test by clicking the Run Test button. The result obtained by running the test is available in the result tab. The clashes are arranged by numbers and their levels automatically at the result table. The status of each conflict classified by New, Active, Reviewed, Approved, and Resolved classes. Once a similar test is run, the status will be updated by clash detective automatically each time. The status also can be updated by the user for each clash. Moreover, click on the report will give the reports of the clash test. Reports are given in detail for all clash results in the intended test. Before writing the report, it necessary for the user to select the format. Which are including: HTML (Tabular), HTML, TEXT, As Viewpoints and XML format.

4.5. Managing/Status clash tests for future use

Navisworks Manage software informs the current situation of the clashes in the model because the status will be updated automatically.

5. Result and Discussion

There are three types of testing, which is a hard clash, clearance clash, and duplicate clash that can be tested using the Navisworks Manage to identify the clash detection in the drawing. All type of clash testing in the case study has been done with the tolerance of 50 mm for hard clash and 10mm for clearance clash.

5.1. Hard Clash Result at Tolerance of 50 mm

Table 1 illustrates a hard clash between architecture, structure, electrical, and sanitary with tolerance 50 mm. Table 1 shows the results of hard clash detection at a different test. It shows that most of the clashes are detected between architecture, structure, and sanitary model.

Table 1. Number of hard clash.

	Architecture & Structure & Sanitary Test	Architecture & Structure & Electrical Test	Structure & Sanitary Test	Total Clash	Tolerance
Number of Hard Clash	334	10	16	360	5cm

Figure 6 shows the percentage of hard clashes between architecture, structure, and sanitary in different levels of construction. According to the result, it shows that most of the clashes are at level1 with 33% and following the ground floor and level2 with 21% and 17% clash, respectively. It means these level needs for multiple changes before the construction process started.

Figure 7 shows the percentage of hard clashes between architecture, structure, and electrical at a different level of buildings. According to Table 1, only ten clashes detected over the whole level in Architectural, Structural, and Electrical.
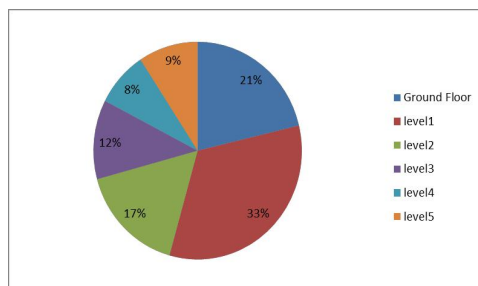
Figure 6. Distribution of hard clash between architecture, structure, and sanitary by level.
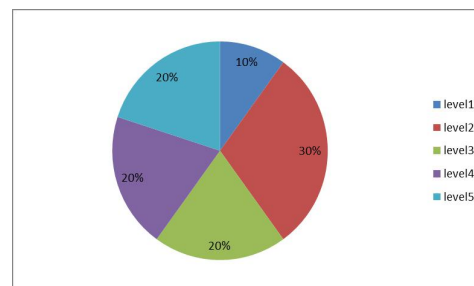
Figure 7. Distribution of hard clash between architecture, structure, and electrical by level.

Figure 8 shows the percentage of hard clashes between Structure and Sanitary in different levels of the building. A total of 16 hard clashes care detected in this analysis. All 16 clashes are divided between the ground floor and level one equally.
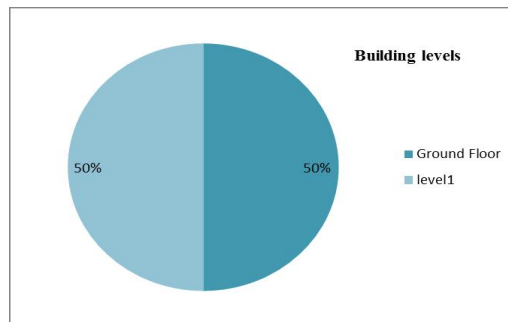
Figure 8. Distribution of hard clash between structure and sanitary by level.

One of the main reasons that led to a vast amount of hard clash in the case study is due to uncertainty in the design phase. Another reason is related to the lack of specificity, agreement prior and during design, on the development of a particular system, and how it may be relative to another system without any disruptions. Moreover, the complexity of the project and the lack of time for project delivery also can lead to hard clashes. Design error is another cause of hard clashes due to the ignorance of some dimension or location of one or several building components by the designer.

5.2. Clearance Clash Results of 10 mm tolerance

Table 2 illustrates a clearance clash between architecture, structure, electrical, and sanitary objects with tolerance 10 mm. It shows the whole building clearance clash detection. The total number of clashes is 2316, which most of the conflicts are regard to architecture, structure, and sanitary. This test is done to maintain the accuracy of the drawing and eliminating the future problem that might arise during the construction process.

Table 2. Number of clearance clash.

	Architecture & Structure & Sanitary	Architecture & Structure & Electrical	Structure & Sanitary	Total Clash	Tolerance
Number of Clearance Clash	1800	504	20	2316	1cm

Figure 9 shows the percentage of clearance clashes between architecture, structure, and sanitary in different levels of construction. According to Table 2, a total of 1800 clearance clash detected, and more than 60 % of all conflicts are in Level 1, and the remaining 40% is distributed among the other levels. Conditions that make hard clashes can also result in soft clashes; therefore, the large number of clearance clash significantly might be reduced if the hard conflicts are evaluated and eliminated.

Figure 10 shows the percentage of clearance clashes between architecture, structure, and electrical in different levels of construction. Five hundred four conflict care detected according to this test. Ninety percent of all clashes equally distributed between levels 2, 3, 4 and 5. It is considerable, the lowest number of conflict belongs to level 1 and ground floor. Therefore, it is required for many changes in the level of 2,3,4 and five drawings before the construction process started.

A soft clash can be resulted in due to blocking out space encompassing the physical volume occupied by the object. The object is geometry modeled by the designer's opinion, not with its actual shape. A soft clash can occur when both blocked out space of two objects are overlapped with each other. Another reason for the definition of blocked out space is the concern of the design-construction or operations-related concerns. Sometimes the limited space of two very closed elements will make it impossible for sufficient construction accessibility.
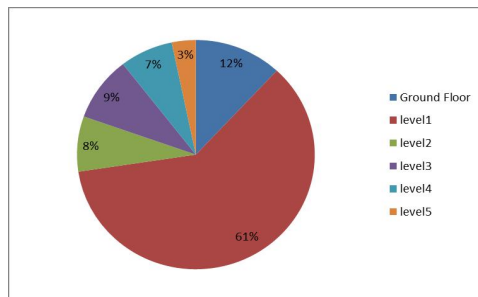
Figure 9. Distribution of clearance clash between architecture, structure, and sanitary by level.
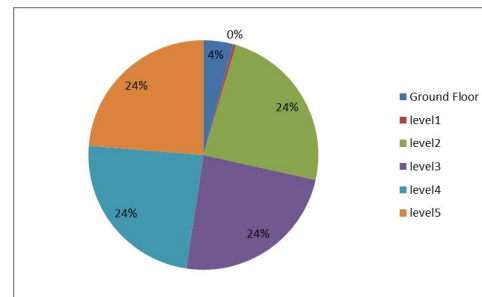

Figure 10. Percentage distribution of clearance clash between architecture, structure, and electrical by level.

A soft clash can be resulted in due to blocking out space encompassing the physical volume occupied by the object. The object is geometry modeled by the designer's opinion, not with its actual shape. A soft clash can occur when both blocked out space of two objects are overlapped with each other. Another reason for the definition of blocked out space is the concern of the design-construction or operations-related concerns. Sometimes the limited space of two very closed elements will make it impossible for sufficient construction accessibility.

Figure 11 shows the total results of hard clash and clearance clash that distributed at each level. Fortunately, there is not any duplicate clash in this case study.
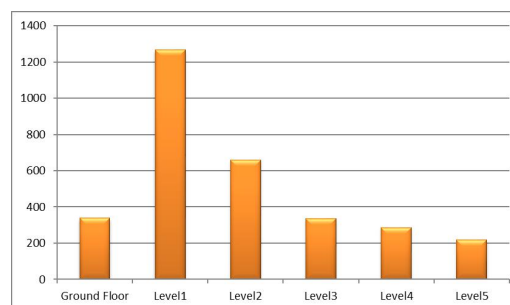

Figure 11. Distribution of all exist clash in whole project by level of buildings.

In conclusion, a large amount of clashes is related to level one, and the lowest number of clashes is belonged to level five with 200 conflicts. According to these results, all the building plans must be reviewed again for eliminating a large number of conflicts detected at all levels.

6. Conclusion

BIM helps construction players by improving project schedule, visualize. It can also help to find possible issues like detect design clashes before going to the construction phase. Time, cost-effectiveness, and the higher quality of the projects are the advantages of using BIM. In order to determine existence clashes in construction Plans from different kinds of literature, Autodesk Revit and Autodesk Navisworks manage were chosen due to its superior software design. The police headquarters building located in Kota Tinggi, Malaysia, was planned, and Autodesk Revit prepared the 3D modeling of the Case study. Clash detection of the different disciplines (architectural, structural, and MEP model) was performed through Autodesk Navisworks manage. The results revealed that BIM Clash detection is a faster and simple process as well as entirely minimizing the field of human errors in the course of implementation. Navisworks adequately recognize design clashes that happen within building components, and they are settled in an appropriate time. Consequently, design errors

removal, cost, and time optimization are essential for the AEC industry in the earlier design phase before the construction commences on the site. This research focused on clash detection in the construction component. Further researches are required to find the solutions for occurred clashes in order to avoid dispute during constructions.

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