Analysis of clash detection and quantity take-off using BIM for warehouse construction

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Abstract. Lack of integration in the design of a construction project planning, often resulting in clashes between elements. The purpose of this study was to analyze the number and causes of clashes between structural design, precast design, and MEP design for warehousing projects. Then the quantity take-off analysis will be carried out after resolving the clashes. In this study, BIM-based software was used namely Revit® 2020 and Navisworks® Manage 2020. The results of this study found that the number of clashes for the Structural vs Precast components was 289 clashes, for Structural vs MEP components was 191 clashes, and for Precast vs MEP components was 42 clashes. The cause of clashes with the highest percentage was caused by design error (52.36%), followed by design inconsistency (39.13%), and the last was a design discrepancy (8.51%). Based on the calculation of cost changes, a potential saving can be made for HCS panel material and for ducting pipe material as much as 10% of the initial cost.

Keyword: BIM, design, clash, Quantity Take-off, cost

1. Introduction

The lack of integration of planning designs on a construction project often results in clashes between elements. The cause of clashes between elements can also be caused by design inconsistencies, design discrepancy, and so on [1]. The discovery of a clash on a project will affect work in the field at a cost that does not require rework. Budget overruns are a consequence of rework carried out by architects and engineers during construction [2]. It takes a method that can make these planning designs can be integrated with each other, in order to do early detection if something goes wrong in the planning design. So, it can improve material efficiency and also avoid problems in the future. Clash detection analysis based on Building Information Modeling (BIM) is a potential job for efficiency in construction projects. BIM can create a virtual image of a pre-construction to detect, simulate and analyze potential problems that can cause delays during construction phase [3]. BIM is known as an advanced technology that supports construction design and process. It allows entire parties to be involved throughout design until the construction process [4].

Based on the formulation of the problem, this study was conducted to find out how many collisions that might occur in a warehouse project and what are the main causes of clashes that occur between the combination of the three elements namely structure, precast, and building service (Mechanical,
Electrical and Plumbing (MEP)). Then find out how big the effect is on changes in material quantity after a collision repair is made with BIM-based technology.

2. **Development of Structural and MEP Model using BIM**

   The initial stage of the study is to make a three-dimensional (3D) model using Autodesk Revit 2020 software ([5], [6]). The three-dimensional (3D) model is made based on the for-construction drawing of structural, precast, and MEP components by the IKEA Jakarta Garden City construction project. Clash detection analysis will then be carried out on the three models using Autodesk Navisworks Manage 2020. The model review will be carried out by comparing two components, namely structural with precast components, structural with MEP components, and precast with MEP components. From the results of the clash detection analysis, clash resolving were made to the components experiencing clash. After all the clashes are fixed, then proceed to the next stage, namely quantity take-off. From the changes caused by resolving the clash, quantity takes-off is carried out by using the quantification tools found in the Autodesk Navisworks Manage 2020 software. Finally, a cost change calculation will be carried out based on the unit price stated in the project Bill of Quantity (BOQ) document.

   3D modeling for Structural, Precast, and MEP elements was carried out by using Autodesk Revit 2020 software. In this study, the structural components to be modeled include Columns, Beams, Shear Walls, and Basement Walls. For the precast components that will be modeled is the Hollow Core Slab (HCS) precast concrete panel. Meanwhile, the MEP elements being modeled include the Heat, Ventilation, and Air-Conditioning (HVAC) system which consists of Ducting Pipe, Riser Shaft, and Inline Axial Fan. Figure 1 – Figure 3 shows the 3D modeling for the Structural, Precast, and MEP Components.
3. **Analysis**

3.1. **Clash Detection**

Based on the categorization of clashes ([7], [8]) and the impact on construction projects, the results of the clash detections carried out on the structural vs precast components showed that the number of clashes that occurred was 289 clashes. For the structural vs MEP components showed that the number of clashes that occurred was 191 clashes. And for the precast vs MEP components showed that the number of clashes that occurred was 42 clashes. Figure 4 – Figure 6 shows the clash detection results for the structural, precast, and MEP components.

![Figure 4. Clash Detection Between Structural and Precast Components](image1)

![Figure 5. Clash Detection Between Structural vs MEP Components](image2)

![Figure 6. Clash Detection Between Precast vs MEP Components](image3)
3.2. **Causes of Clashes**

The main causes of clashes can be divided into three types, namely design error, design inconsistency, and design discrepancy [8]. In this study, the causes of the clashes with the highest percentage was caused by a design error, which is around 52.36%, this type of clash was mostly found in the clash between structural vs MEP components. Then followed by the design inconsistency which is around 39.13%, this type of clash is mostly found in the clash between the structural vs precast components. Then the last one is the design discrepancy, which is about 8.51%, this type of clash is mostly found in the clash between precast vs MEP components. It can be seen in Figure 7 which shows a comparison chart of the causes of clashes.

![Figure 7. Causes of Clashes Comparison](chart.png)

3.3. **Clash Clustering**

Clash clustering is a process of grouping a clash based on the predetermined clash element equation. The cluster of the clash is determined based on the similarity in the type and location of each clash. The clash classification process is carried out in order to make it easier when making clash resolving based on the cluster of each clash element. Clash clustering will be carried out on structural vs precast components, structural vs MEP components, and precast vs MEP components.

a. **Structural vs Precast Components**

In the clash of structural vs precast components, the most clashes was found in beam clusters, which was 242 clashes. An example of clashes that have been clustered for structural vs precast components can be seen in Table 1.
Table 1. Clash Clustering for Structural vs Precast Components

| Cluster   | Issue               | Description                        | Snapshot |
|-----------|---------------------|------------------------------------|----------|
| Beam      | Design Inconsistency| Clash 42: Clash between Beams and HCS | ![Beam Clash Example](image1) |
| Column    | Design Discrepancy  | Clash 62: Clash between Column and HCS | ![Column Clash Example](image2) |
| Shear Wall| Design Error        | Clash 31: Clash between Shear Wall and HCS | ![Shear Wall Clash Example](image3) |

b. Structural vs MEP Components

In the clash of precast vs MEP components, the most clashes was found in beam clusters, which was 178 clashes. An example of clashes that have been clustered for structural vs MEP components can be seen in Table 2. In the clash between the structural and precast components, there was no clash on the 1st and 2nd floor. Due to the MEP modeling that was carried out only in the parking area of the building, namely on the 2nd basement, 1st basement, and ground floor.

Table 2. Clash Clustering for Structural vs MEP Components

| Cluster   | Issue     | Description                        | Snapshot |
|-----------|-----------|------------------------------------|----------|
| Beam      | Design Error| Clash 101: Clash between Beams and Ducting Pipe | ![Beam Clash Example](image4) |
| Column    | Design Error| Clash 173: Clash between Column and Ducting Pipe | ![Column Clash Example](image5) |
c. **Precast vs MEP Components**

In the clash of precast vs MEP components, the most clashes was found in the riser shaft cluster, which was 20 clashes. An example of clashes that have been clustered for structural vs precast components can be seen in Table 3.

### Table 3. Clash Clustering for Precast vs MEP Components

| Cluster   | Issue         | Description                                      | Snapshot |
|-----------|---------------|--------------------------------------------------|----------|
| Duct      | Design Error  | Clash 14: Clash between HCS and Ducting Pipe     |          |
| Fan       | Design Error  | Clash 31: Clash between HCS and Inline Axial Fan |          |
| Riser Shaft| Design Error | Clash 2: Clash between HCS and Riser Shaft       |          |

4. **Results & Discussion**

4.1. **Clash Resolving**

To fix the clash (clash resolving) on elements that experience clash, resolve options will be made based on the type of existing cluster. After creating a resolve option, several parameters are used to evaluate the options that have been made. The assessment parameters used in this study consisted of three components consisting of:

- **Stakeholder dependency**
  
  Stakeholder dependency is an assessment parameter regarding the effect of improved options taken on other stakeholders such as Contractor (CONTR) and Consultant (CNSLT).

- **Analytical Dependency**
  
  Analytical dependency is an assessment parameter regarding the effect of improved options taken on other components such as Structure (STR), Precast (PRC), Architecture (ARC), MEP, and so on.
c. **Change Impact**  
Change impact is an assessment parameter regarding the effect of improvement options taken on changes with other project constraints, namely cost, quality, time, function (scope).

4.1.1. **Structural vs Precast Components**  
The clash resolves options for the clashes between structural vs precast components are resizing the HCS panels, resizing of the structural elements, and repositioning of the structural elements. An example of clash resolving between structural and precast components can be seen in Table 4.

| Cluster   | Solution | Before | After |
|-----------|----------|--------|-------|
| Beam      | Resize HCS | ![Beam Before](image) | ![Beam After](image) |
| Column    | Resize HCS | ![Column Before](image) | ![Column After](image) |
| Shear Wall | Resize HCS | ![Shear Wall Before](image) | ![Shear Wall After](image) |

4.1.2. **Structural vs MEP Component**  
The clash resolves options for the clashes between structural vs MEP components are repositioning of the ducting pipe, rerouting of the ducting pipe, and resizing of the structural elements. An example of clash resolving between structural and MEP components can be seen in Table 5.

| Cluster   | Solution | Before | After |
|-----------|----------|--------|-------|
| Beam      | Reposition Duct | ![Beam Before](image) | ![Beam After](image) |
4.1.3. Precast vs MEP Component

The clash resolves options for the clashes between precast vs MEP components are removing the HCS panel, repositioning of the ducting pipe, and rerouting of the ducting pipe. An example of clash resolving between precast and MEP components can be seen in Table 6.

Table 6. Clash Resolving between Precast and MEP Components

| Cluster  | Solution       | Before                                      | After                                      |
|----------|----------------|---------------------------------------------|--------------------------------------------|
| Duct     | Remove HCS     | ![Before Duct](image1.png)                 | ![After Duct](image2.png)                 |
| Fan      | Reposition Duct| ![Before Fan](image3.png)                  | ![After Fan](image4.png)                  |
| Riser Shaft | Remove HCS | ![Before Riser Shaft](image5.png)         | ![After Riser Shaft](image6.png)         |

4.1.4. Quantity Take Off Analyst and Cost Calculation

In this study, the calculation of the quantity take-off analysis will be carried out before and after the clash resolving. Resolving the clash on precast and MEP components resulted in changes in the quantity of these materials. Quantity takes-off is carried out by using the quantification tools found in the Autodesk Navisworks Manage 2020 software. Figure 8 - Figure 9 shows the quantification workbook on Navisworks and the results of the quantity take-off for Precast and MEP Components.
Clash resolving that was carried out on the clash between structural vs precast components, structure vs MEP components, and precast vs MEP components resulted in a change in the quantity of HCS panels and ducting pipes. The total material cost calculation is calculated by multiplying the unit price by the quantity of material. Table 7 shows the total cost of the HCS panels for each floor. Based on the table, with resolving the clashes prior to construction work, a potential saving of Rp3,752,434,165.97 can be made, or around 5.477% of the initial cost for the HCS panel.

| Location     | Total Cost (Rupiah) Before Clash Resolving | Total Cost (Rupiah) After Clash Resolving |
|--------------|--------------------------------------------|-------------------------------------------|
| Basement 2   |                                            |                                           |
| Basement 1   | 18,031,646,721.03                          | 17,501,394,946.26                         |
| Ground Floor | 19,520,322,368,53                           | 17,257,835,849.49                         |
| 1st Floor    | 21,268,101,977.73                           | 20,437,993,530.61                         |
| 2nd Floor    | 10,068,197,048.27                           | 9,938,609,623.23                          |
| Total        | 68,888,268,115.56                           | 65,135,833,949.59                         |

Table 8 shows the total cost of ducting pipes for each floor. Based on the table, with resolving the clashes prior to construction work, a potential saving of IDR 396,775,512.21 can be made or around 5.220% of the initial cost for ducting pipes.

| Location    | Total Cost (Rupiah) Before Clash Resolving | Total Cost (Rupiah) After Clash Resolving |
|-------------|--------------------------------------------|-------------------------------------------|
| Basement 2  | 3,708,184,766.19                           | 3,454,579,201.19                         |
| Basement 1  | 2,697,500,430.04                           | 2,664,323,926.97                         |
| Ground Floor| 1,196,045,293.38                           | 1,086,051,849.24                         |
| 1st Floor   |                                            |                                           |
| 2nd Floor   |                                            |                                           |
| Total       | 7,601,730,489.61                           | 7,204,954,977.40                         |
5. Conclusion
According to the results obtained from the analysis carried out in the previous chapter, several conclusions can be drawn as follows:

a. From the clash detection analysis carried out in this study, it was found a total of 289 clashes for structural vs precast components, a total of 191 clashes for structural vs MEP components, and 42 clashes for precast vs MEP components. Thus, the total number of clashes that occurred in this project was 552 clashes.

b. The cause of the clash with the highest percentage was caused by a design error which is around 52.36%. Then, followed by design inconsistency which is around 39.13%. Then, the last is design discrepancy which is around 8.51%.

c. Clash resolving was carried out in this study by resize, remove, repositions, and reroutes on some ducting pipes.

d. Based on the calculation of the change in costs after resolving the clash, a total potential saving is 10%: (1) HCS panel material can be made as much as Rp3,752,434,165.97 or 5,477% of the initial cost, (2) ducting pipe material, a potential saving can be made as much as Rp396,775,512.21 or 5,220% of the initial cost.

e. Comprehensive modeling and with a higher Level of Development (LOD) value are required to obtain more accurate calculation results.

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