Application of BIM in design conflict detection: a case study of Vietnam

Quan T Nguyen¹,², Phuong Q Luu³ and Yen V Ngo¹,²
¹Faculty of Construction Economics and Management, National University of Civil Engineering, Hanoi, Vietnam
²Institute of Investment and Construction Management, National University of Civil Engineering, Hanoi, Vietnam

E-mail: quannt@nuce.edu.vn

Abstract. Design conflict detection in construction projects is a very important task for ensuring the quality, time and cost. This job now has become more convenient due to the use of BIM. This paper proposes a process for BIM-based clash detection for introducing to the BIM practitioners in Vietnam. This process was then adopted in a complicated control house, which is a part of transformer station project in Vietnam, where the design was developed with 2D-CAD. The process discovered 36 design conflicts, including inconsistencies and geometric interferences. The results contribute as a proof-of-concept of BIM-based design conflict detection in Vietnam, where BIM is not very widely adopted.

1. Introduction

Building Information Modelling (BIM) has become more and more popular all over the world. There are some undeniable benefits BIM can bring to a construction project, not only in design and construction stages, but also in operation stage. However, in a country at an early phase of BIM adoption like Vietnam, BIM-based design becomes the dominant use in BIM-adopted construction projects, in comparison to construction and operation stages.

In Vietnam, the design process is divided into preliminary design (sometimes called conceptual design – integrated with a pre-feasibility study report), basic design (as a part of feasibility study), technical design and construction drawing design [1]. The system is different from that in Western countries, specifically in the United Kingdom, where the design process consists of three main phases: the concept design, the developed design and the technical design as in RIBA Plan of Work 2013 [2], and now changed to concept design, spatial coordination and technical design in the RIBA Plan of Work 2020 [3]. Though there is no specific stage in Vietnam for design coordination, this job is essential and always performed in complicated construction projects, though it is claimed as a challenging task [4], but useful in minimizing the project uncertainty by decreasing disruption, and reducing waste [5]. According to Lee and Kim [6], as the nature of design work, the larger the amount of information incorporated into the design, the more possible the chances of errors occurring, so as the coordination efforts of participating organizations. Design coordination when being performed, must ensure to have in time “a fault-free and high-quality integrated design” [7]. That is why design coordination becomes an essential part of the design job.

As “the process of ensuring integrated design between various disciplines involved in creating a facility, be it a building, infrastructure, or an industrial plant” [8], design coordination aims at discovering clashes, or design conflicts (the practice when two or more elements interfering in the
same space [9]), not only in individual design in terms of disciplinary, but also between various disciplines; then, inspection process steps in, and solutions for resolving clashes will be proposed, studied and implemented [10] to avoid risks in the next phases of the projects. BIM-based clash detection, the first phase in the design coordination process using BIM, is believed to help limit the weakness of traditional use of 2D drawings for design coordination, such as human cognitive limitations to visualize clashes, time consuming and iterative process etc. [8]. In addition, BIM-based clash detection can begin earlier in the project life cycle and enable more effectively collaboration between stakeholders from different disciplines [8]. Another benefit is the quality of the job; it is claimed that BIM can help detect 75% more design conflicts and mistakes than the use of 2D-CAD [11], and there are lots of benefits of BIM-based clash detection, as many research projects have claimed [12, 13]. Together with 4D construction process animation, BIM-based clash detection has become the most perceived use of BIM adoption in the construction industry in the world [4] as well as in Vietnam.

However, clashes in construction projects, which can be classified as hard clash, soft clash, time (or 4D/workflow) clash and animated clashes [14], have several root causes, such as design uncertainty, failing of design rules, design complexity, balancing effort in resolving the dilemma between model accuracy vs. meeting a deadline and design error [10]. Some of the root causes are corporate culture-based, human-related (tied to the quality and expertise of the BIM practitioners), or dependent on the practical adoption of BIM, also the BIM maturity of the country. Therefore, the BIM-based clash detection process in general and in the design phase in particular must identify and incorporate the local and industrial contexts.

This paper aims to propose an application of BIM in design conflict detection in BIM-adopted construction projects in Vietnam, considering the BIM maturity and the BIM human resources in the country. Then, the proposed process will be applied into a case study of a transformer station project for illustration. This research utilizes Autodesk Revit and Autodesk Navisworks Manager software (version 2020) as BIM tools.

2. Literature review

In a recent publication, Leite [8] has reviewed very carefully the BIM-based design coordination, with the participation of designers, general contractors and MEP subcontractors. She claims that it is necessary to first set the ground rules for the team, confirms the LOD will be used by each trade, then the design coordination workflow can process. Also, there is a need of acquiring a design coordination team, with specified BIM-related roles and the essential skills for each role which should be stipulated in the BIM Project Execution Plan.

In terms of the design coordination process, Staub-French and Khanzode suggested a 10-step process for 3D design coordination [12]: (i) Identify the potential uses of the 3D models, (ii) Identify the modelling requirements, (iii) Establish the drawing protocol, (iv) Establish a conflict resolution process, (v) Develop a protocol for addressing design questions, (vi) Develop discipline-specific 3D models, (vii) Integrate discipline-specific 3D models, (viii) Identify conflicts between components/systems, (ix) Develop solutions for the conflicts identified, and (x) Document conflicts and solutions. It is noted that their design conflicts detection directly involves steps from 4 to 8. However, this approach does not address fully the responsibility of the design coordination team through the process, as well as the quality assurance of the process as a whole or for each of the steps.

Dividing the design coordination workflow into only 6 steps (Figure 1), Leite [8] allocates the jobs for different team members, which she claimed include the BIM Manager and Project Manager of the General Contractor, the BIM Manager of the Designer and the BIM Technician(s) of the Subcontractor. After the individual discipline-specific models developed (the structural and architectural should be established first to act as the base model), each BIM author needs to do internal coordination before sending out their individual models to the BIM manager. Then, the federated model (an integrated model from individual discipline-specific models) will be generated. The federated model will be used for clash detection, which includes (1) visual inspections and (2)
automatic clash detection. The clashes discovered will be sorted and grouped to be discussed in a
design coordination meeting for making decisions about how to resolve conflicts among the
participants themselves and committing to the decisions implemented.

![Design coordination workflow](image)

**Figure 1.** Design coordination workflow (Adopted from [8])

Leite [8] also emphasizes the importance of the federated model (Figure 2), which is developed by
combining several models created by designers and subcontractors. The LOD of the federated model
also needs to be defined as of LOD 350 (i.e., some elements such as architectural and structural
models are in LOD 300, while others like MEP models are in LOD 400). Leite [8] claimed that, in
order to assure the quality of the federated model, LOD requirements need to be identified, guidelines
need to be developed for conducting intradisciplinary coordination, avoiding duplicates of modeled
elements or overlapping elements (to avoid false positives), positioning models (using an origin point
to orient each model to make sure they are in the correct location); naming convention, BIM color
scheme rules should also be developed.

![Example federated model](image)

**Figure 2.** Example federated model (Adopted from) [8]

Design conflicts, or clashes, as mentioned above, can be of four major types. Hard clash is a type
of geometrical conflicts, which occurs when two physical elements are placed at the same space. Hard
clashes need to be eliminated as soon as possible since if being discovered on site, they make the
project be both costly and time consuming to address. Soft clashes (or clearances) happen when there are not enough spatial tolerances given to fulfill space utilization, connection, installation and manipulation requirements. 4D/workflow clashes are timeline/scheduling-type conflicts, e.g. temporary scaffolding blocking a main access. Animated clashes are actually soft clashes but using dynamic buffer instead of static. An example of this type is moving a virtual person through corridors and stairs to check if the prescribed dimensions are correct [8, 14]. Classes can be incorporated in a design issue classification framework [4] with multi-level categories for the ease of reference in the future.

Clashes can also be categorized as true positives, false negatives, or false positives. True positives are the conflicts identified as clashes and they actually are, false negatives are clashed that have not been identified, while false positives are incorrectly identified clashes [8, 14]. This classification help raise the awareness on the precision of clash detection, then either help reduce future risks or increase the speed. The positive relationships between clash detection and design-, buildability-, or building-performance qualities are then being confirmed [14, 15].

3. The proposed BIM-based clash detection for Vietnam
Considering the country’s BIM maturity and human resources, adapting the clash detection steps in the workflows proposed by Staub-French and Khanzode [12] and Leite [8], the paper proposes a process for design conflict detection as shown in Table 1. The steps are developed in more detailed in comparison to the original processes of Staub-French and Khanzode [12] and Leite [8], in order to make it easy-to-use to the less-experienced BIM human resources in Vietnam. Also, the proposed process has considered to fit with design – bid – build, the popular project delivery system in Vietnam.

The proposed process consists of 11 steps and is just for the phase of clash detection, it does not cover the full workflow of a typical design coordination job. It is designed to run in a technical design phase, by the designer consultant of the concerned projects. This process is applicable in both cases when there is a Project Manager involved in the process or not. The clash detection team consists of a BIM Manager of the designer (BMa), BIM Coordinators (BCo) of the designers and its subcontractors (if any) who are responsible for each of the intradisciplinary model, and the BIM Modelers (BMo). Table 1 also shows the responsibility of each team role in the steps of the process. If the Project Manager participates in the process, he will be informed of all of the key steps. Though most of BIM models in construction projects in Vietnam now are created from existing 2D drawings, this process also is applicable to the cases where BIM models are developed directly with authoring software, not through an interim step of 2D drawings.

After the team has been established, a Design conflict detection Plan will be developed as a guide for the whole process. This Plan should clarify what LOD to be used, procedures for conducting intradisciplinary coordination, method for avoiding duplicates of modeled elements or overlapping elements, for positioning models, rules for naming convention and BIM color scheme, as emphasized by Leite [8], to assure the quality of the federated model as well as individual models. Specific modelling requirements such as information requirements will be identified at Step 2. Though the information requirements should be included in the BEP (BIM Execution Plan) of the Project, it should be noted that the client, end-users and contractors should be consulted if they are available. Based on that, each discipline-specific model is created (directly with 3D authoring software or from existing 2D drawings, depending on each circumstance). An intradisciplinary clash detection then needs to be conducted for each of the individual models in Step 5, then the federated model will be created in Step 6. Aa clash detection on the federated model, which should be used with an algorithm of conflict detection [16], is conducted in Step 8, discovered clashes will then be inspected (Step 9), and if they are true clashes, they will be recorded in the Conflict detection report (Step 10). Step 11 is for incorporating the continuous improvement principles into the process, by collecting lessons learnt then integrating into the next Design conflict detection Plan.
Table 1. Proposed process of design conflict detection

| No | Process                                      | Responsibility | Output                                              |
|----|----------------------------------------------|----------------|------------------------------------------------------|
|    |                                              | BMa | BCo | BMo |                        |                                      |
| *  | Start                                        | R   | I   | I   | Kick-off meeting       |                                      |
| 1  | Develop design conflict detection plan       | R   | C   | C   | Design conflict detection Plan |                                      |
| 2  | Identify the modelling requirements          | I   | C   | R   | Modeling requirement documents |                                      |
| 3  | Develop discipline-specific BIM models from technical design | C   | R   | I   | Discipline BIM models; Progress reports |                                      |
| 4  | Modify discipline-specific BIM models        | I   | C   | R   | Modified Discipline BIM models |                                      |
| 5  | Review interdisciplinary models NO            | C   | R   | I   | Preliminary model report; Model modification requirements; Updated plan |                                      |
|    | YES Integrate discipline-specific BIM models | C   | R   | I   | Federated BIM model     |                                      |
| 7  | Develop rules for clash detection            | C   | R   | I   | Clash detection Rules: Matrix for design conflict detection, Correlation between components, etc. |                                      |
| 8  | Perform coordination conflict detection on federated BIM model | C   | R   | I   | Preliminary conflicts report exported from BIM tool |                                      |
| 9  | Inspect discovered clashes NO                | I   | R   | I   | List of classified conflicts |                                      |
|    | YES Develop conflict detection report        | R   | C   | I   | Conflict detection report |                                      |
| 11 | Document lessons learnt                      |     |     |     | Lessons learnt documents |                                      |

**Close stage**

*Note:*
BMa: BIM Manager
BCo: BIM Coordinator(s)
BMo: BIM Modelers
R: Responsible
C: Consult
I: Inform
4. A case study of BIM-based clash detection process in a transformer station project

In order to illustrate the proposed process for design conflict detection, the process was applied in a transformer station project in Vietnam, with the item of a control house. This house was designed and there are 2D CAD drawings available. Key steps of the process are presented below.

4.1. Development of the discipline-specific models

The separate BIM models were developed from 2D drawings for each of the three disciplines: architectural, structural, and MEP. For the ease of the model development, MEP models were created separately for each sub-discipline: plumbing, HVAC and electrical. The individual models are presented in order in Figure 3 to Figure 7.

4.2. Development of a Matrix for design conflict detection

This Matrix is created as a guide for the clash detection procedure with the federated model. It shows the probability of conflicts between the main discipline-specific models (Table 2, adopted from [11]).
Table 2. Matrix for design conflict detection

| Disciplines | Architecture | Structure | MEP |
|-------------|--------------|-----------|-----|
| Architecture | Windows | Ceilings | | |
|  | Doors | | | |
| Structure | Columns | Windows | Doors | |
|  | Ceilings | | | |
|  | Doors | | | |
|  | Beams | Windows | Doors | |
| MEP | Pipes | Doors | | |
|  | Windows | Pipes | Columns | |
|  | Accessory | Doors | Accessory | |
|  | Equipment | Ceilings | Equipment | |
|  | Fixtures | Doors | Beams | |
|  | Windows | Fixtures | Columns | |
|  | Beams | | | |

4.3. Design conflict detection results
Conducting a clash detection process in the case study project, 36 conflicts, including inconsistencies and geometric interferences, have been found with the federated BIM model. The results, categorised in multilevels for the ease of solution proposal and selection, are shown in Table 3 and Figure 8 below.

Table 3. Table of clash detection report

| Column & Ceiling | Grid Location | Clash Point | Column ID | Ceiling ID |
|-----------------|---------------|-------------|-----------|------------|
| C-5: Level 1    | x:14.910, y:6.107, z:4.143 | 938890 | 990979 |
| B-5: Level 1    | x:14.910, y:2.907, z:4.143 | 938675 | 990979 |

| Beam & Door | Grid Location | Clash Point | Beam ID | Door ID |
|-------------|---------------|-------------|---------|---------|
| B-11: Level 1 | x:36.465, y:3.970, z:0.600 | 947431 | 1184034 |
| C-5: Level 1  | x:14.865, y:5.500, z:0.600 | 947229 | 1183926 |
| C-1: Level 1  | x:-0.065, y:5.500, z:0.600 | 947052 | 1184262 |
| C-2: Level 1  | x:3.935, y:5.500, z:0.600 | 947118 | 1184227 |

| Pipe & Beam | Grid Location | Clash Point | Pipe ID | Beam ID |
|-------------|---------------|-------------|---------|---------|
| C-1: Level Roof | x:1.172, y:6.310, z:4.499 | 1019538 | 946225 |
| D-1: Level Roof | x:1.160, y:9.310, z:4.514 | 1019538 | 946108 |
| B-1: Level Roof | x:1.190, y:3.110, z:4.519 | 1019538 | 946195 |
| A-3: Level 1  | x:8.220, y:0.110, z:3.340 | 1023368 | 959919 |
| D-10: Level 1 | x:31.701, y:9.310, z:3.338 | 1023707 | 959888 |
| D-6: Level 1  | x:17.301, y:9.310, z:3.338 | 1023626 | 959888 |
| D-8: Level 1  | x:24.501, y:9.310, z:3.338 | 1023680 | 959888 |
| A-6: Level 1  | x:17.290, y:-0.110, z:3.338 | 1022726 | 959919 |
| A-10: Level 1 | x:31.690, y:-0.110, z:3.338 | 1023448 | 959919 |
| A-8: Level 1  | x:24.490, y:-0.110, z:3.338 | 1023409 | 959919 |
| D-3: Level 1  | x:8.220, y:9.090, z:3.335 | 1023653 | 959888 |
| B-1: Level Roof | x:1.175, y:2.964, z:4.550 | 1019524 | 946195 |
| A-3: Level Ground | x:8.220, y:-0.165, z:0.581 | 1023738 | 946829 |
| A-6: Level Ground | x:17.295, y:-0.165, z:0.581 | 1023074 | 946829 |
### Table 1

| Pipe & Fixture | Grid Location | Clash Point | Pipe ID | Fixture ID |
|----------------|---------------|-------------|--------|------------|
| B-1: Level Roof | x:1.775, y:2.360, z:4.320 | 995285 | 992657 |
| B-1: Level Roof | x:1.182, y:2.370, z:5.570 | 1019333 | 992657 |

**Figure 8.** Selected clashes detected

### 4.4. Discussions

The proposed process for design conflict (or clash) detection was applied in a real project, which has been designed with 2D CAD.

Generally, the coordination of the discipline-specific BIM models among themselves and in the form of a federated model is claimed as a challenging and time consuming task on the design phase, especially in complicated project, e.g. multistory buildings [17]. Not an exception, the modelling process for each of the discipline-specific models in this case study was labor-intensive and time consuming, because the models were developed from technical design, which lacks of lots of details, as the "rule of thumb" in Vietnam. There are some difficulties arising when developing the models. Most of the technical designs have not enough detailed information to get to LOD of 300-400. The most difficult part fell on MEP-related jobs, therefore, lots of research have been done on this [18].
Not only in Vietnam, the design of the MEP systems in construction projects are considered as very challenging, especially in complex projects [19]. Also, since there was not any MEP engineers who are capable of authoring all of the sub-disciplinary models in one integrated MEP model, separate electrical, plumbing and HVAC models were developed by different BIM Modelers. Autodesk Revit MEP, the authoring software used for developing the MEP models is a North American software and it uses a different system from the standards and norms in Vietnam. Therefore, its built-in MEP components that users in other parts of the world can just drag into the drawing area when developing the models [20], have limited used in Vietnam. That is why the development of the MEP models in this case was labored-intensive, time consuming, especially the creation of new BIM objects of components to meet design specifications and to compose connected systems.

What is more, the unavailability of BIM Objects made the BIM Modelers to create them by themselves, which lengthened the process duration, though the modelers have tried to contact people in his network to ask for help in finding the BIM library. The BIM coordinator of the Project had to work with each of the team to do intradisciplinary coordination, and that process took a bit long time since some of the modelers did not follow the established rules completely, especially the rule for positioning.

The Matrix for design conflict detection, adopted from the work of Goes, R. and E. Santos (2011) [11] was used as a guide for the BIM coordinator to check conflicts. Also, a list of clashes collected as lessons learnt from the literature review and from professional forums was introduced to them to suggest the positions with high possibility of having a conflicts. The list of clashes collected after each of the process run can be included in the design issue classification framework, a tool suggested by Mehrbod [4] for the case of using them, especially when the list becomes too large.

It was surprised that in a simple project like that control house in the transformer station, there were such too many clashed detected. The list of clashes then handled to the BIM Manager to carry out with the next steps of the design coordination, where he has to work with individual design teams in different disciplines to make decisions about design revisions.

5. Conclusion
Since most of the design companies in Vietnam are at their initial steps of BIM adoption, there is a lack of capable BIM human resources in the country. In order to upskill the BIM human resources, proper and detailed guidelines are needed. This paper presents the process of design clash detection, a part of a large workflow of design coordination, which aims to ensure the quality of the BIM model to be used in the next phases of the project lifecycle. If being used properly, the process can help designers to move from clash detection to clash avoidance, which can bring much larger benefits. The process can be used as good example for training BIM human resources to contribute to the development of BIM human resources for Vietnam. It can also be a good reference for design consultants who would like to adopt BIM into their business. The proposed process is developed for the project delivery method of design – bid – build, which is currently the most popular project delivery system in Vietnam, like in many country, as a research of Jang et. al. reveals [21]. In the future, when BIM becomes more popular in Vietnam, modern systems like integrated project delivery will be applicable, then the process may need to be revised accordingly.

This paper focuses on the first stage of BIM coordination process. Future research will be carried out for the next stages of clashes inspection and problem solving.

Acknowledgements
This research in funded by National University of Civil Engineering (NUCE) under grant number 223-2018/KHXD-TD

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