DIGITAL ENHANCEMENT FOR BUILDING INFORMATION MODELLING (BIM) CLASH DETECTION

PROMSRI. N
UNSW, Sydney, Australia
Merk717@hotmail.com

In Collaboration with:

CHERNYAVSKY. M
AURECON, Sydney, Australia

Abstract. This paper discusses the current and potential future state of multi-disciplinary Building Information Modelling (BIM) clashes and aims to apply practical applications of ideas and tools for architects, designers, engineers and other professions when designing and documenting projects. BIM enables designers to leverage the gap that involves interdisciplinary and intradisciplinary coordination and collaboration within teams. Coordination between architects, engineers and construction (AEC) industry and other design team members are the key to reducing construction costs and unexpected clashes on site. BIM has improved a multi-disciplinary coordination and has aided in resolving clashes within models before any resources are committed on site. This research aims to provide easy to use and compatible clash detection tools to spot potential faults and investigate the quality of your BIM files. The case study investigated demonstrates how automating clash detection into the current design process can help limit expensive reworking and ensure Building Information Models are co-ordinated.

Keywords. Building Information Modelling (BIM); Clash Detection; AEC; Coordination

1. Introduction: Research Aims and Motivations

This research explores the nature of procedures used within the architecture, engineering and construction (AEC) industry and considers an alternative approach in early collaboration is essential to deliver a clash-free design model. Many scholars have their own definition of clash detection, its commonly referred to as; “detecting clash and interferences in a 3D project model” or one more detailed definition is; “iterative process in which all noted project conflicts are addressed and reevaluated until the desired level of coordination has been achieved” (Wang, 2013). For 3D model to be a ‘clash-free’, communication and collaboration are equally important, with Building Information Modelling (BIM), which contains physical and functional characteristics through 3D design coordination in reducing clashes. As common practice in the AEC industry today the majority of problems arise in the design and construction phases of projects due to poor coordination and design complexity. However, through the implementation of co-ordination using Building Information Models (BIM) designers and architects have improved their ability to understand one another and solve these problems much more effectively. This has been evident in various complex infrastructure and built environment projects. As this capability improves BIM-based clash detection is becoming more crucial in early design stages and plays a major role throughout the design process to design production than ever before (Jung-Ho S, 2012).

The role of the Architects and designers historically has evolved drastically due to the advancement of technology. Previously, the traditional method to identify clashes was to manually overlay 2D drawings on a light table to visually see clashes against another. With the early 3d graphics integrated later has allow users to better visualise and analyse clashes but was still not 100 percent accurate and time consuming (Wang, 2013). Consistency is still a common issue with every project because architect’s roles changes from time to time in every project and every firm. With this exchange of cross-disciplinary collaboration, this research explores the possibility of automated comparable clash analysis predictive capabilities to achieve this research aims. This attempt to better understand on visualising and analysing clashes for users through 3D graphical representations.

2. Research Observations and Objectives

The objectives and key insights of this research is to increase computational efficiency for the Built Environment to understand and interpret the diverse field of complexity involved in coordinating large and complex multi-disciplinary projects. This research paper will underpin some of the key focal points and the foundations of how clashes occur, is it a miscommunication factor, complexity of the design or is it the shift of attention from the design process to a design product (Chougui, Ali 2006). It is believed that importance of BIM will only become more important in the future of design coordination in the AEC industry. BIM provides the ability to integrate 3d environment with a clearer overall vision of the projects and capable of making informed decision faster. Clash detection is considered a crucial component to be implemented frequently throughout the design process and design product (Chougui, Ali 2006).

3. Research Questions

The advancement of technology available for designers and architects today has accelerated rapidly in recent years, however current processes of clash detection are yet to be fully utilised in the Built Environment. Research studies have proven that miscommunication and design complexity are the main components which lead to the occurrence and reoccurrence of clashes. The current state of design practice is significantly reliant on clash detection tools to coordinate and solve problems which are uncovered often late in the design stage with regular meetings to deliver a clash free 3D-BIM model just prior to construction works beginning (Akponeware and Adamu, 2017). Therefore, this information raises a question and an opportunity;

Is there a better system to optimise the current BIM-based clash detection process to reduce coordination conflicts and improve efficiency?

This paper aims to discuss the current state of the art in architectural design positions to redefine and evaluate the design process to achieve better coordination with accurate and efficient estimations to perform construction analysis that lead to more coordinated projects with great cost savings and improved confidence in design co-ordination.

4. Methodology

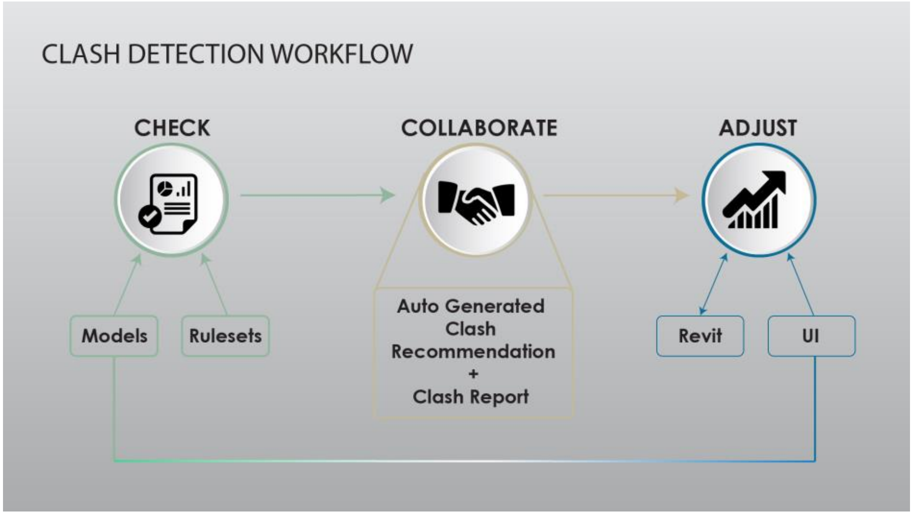

Figure 1. Clash Detection Workflow

This paper proposes an enhanced workflow that streamlines the process of clash detection, yields an incremental increase in both precision and computational efficiency. This work is to be expanded and carried out in collaboration with Aurecon through case studies and analysis of existing clash detection software and processes in the AEC industry.

Through the analyses of current clash detection procedures and extensive literature reviews, the proposed clash detection methodology attempts to rationalise and simplify the collision of multiple inputs with meaningful suggestions provided. This is evaluated against Rule-based clash detection algorithm such as Solibri Model Checkerand geometry-based such as Autodesk Navisworks Manager (Guangbin, 2011). The methodology leverages the standard BIM application such as Autodesk Revit and Dynamo to support collaboration between parties whom are both working on the Autodesk Revit software, which is common in the AEC industry.

The final prototype involves a rule-based algorithm with constraints to determine the geometry compliance of true positive (*true*) and false positive (*false*) for auto generated clashes. Design recommendations to resolve the clashes are then incorporated into the 'clash report'. A rule based auto generated algorithm will form the basis of geometrical clash detection and classification. Classification comprises of two classes, 'hard clashes' and 'soft clashes', this procedure is set to optimise the design decision making process and empowers the designers to prioritise and investigate the clashes and amend the BIM. The proposed clash detection methodology is to be carried out to enable users to better understand the clashes and to understand their importance, this is an important simplification from the currently complex clash reports generated by Solibri and Navisworks.

The purpose of auto generated clash recommendations is regarded as a valuable addition to the clash detection process at Aurecon and similar consultancies is due to the current complexity of the clash reports in the available software namely Solibri and Navisworks, both of which in practice provide a substantial list of clashes that is of great difficulty for any untrained designers to understand, with many of the clashes reported being irrelevant or negligible. "…A significant number of designers have learnt clash detection "on the job" i.e., informally, while only 22% reported that they have over six years of experience doing clash detection" (Akponeware and Adamu, 2017). The methodology of this research aims to improve the yield and usability of clash reporting and understanding through visually representing each clash and prompting recommended solutions. This aims to enable users to identify and solve clashes faster and with greater ease with the ultimate goal to deliver a 'clash-free' 3D BIM model.

5. Background Research

In the AEC Industry, the need of clash detection tools to be precise and accurate is important for consultants to deliver fully coordinated design documentation. BIM-based clash detection is becoming more crucial and plays a major role in both the design process and design production (Jung-Ho S 2012). Current existing clash detection algorithm are Rule-based algorithm like Solibri Model Checker and geometry-based such as Autodesk Navisworks Manager (Guangbin, 2011). Theses clash detection algorithms generally identify the three common clash classes, firstly is what known as hard clash, secondly is the soft clash/clearance clash and lastly is the 4D/ workflow clash (ACD 2017). The differences between these three are the level of detail (LOD) of the BIM model.

The hard clash detection is the geometry base detection, commonly between two main architectural or structural elements that is occupying in the same physical space which intersect each one another such as the duct and the beam its interfering with one another. The soft clash/Clearance clash are geometries requires to be within the tolerance where objects have spatial dependencies around it such as an HVAC equipment that require a certain clearance so that the door can be open on it and filters can be changed. The 4D/Workflow clash detection is aimed to improve the clash delivery prediction timeline or schedule related information where something that's happening in a sequence which cannot happen in reality, such as an electrical installation which requires to be installed before the built in that's going to go in front of it (ACD 2017). This research will mainly be focusing on the two clash classes of the hard and soft clash.

5.1. Autodesk Navisworks (geometry-base algorithm)

Autodesk Navisworks is commonly used in the AEC industry, Navisworks enables user to detect all types of complex and minor clashes. Navisworks objectives is to reduce potential clash and interference problems before construction, minimising expensive delays and re-work (Autodesk, 2017). Autodesk Navisworks marketed their products as following;

- Perform clash detection tests against specified geometry to help find and resolve conflicts.
- Check as-built laser-scan data against 3D designs.
- Open current clash in many original design software applications.
- View clashes in context with geometry in the model and in relation to other clashes.
- Make all non-clashing items transparent to more easily locate clashes in the model.
- Move between clash results to maintain orientation in the model.
- Create Hard, Clearance and Duplicate clash tests to support multiple co-ordination scenarios.
- Analyse space and time by linking clash tests to 5D simulations and object animations.

Navisworks can read various file types from dwg to nwc file format, the disadvantage of this software is that it cannot read other BIM application native like Revit .rvt file type. It is important to note that if the 3D model has been designed via Revit application, user will need to export the 3D model as a dwg file type (Ales, 2010).

5.2. Solibri Model Checker (rule-based algorithm)

Solibri Model Checker is equally widely used among the AEC industry. The Solibri model checker objective is to reveal potential flaws and weaknesses of the BIM model to run and check if the model “complies with the building codes and organization's best practices” (SSP, 2017). Solibri Model Checker marketed their products as following;

- Automatically analyze and group clashes according to severity. Find relevant problems quickly and easily. Investigate the quality of your BIM files.
- Prevent issues in advance. Use SMC and its logical reasoning rules to search for components and materials missing from the model.
- Use SMC to locate flaws and exceptions in models made by different design teams. Avoid expensive rework by knowing both models match.

- Manage and track changes between two design versions of the same model. Save time with easy visualization and verification of model changes.
- Be assured on the quality of information in BIM designs. Then use SMC for easy and instant information takeoff. Use multiple report templates that best suit your user role or create one yourself. Measure spaces and materials on the fly and share with others.

Solibri Model Checker provides a similar characteristic to Navisworks. The differences between these two is that Solibri has the ability to provide a wide range of custom rule-based checks using IFC file format to allow for the code compliance that goes beyond just a clash detection tool.

TABLE 1. Clash detection applications

	Autodesk Navisworks	**Solibri Model Checker**
Clash Detection Algorithm	Geometry-base	Clash Detection Algorithm
Clash Report	Generate in html format	Generate
Import Options	dwg, .dxf, .dwf, .dwfx, .fbx, .ifc, .rvt, .skp, .3dm, .stl etc.	ifc, rcp or dwg files
Native File	NWC, NWF, NWD	SMC
Level of Difficulty	Moderate	Moderate
Pros	Tracking changes and reporting, handles variety of file types and built it rendering.	Read Excel structured info of COBie data, tracking changes and reporting.
Cons	Cannot navigate in 3D, limited render styles	Moderate

With these two applications being the common application for clash detection for the AEC industry. These two applications have their advantages and disadvantages as shown on table 1, we see this as an opportunity to further discuss and develop for this research.

5.3. Causes of clash

In a constantly changing environment, nothing its perfect, precise and accurate, this is because one attempts to represent a perfect design in an imperfect world through various software, where parties are still working independently. For these reasons, there's always going to be clashes and hidden errors in every project.

Architects, designers and engineers requires efficient and effective communication throughout the project. Miscommunication often occur and reoccur during all stages of the project from design process to construction due to the complexity of the design. Miscommunication and design complexity are the main components which leads to the occurrence and reoccurrence of clashes "Decisions during this planning phase have direct impact on cost development and occupational safety on site during construction" (Schwabe, 2016).

6. Case Study

The case study of this research aims to demonstrate a more meaningful and simplified approach to clash detection which is usable and adds value to all designers and modellers, regardless of their background or training in clash detection. The ultimate goal is to engage all designers and modellers in the process of clash detection and embed it in the way the AEC industry designs and documents. The clash detection tools developed are prototyped on a simplified Revit model to evaluate and test its feasibility for application on larger complex projects. This case study solution was developed in collaboration with Aurecon and is non-standard in the current AEC industry. The approach is computationally driven using Autodsk Revit and its visual scripting capabilities through Dynamo.

Autodesk Revit and Dynamo have been implemented due to its commonality in the AEC industry. Autodesk Revit is becoming the standard BIM application for all designers, architects and engineers to work on.

6.1 Conventional methods for identifying clashes

A typical process implemented for clash identification involves sharing each disciplines BIM at the end of the week, after which the models are linked into a central model with clashes identified through appropriate software or visually inspected in critical regions. The general experience with the external clash detection software is that, designers and architects generally don't use it until later in the design stage, the significance of this process is computationally generated in dynamo to identify clash elements against one another and only isolating selected clash elements to visually displayed within the Autodesk Revit space as shown on figure 4.

as it is difficult to get meaningful insights from the generated clash detection reports.

6.2 Generating clash detection interface.

For the case study a simple interface was created to provide a user friendly and intuitive interface when engaging the geometry and generating the report. The new clash detection interface will be run on the Autodesk Revit platform and involves the use of dynamo player and dynamo. Dynamo player is a recent add-in for revit which enables users to run dynamo scripts in the background without needing to access the complex dynamo scripting. The purpose of this is to allow untrained dynamo users to use and understand the process with a click of a button as shown on *figure 2*.

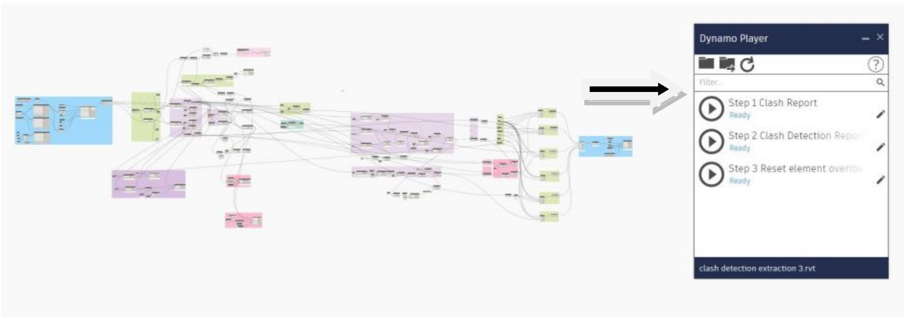

Figure 2. Dynamo to Dynamo Player.

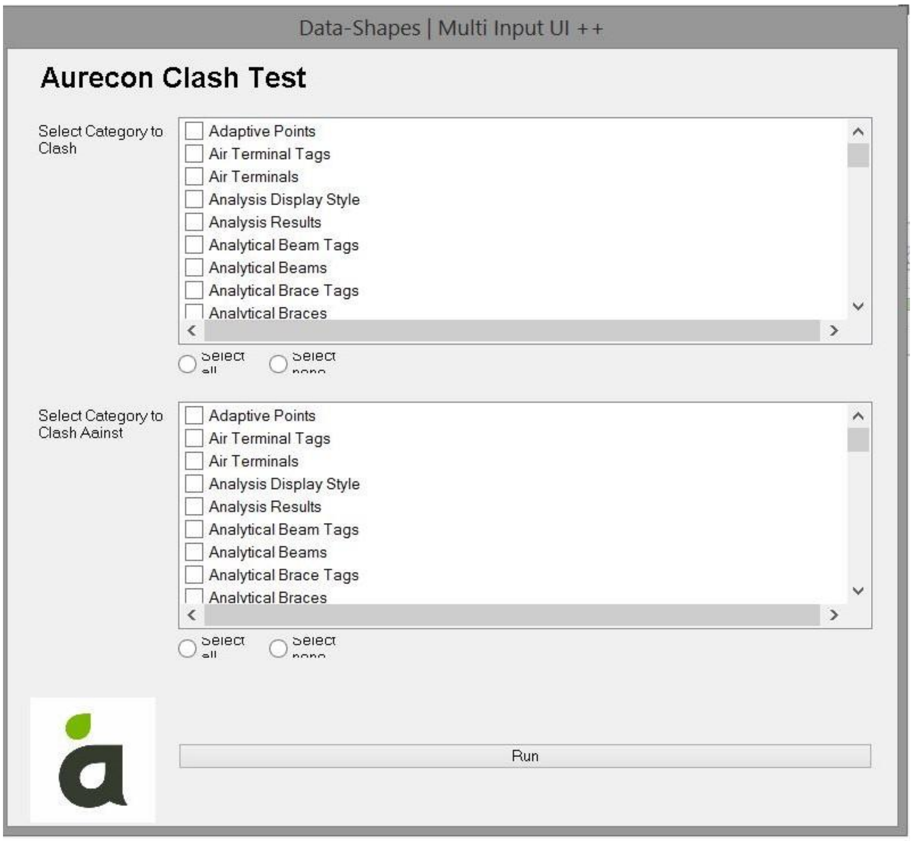

Figure 3. Dynamo to Dynamo Player.

The customized user interface as shown in *figure 3* will empower users to run a general clash report though selection of desired clash elements. This process was done within dynamo script using the Data-Shapes package provided within dynamo. The new user interface has allowed for a better coordination within the project without needing to export the project model to an external software.

Through interviewing of designers and modelers at Aurecon the visual representation of clashes was identified as a key design element in the engagement of the tool. As such a simple yet intuitive interface was developed, iterated and co-designed with the end users.

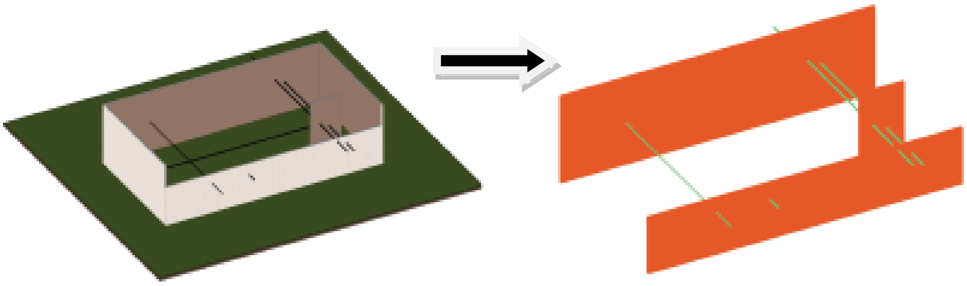

Figure 4. Identifying clash elements (Orange as primary element), (green as secondary element).

Refer *Section 6.4* for further information regarding the visualization of clashes.

6.3 Generating the clash report

Exporting clash detection data to Excel format is based on the same dynamo script as used to identify the clash elements. The current clash report at Aurecon is being generated though the used of Autodesk Navisworks. The current workflow of generating the clash report at Aurecon as shown on figure 5. The problem issues identified by end user at Aurecon is that it is extremely difficult for any untrained designers to understand and comprehend the key insights from the generated clash detection reports of complex projects.

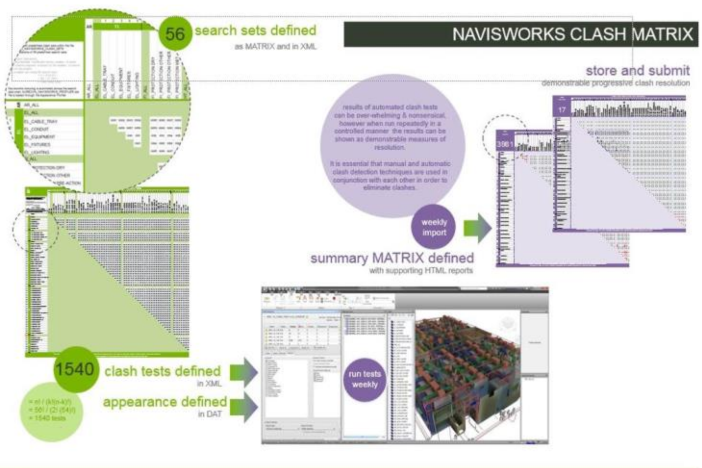

Figure 5. Extract from example Aurecon clash detection report.

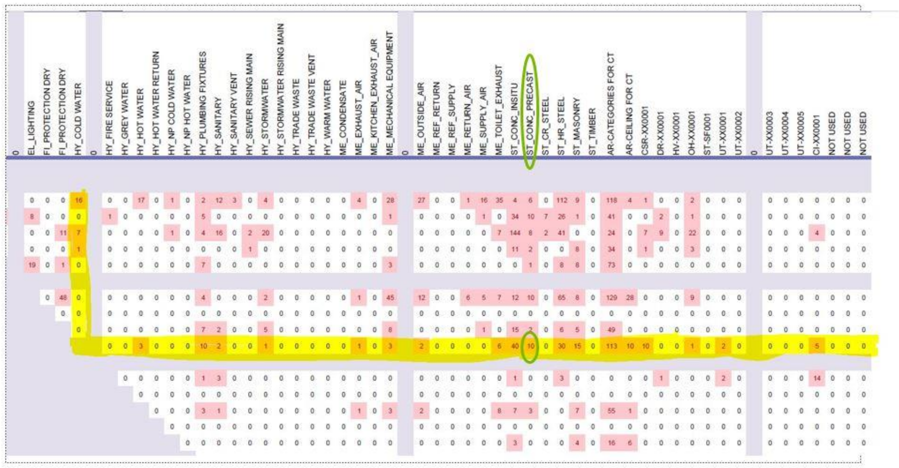

Figure 6. How to use the clash matrix report.

As shown in *figure 6*, the current process results in an over-whelming and tedious task of comprehension and understanding which is both time consuming and tedious. As shown in *figure 7*, the clash matrix time graph by Aurecon demonstrates the differences between the theory and the actual time required to eliminate clashes. For this reason, we seek this as an opportunity to provide a meaningful clash report by providing an auto generated clash recommendation report to improve the current workflow as shown in *figure 8*.

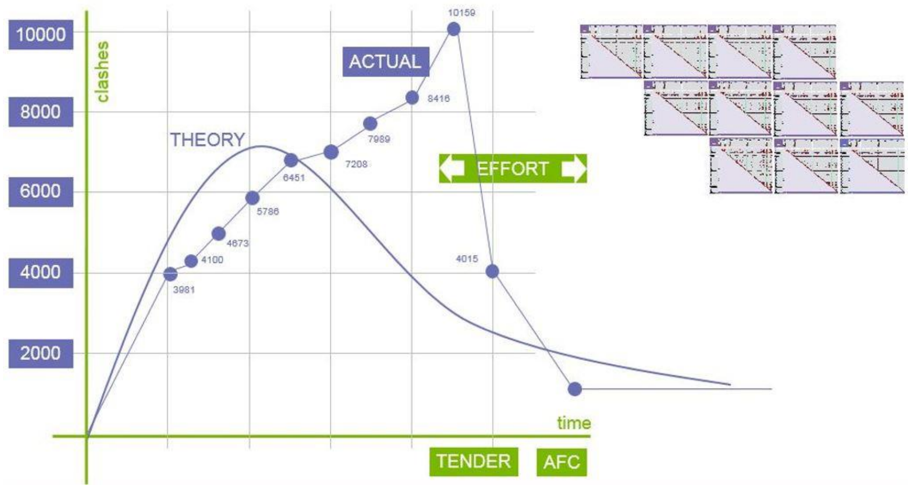

Figure 7. Clash matrix time graph

Clash Report	Walls vs Pipes	01-November-20:04-2017	-	-	-
-	-	-	-	-	-
Clash Category Type	Clash Element ID	Clash Category Type	Clash Element ID	Clash NO.	Recommendations
Wall : Double brick - 270	210338	Pipe : Default	210353	1	Change element height above floor (Offset) from 3900 to 5338 Or Create 150 Dianmeter penetration in wall
Wall : Double brick - 270	210340	Pipe : Default	210369	2	Change element height above floor (Offset) from 4780 to 8200 Or Create 225 Dianmeter penetration in wall
Wall : Double brick - 270	210338	Pipe : Default	227235	3	Change element height above floor (Offset) from 2743 to 5388 Or Create 225 Dianmeter penetration in wall
Wall : Double brick - 270	210340	Pipe : Default	227253	4	Change element height above floor (Offset) from 4180 to 8200 Or Create 225 Dianmeter penetration in wall
Wall : Double brick - 270	227334	Pipe : Default	210353	5	Change element height above floor (Offset) from 3900 to 8150 Or Create 150 Dianmeter penetration in wall
Wall : Double brick - 270	210338	Pipe : Default	210369	6	Change element height above floor (Offset) from 4780 to 5388 Or Create 225 Dianmeter penetration in wall
Wall : Double brick - 270	210338	Pipe : Default	227253	7	Change element height above floor (Offset) from 4180 to 5388 Or Create 225 Dianmeter penetration in wall
Wall : Double brick - 270	210340	Pipe : Default	210369	8	Change element height above floor (Offset) from 4780 to 8200 Or Create 225 Dianmeter penetration in wall
Wall : Double brick - 270	227334	Pipe : Default	227253	9	Change element height above floor (Offset) from 4180 to 8200 Or Create 225 Dianmeter penetration in wall
Total Clash				9	

Figure 8. Auto generated clash recommendation report

After the report has been run, the Excel clash report is now compatible with the action recommendation for the user to identify, understand and respond. This workflow is streamlined when compared to other existing clash detection software available in the market.

6.4 Tagging clash elements

Existing clash detection software such as Navisworks can only detect clashes and highlighting the clash elements from a list of selections. This process is very tedious because the user is required to switch back and forth to the original project design platform to solve the problem. This was identified as an area in need of significant improvement. The tagging implemented and visual representation of clashes aid to speed up clash identification and resolution. Each clash element are given an element identification number and an associated clash number which correlate to those specified in the clash report as shown in figure 9, this will enables users to solve clashes faster and easier to and bring designers closer to delivering a clash-free 3D BIM model.

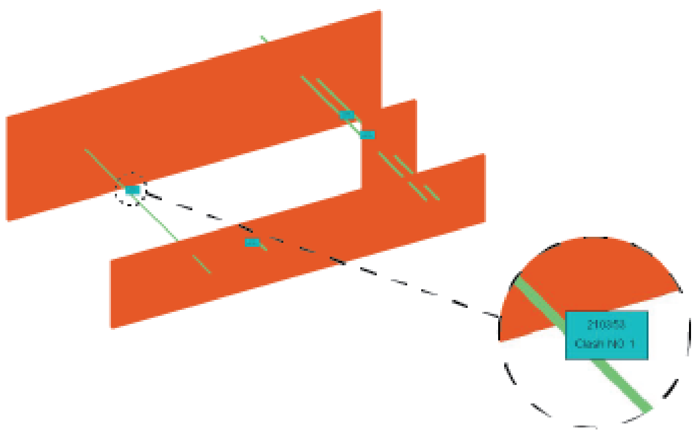

Figure 9. Tagging clash elements

7. Research Significance

Through discussions and research of contemporary clash and error detection methods, this research explores the nature of procedures used within the architecture, engineering and construction (AEC) industry. Throughout both design and documentation, the objectives of these tools are to spot potential faults by performing clash detection of Building Information Models and to analyse and raise potential co-ordination concerns in a concise and intuitive way. Well-coordinated models limit the risk of delays, defects and rework of design for sub consultants and construction companies alike.

The case study outlined in this research demonstrated a prototype for a clash detection method which provides both auto generated clash recommendation and tagging for visual representation. From a comprehensive literature review, it is concluded that during the construction phase of a project, BIM-based clash detection is equally important as in the design process due to the importance of construction review and decision making (Jung-Ho S, 2012). One of the significant aspects of this research is the ability to interact, respond and understand the clash detection data swiftly. This information can be easily interpreted and understood by all stakeholders in a design and construction project. The ability to visually see clash elements and the solution to its problem is one valuable asset and a step forward to achieve clash-free Building Information Models.

8. Evaluation of research project

The outcome of this research is to provide a user friendly and intuitive interface, capable of providing the user with more efficient methods of clash visualisation and suggested rectification. The Expected result aims to provide the feasibility of clash detection and avoidance to improve current coordination issues to minimise numberless hours and with a more intuitive experience compared to the current process of change in software.

The current development and achievements of this research and the prototyped solution now provides an alternate design process by highlighting, isolating and tagging the detected clash elements, this intuitive user interface provides better understanding for the users and opens clash detection to a broader reach of designers and modelers.

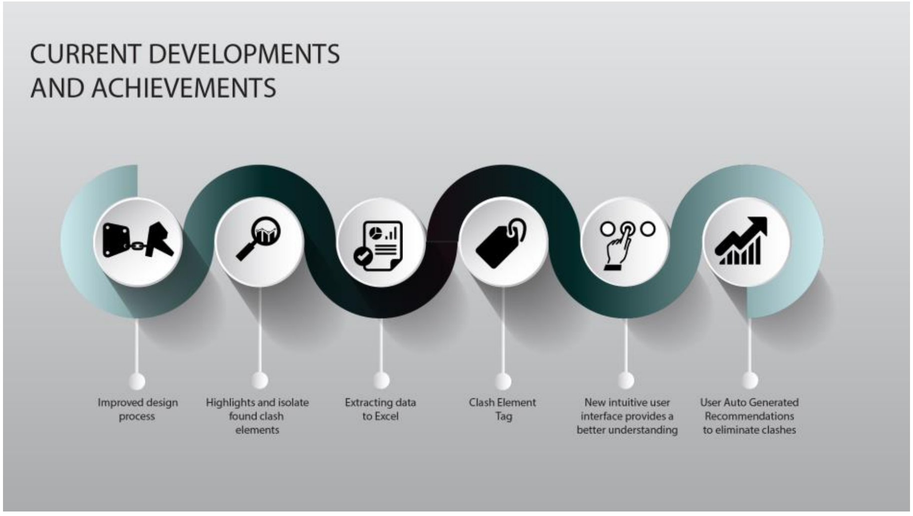

Figure 10. Current Development and Achievements

Throughout the framework of this research, we encountered several of limitations along this process. Clash report can only be readable in the Excel file format and clash detection at this stage is limited to singular element category and variable adjustments with minimal interaction with the new user interface

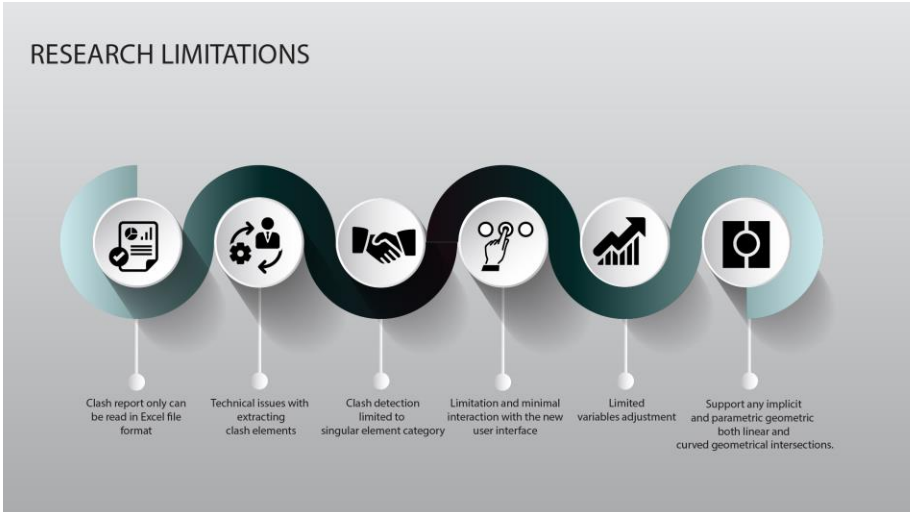

Figure 11. Research Limitations

Preliminary testing for the existing methodology has been performed with 13 Aurecon designers and modelers and has demonstrated a positive uptake in the process developed. 11 out of 13 testers stating that the clash detection methodology and software developed would be of use to them in their daily work.

For future testing, our approach aims to support any implicit and parametric geometric representations that support both linear and curved geometrical intersections. At some point of practical testing, some of the approaches would begin to intersect the balance between accuracy and computational efficiency and are to be considered in due course.

9. Conclusion

In Clash detection is not something new to the built environment, for decades, architects, designers and engineers is still constantly trying to resolve this problem. With comprehensive literature review and analysis, by integrating the proposed clash detection methodology during the design, construction and post-construction phases has shown to minimize and increase BIM coordination (clash detection) effectively at Aurecon. With the advancement of technology available has enabled designers and architects to explore more than just three-dimensional space. To understand clash detection, one must first experience the behavior of the building as an event through elements and characteristics to influence the way the building is conceived, to truly achieve clash-free Building Information Models.

Acknowledgements

In various stage in doing this research, number of people have given me the help and support to finalise this research to obtain my bachelor degree pf Computational Design (CODE). I would like to thank Michael Chernyavsky from Aurecon and Nicole Gardner, Ben Doherty, Hank Haeusler and Alessandra Fabbri from UNSW for the guidance and facilitating this research.

References

Akponeware, A and Adamu, Z: 2017, Clash Detection or Clash Avoidance? An Investigation into Coordination Problems in 3D BIM, United Kingdom, 1-28.

Association of Construction and Development ACD: 2017, Clash Detection in BIM Modeling, <http://www.associationofconstructionanddevelopment.org/articles/view.php?article_id=10780> (access 18 August 2017).

Autodesk Navisworks: 2017, Clash detection and interference checking, <https://www.autodesk.com.au/products/navisworks/features/coordination/clash-detection-and-interference-checking> (access 12 August 2017).

Chougui, Ali: 2006, THE DIGITAL DESIGN PROCESS: *Reflections on architectural design positions on complexity and CAAD*, *Department of architecture, University Ferhat Abba, Said Boukhrissa, Algeria*, 273-288.

Efendy L, Hashimoto M, and Hirota T, Adoption of Structure Clash Detection Method for Architectural, *Faculty of Computer Science and Systems Engineering, Japan, 237-244.*

Guangbin W, Wei, L and Xuru, D: 2011, Exploring the High-efficiency Clash Detection between Architecture and Structure, *School of Economics and Management, Tongji University, Shanghai, China*.

Jung-Ho. S, Baek-Rae. L, Ju-Hyung. K, Jae-Jun. K, 2012, Collaborative Process to Facilitate BIM-based Clash Detection Tasks for Enhancing Constructability, *Department of Sustainable Architectural Engineering, Hanyang University, Seoul, Korea,* 299-314.

Schwabea, M, Königa, M and Teizerb, J (2016), BIM Applications of Rule-based Checking in Construction Site Layout Planning Tasks, *Department of Civil and Environmental Engineering, Ettlingen, Germany*.

Solibri Silver Partner SSP: 2017, Solibri Model Checker, <http://www.solibri.com.au/Products/solibri-model-checker> (access 12 August 2017).