DESIGN COORDINATION IN DESIGN DEVELOPMENT USING BUILDING INFORMATION MODELING

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Thesis submitted in fulfilment of the requirements
for the award of degree of
B.Eng. (Hons.) Civil Engineering

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JUNE 2014

ABSTRACT

Ambiguity in design, requires coordination among multidisciplinary profession, activities and information which are lively during the design process. Although efforts have been made throughout the decades, the lack of coordination among building designers are still the major problem in the construction industry. Developing technology nowadays have given a huge opportunity for improvement to take place. The product from the Building Information Modeling (BIM), building information models are capable to aid designers in coordinating multiple designs and assist the planning work. However, knowledges are required to develop these models and to help in the coordination process. In this paper, we describe our final findings into clashes. It describes current practice in the industry and the revised coordination process using BIM, required knowledge, and development of building information models. These results verify the usefulness of securing the distributed knowledge needed and of developing a building information model to aid with the coordination process.

ABSTRAK

Kekaburan dalam process reka bentuk, memerlukan penyelarasan antara pelbagai disiplin profesion, aktiviti dan maklumat yang berubah-ubah semasa proses reka bentuk. Walaupun usaha-usaha telah dibuat sepanjang dekad, kekurangan penyelarasan di kalangan pereka bangunan masih merupakan masalah utama dalam industri pembinaan. Teknologi yang canggih hari ini telah memberi peluang yang besar untuk penambahbaikan berlaku. Produk dari Pemodelan Maklumat Bangunan (BIM), model maklumat mampu membantu pereka dalam menyelaraskan pelbagai reka bentuk dan membantu kerja perancangan. Walau bagaimanapun, ilmu diperlukan untuk membangunkan model ini lalu menyumbang dalam proses penyelarasan. Dalam kertas ini, kami mnunjukkan penemuan terakhir dalam bentuk objek yang bertentangan dalam reka bentuk. Ia menerangkan amalan dalam industri dan proses penyelarasan yang digubah menerapi proces BIM, pengetahuan yang diperlukan, dan pembangunan model maklumat yang berkaitan. Keputusan ini mengesahkan kepentingan mendapatkan pengetahuan yang diperlukan dan dalam pembangunan model maklumat bangunan untuk membantu dengan proses penyelarasan.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	SUPERVISOR'S DECLARATION	ii
	STUDENT'S DECLARATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	xi
	LIST OF FIGURES	xii
CHAPTER 1	INTRODUCTION	
	1.1 Introduction	1
	1.2 Background of Study	2
	1.3 Problem Statement	3
	1.4 Aim and Objectives	4
	1.5 Scope of Study	5
	1.6 Significance of Study	5
CHAPTER 2	LITERATURE REVIEW	
	2.1 Introduction	6
	2.2 Chronicle of Design Theory	6
	2.3 Multidisciplinary Design Interrelationships	7
	2.4 Introduction to Design Coordination	8
	2.5 Coordination Design Changes	9
	2.6 Coordination Overlay	9
	2.6.1 Hard Clash	10
	2.6.1.1 Root for Hard Clash	10
	2.6.2 Soft Clash	11
	2.6.2.1 Root for Soft Clash	11
	2.7 Current Design Coordination Process	13

		2.7.1 Drawback of Current Design Coordination	14
		2.7.1.1 Lack of Visualization	15
	2.8	Benefits of Better Design Coordination System	15
	2.9	Design Information Representation Model	16
	2.10	Building Information Modeling (BIM)	17
		2.10.1 History of BIM	19
		2.10.1.1 Hand Drafting	19
		2.10.1.2 Computer-Aided Design (CAD)	19
		2.10.1.3 3D CAD Modeling	20
	2.11	Revised Work Process Using BIM	20
	2.12	Design Phase Team	22
	2.13	Limitation of BIM	23
CHAPTER 3	**METHODOLOGY**		
	3.1	Introduction	24
	3.2	Develop Essential Knowledge	25
	3.3	Preliminary Stages of Modeling	26
		3.3.1 Project Selection	26
		3.3.2 Data and Information Gathering	27
		3.3.3 Autodesk Revit 2013	29
	3.4	Developing 3D Building Information Model	30
		3.4.1 3D Architectural Modeling	30
		3.4.2 3D Structural Modeling	31
	3.5	BIM for Design Coordination (Clash Detection)	32
	3.6	Summary	34
CHAPTER 4	**RESULTS**		
	4.1	Introduction	35
	4.2	Grid Lines and Levels	35
	4.3	Structural BIM Model	37
		4.3.1 Elevation View	38
		4.3.2 Structural Plan	40
	4.4	Architectural BIM Model	43

		4.4.1 Elevation View	44
		4.4.2 Structural Plan	46
	4.5	Multidisciplinary BIM Model (Revit)	48
		4.5.1 Elevation View	49
		4.5.2 Clash Detection (Revit)	51
	4.6	Structural BIM Model (Naviswork Manage)	52
		4.6.1 Elevation View	53
	4.7	Architectural BIM Model (Naviswork Manage)	55
		4.7.1 Elevation View	55
	4.8	Multidisciplinary BIM Model (Naviswork Manage)	57
		4.8.1 Elevation View	58
		4.8.2 Clash Detection (Naviswork Manage)	60
	4.9	Summary	61
CHAPTER 5	**DISCUSSION**		
	5.1	Introduction	65
	5.2	Issues Arised	65
		5.2.1 Insufficient Data	66
		5.2.2 Lack of Functionality	66
	5.3	Need for Theoretical and Technical Knowledge	67
		5.3.1 Theoretical	67
		5.3.2 Technical	68
	5.4	Demand for Early 3D Visualization	68
	5.5	Source of Clashes	69
		5.5.1 Hard Clash	69
		5.5.2 Soft Clash	70
	5.6	Advantages of BIM Technique	70
	5.7	Disadvantages of BIM Technique	71
	5.8	Summary	71
CHAPTER 6	**CONCLUSION**		
	6.1	Introduction	72
	6.2	Conclusion	72

6.3 Recommendations 74

REFERENCES 75

APPENDICES

Drawing No: PSSL/STRUC/1114/L1 78

Drawing No: PSSL/STRUC/1114/L2 79

Drawing No: PSSL/STRUC/B1/P1-2 80

Drawing No: PSSL/STRUC/B2/P1-2 81

Drawing No: PSSL/STRUC/B3/P1-2 82

Drawing No: PSSL/STRUC/B4/P1-2 83

Drawing No: CSD/K/2011/PT32696/M.SMH/SP-1 84

Drawing No: CSD/K/2011/PT32696VD/M.SMH/SP-2 85

Drawing No: CSD/K/2011/PT32696VD/M.SMH/SP-3 86

Drawing No: CSD/K/2011/PT32696VD/M.SMH/SP-4 87

LIST OF TABLES

TABLE NO.	TITLE	PAGE
3.1	Main Sources Used for Literature Review	26
4.1	Summary of Clashes	61

LIST OF FIGURES

FIGURES NO.	TITLE	PAGE
2.1	Interrelationship in Design Development	7
2.2	Hard Clash Between Pneumatic Tube (purple) and Waste and Vent (red), and Soft Clash between Pneumatic Tube (purple) and Fire Pipe (red)	12
2.3	Current Coordination Process Using SCOPE Process	14
2.4	Revised Coordination Using Building Information Modeling	21
2.5	Design Phase Team	22
2.6	Pre-BIM Design Phase Team	23
3.1	Flowchart of Methodology	25
3.2	Flowchart for Project Selection	27
3.3	Flowchart for Data and Information Gathering	28
3.4	Drawings Gathered in Form of Hard Copy	28
3.5	Drawings Gathered in Form of Soft Copy	29
3.6	Revit BIM 3D Model Approach Overview	30
3.7	Properties of Architectural Component	31
3.8	Properties of Structural Component	32
3.9	Process of Appending Files of Different Disciplines	33
3.10	Carrying Out Clash Detection Analysis	33
4.1	Grid Lines for Project	36
4.2	Level for Project	36
4.3	Structural BIM Model	37
4.4	Structural East Elevation	38
4.5	Structural North Elevation	38

4.6	Structural South Elevation	39
4.7	Structural West Elevation	39
4.8	Factory Roof Level	40
4.9	Ground Floor Level	40
4.10	Office Roof Level	41
4.11	Stump Level	41
4.12	Top of Frame Level	42
4.13	Architectural BIM Model	43
4.14	Architectural East Elevation	44
4.15	Architectural North Elevation	44
4.16	Architectural South Elevation	45
4.17	Architectural West Elevation	45
4.18	Factory Roof Level	46
4.19	Ground Floor Level	46
4.20	Office Roof Level	47
4.21	Top of Frame Level	47
4.22	Combination of Structural and Architectural Model Forming a Multidisciplinary Model	48
4.23	Multidisciplinary East Elevation	49
4.24	Multidisciplinary North Elevation	49
4.25	Multidisciplinary South Elevation	50
4.26	Multidisciplinary West Elevation	50
4.27	Clash Detection Using Revit	51
4.28	Structural BIM Model (Naviswork Manage)	52
4.29	Structural East Elevation	53

4.30	Structural North Elevation	53
4.31	Structural South Elevation	54
4.32	Structural West Elevation	54
4.33	Architectural BIM Model (Naviswork Manage)	55
4.34	Architectural East Elevation	55
4.35	Architectural North Elevation	56
4.36	Architectural South Elevation	56
4.37	Architectural West Elevation	57
4.38	Combined Models Forming Multidisciplinary Model in Autodesk Naviswork Manage	58
4.39	Combine Model East Elevation	58
4.40	Combine Model North Elevation	59
4.41	Combine Model South Elevation	59
4.42	Combine Model West Elevation	60
4.43	Clash Detection Using Autodesk Naviswork Manage	60
4.44	Hard Clash Example 1	61
4.45	Hard Clash Example 2	61
4.46	Hard Clash Example 3	62
4.47	Hard Clash Example 4	62
4.48	Hard Clash Example 5	62
4.49	Soft Clash Example 1	63
4.50	Soft Clash Example 2	63
4.51	Soft Clash Example 3	63
4.52	Soft Clash Example 4	64
4.53	Soft Clash Example 5	64

CHAPTER 1

INTRODUCTION

1.1 Introduction

An activity to manage uncertainty and to synchronize the flow of design information could be seen as coordination. Apart from that, it is also about coordinating the collection, processing, storage and transferring of Intel, which is crucial for an adequate design process (McGeorge, 1988). Design coordination is the decisive factor to diminish uncertainty in the manufacturing processes on construction projects (David and Michael, 2001). Project success is highly dependent on design coordination where clashes between building components are eliminated and design quality is ensured before installation in the field. The cost of a change could be minimized to the minimum when it is made earlier (Paulson, 1967).

David and Michael (2001) claimed that design coordination process always needs to be carried out by comparing or combining shop drawings in a coordination meeting to determine the systems that overlay namely conflict by visual inspection. Overlapping of systems need to be relocated and this process continues until all the interferences are resolved. The end product which should be a set of coordinated shop drawings is submitted to the design engineer for approval (Thomas et al. 2008).

The success of a project is determined by the efficiency of the process adopted by the participants to solve the conflicts by implementing good coordination among the participants (Kim and Grobler, 2009).

The process of design is an iterative process as the information within it is not constant and always subject to change (Behzad and Sheryl, 2012). To cope with such changes, flexible and dynamic information model is developed (Leuwen, 2000). Emerging Building Information Modeling technology (BIM) has provided the industry with a model that fully incorporate with the requirements.

The product from BIM, building information models are integrated databases which possesses the ability to process dynamic data. In the process, a design model consisting geometry and data is merged with a behavioral model (change management) to provide real-time coordination of the information in every view of the model (Autodesk White Paper, "Parametric Building Modeling: BIM's Foundation"). Behzad and Sheryl (2012) stated that, "BIM has the potential to coordinate changes all over the dynamic process of building design".

1.2 Background of Study

Ambiguity in design, requires coordination among the following; multidisciplinary professions, activities and information which are lively during the design process. The major problem nowadays in the construction industry undoubtedly is the lack of coordination among building designers (Hegazy et al, 2001). As a result, time is wasted and multiply changes in design occurred during the construction due to lack of integration of design information. In order to produce complete and error-free drawings, an architect needs complete and accurate design information. However, this may not so ideal in reality as the design information in projects were sourced out from various sources and uncertain. Undurraga (1996) conducted a study that shows 20-25% of the time taken for a construction is due to lack in design information. Another study conducted by Kokkela in year 1992 shows 78% of problem related to quality problems are contributed by lack in design information (Kokkela, 1992). To sort the problem, Galbraith (1973) suggested that more design information needs to be processed for it to reach an acceptable performance level. In other words, more information-processing capacity needs to be performed for works containing high level of uncertainty. When there is more work to be done, a better coordination among the participants is needed to provide satisfactory speed and accuracy of design information. Successful design coordination is crucial for an effective project delivery (Behzad and Sheryl, 2012).

For the past decades, researchers such as Mokhtar et al (1998) and Hegazy et al (2001) had been carrying out research to develop information models proposed to aid the coordination of design information through the management of design changes. The challenges came through with such changes and updating building information models are discussed by them (Behzad and Sheryl, 2012). The issue of managing changes using BIM has not received much attention in the literature, despite there were already few research attempts have been done on developing change management. Leaving that aside, implementation of BIM is becoming a hot topic in the construction industry that has been looking for a new approach to boost the productivity, efficiency, quality, and sustainability in a project (Arayici et al, 2011). Thus, considering the changes that BIM could provide in design and construction of building projects, there is a need to explore the requirements of change management systems in the context of a BIM environment for a better design coordination system in projects.

1.3 Problem Statement

Throughout a planned construction project, conflict among participants always rises (Kim and Grobler, 2009). This is due to the lack of coordination between the building designers and the inefficiency of the design-change management applied. There is no doubt that these are the problems that the construction industry is undergoing nowadays and are getting more significant and widespread (Morcous, 2001). Being the consequences, construction delays, cost overruns, structural failures, functional failures and contractual disputes may occur. To explain the occurrence of this incident, three reasoning are given and as followed; multidisciplinary nature of building design, complexity of the design process and the evolving nature of design data.

Undeniably, all the consequent phases of a project's life cycle is highly dependent on the quality of design. To produce a quality design, effective coordination between all the multidisciplinary professions is most likely needed in the process. Easy to say, hard to be done, effective coordination is not that simple using the current method which is primarily relying on manual methods of cross-checking and manual procedures for communicating design changes and information. A poorly communicated design change often leads to re-work and modification which are costly and difficult to handle. Design process, being a process that possesses the dynamic nature and the fact of frequently brought changes in the design, the current manual practices is not suitable for its application as it leads to inefficiencies in the design, affecting the overall quality of the construction (Dubois and Parand, 1993). Hegazy et al. (2001) states that the primary reason for the occurrence of these problems is the absence of a unified computer-based model for managing design information and storing its rationale.

According to a study done by Ahmad Tarmizi (2013), companies utilizing BIM could provide better confidence to clients as it could reduce significant time and cost compared to traditional method. Clash detection is done by using BIM method to ensure clash free design during the design development phase. Hence, there is a need for this paper to be carried out to explore and introducing the application of BIM in aiding the design coordination in design development process.

1.4 Aim and Objectives

I. To study the concept of design coordination and clash check procedure in Building Information Model through literature review

II. To provide early visualization of a building using Building Information Modelling (BIM) method.

III. Determine the number and area of clashes in the model.

1.5 Scope of Study

This study involves preliminary designs from only two disciplines which are the structural and architectural and only limited to design development phase. Two building information models will be proposed as case studies to show the capability of Building Information Modeling (BIM) in design coordination. Structures involved in the case study will be only a factory building with an office building connected to it. Processing and simulation of data will be done by using Autodesk Revit and Autodesk Naviswork Manage software as BIM and clash detective tools.

1.6 Significance of Study

The current design coordination system is slow and ineffective due to the fast pace of design development. On top of that, as the period of time taken for the process extend, the cost for it will increase as well. To due to the problem, building information modeling is implemented in the design coordination system. The new revised design coordination using BIM could improve the collaboration between participants, decrease the time and cost, and also directly increase the quality of a project. Improving the design coordination will benefit the design and also the construction field as the building information model could be used for a building's life cycle. Apart from that, the early 3D design visualization could give a clear picture to the designers and also the clients in choosing the best and appropriate design options. The conflicts within multiple disciplines is identified earlier in the design phase saving time and cost for reconstruction. All of the mentioned advantages served to be the reason for revised design coordination utilizing building information modeling to be adopted.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In order to fully understand the purpose of this research to be carried out, overall understanding and skills must be developed. Before moving to the advanced knowledge, current knowledge must be known too for the identification of the area of strength and weakness. Understanding current practice for design coordination is essential to recognize the opportunity to improve and to utilize existing technology for better practice.

In this case, the technology to be implemented will be related to building information modeling (BIM). This chapter will discuss about the current practice in design coordination and the changes that could be made by implementing BIM.

2.2 Chronicle of Design Theory

Many attempts had been done to describe the design process and one of them is the issue-based information system (IBIS) as stated by Rittel and Webber (1973). IBIS could play and record information generated during the early stage of design, but does not represent the whole design process (Jeon et al., 1994). There are other research, such as the active design document ADD which is applicable to the preliminary design of HVAC systems of commercial office buildings (Garcia and Howard, 1991), the skull object space (SOS), a system that memorize the design rationale for building construction cost estimating utilizing the hierarchical representation to store the design and its rationale and another system built by Ganeshan et al. (1994) that can record the sequence of the decision making process. However, all the mentioned systems have the very same one weakness, they assumes a single designer and a single-task situation which is not suitable to be used in a multidisciplinary surrounding.

2.3 Multidisciplinary Design Interrelationships

A study conducted by Hegazy et al. (1998) extorted the manner by which expert designers avoid mistakes, notice mismatches, and communicate design changes among multidisciplinary design teams. The study shows that the design changes are traditionally documented in memos and "change advice notices" that are documented properly. The common interrelationships among the participants throughout the design process for building projects are shown in Figure 2.1. The advantages of the workflow are that it can serve to identify the parties to be engaged with when a change is introduced by a team.

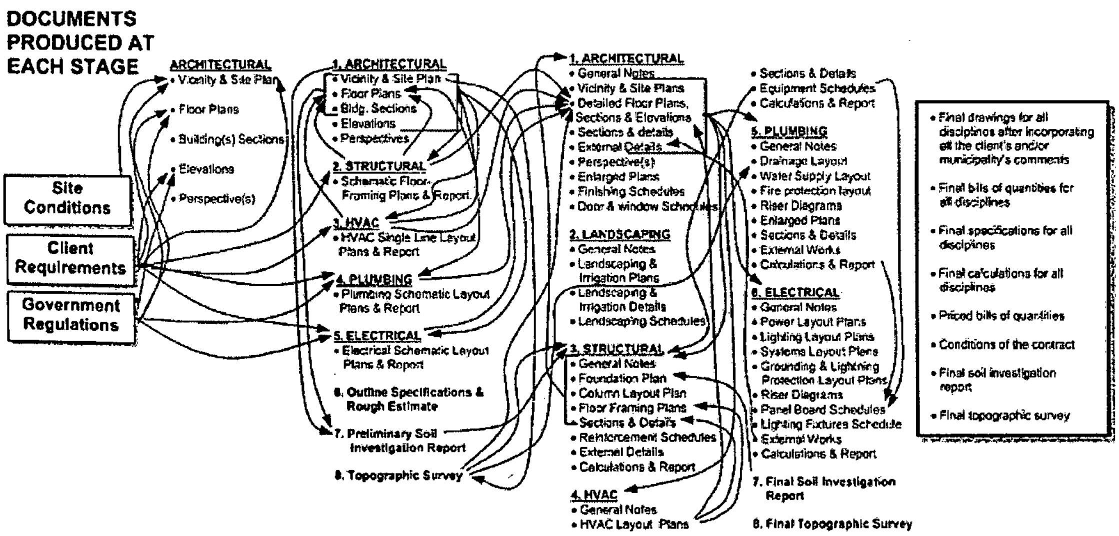

Figure 2.1 : Interrelationship In Design Development

(Source : Zaneldin & Grierson, 2003)

2.4 Introduction to Design Coordination

Looking at the projects carried out at the past right until today, one of the main problem faced is the lack of coordination among building designers and the inadequacy of the design-change management. Change is an integral part of a building design as the design process is iterative in nature and involves the exploration and analysis of many alternatives (Tory et al. 2008). Changes are not limited to design phase only, but often continue throughout the construction phase due to the concurrency of design and construction, particularly on a fast-track project, or in order to remove inconsistencies and enhance quality. A research carried by Undurruga in 1996 shows that 20-25% of the construction period is lost due to deficiencies in design. On top of that, Koskela (1992) states that 78%of quality problems are attributable to design. Hence, successful management of design changes is of vital importance for the efficient delivery of construction projects.

During such an iterative process, the content and structure of the design information is not static but subject to continual changes. In this dynamic environment, information models that are developed to coordinate design changes must be flexible and dynamic as the design process itself (Leeuwen, 2000). This is a significant challenge in the development of computer-based information models.

An activity to manage uncertainty and to synchronize the flow of design information could be seen as coordination. Apart from that, it is also about coordinating the collection's processing, storage and transferring of intel, which is crucial for an adequate design process (McGeorge, 1988). In order for a construction project to be carried out smoothly, a diverse group of people is needed in the project to carry out the job of developing and updating of plans or so-called design coordination. The project's success or failure is determined by the efficacy of the process utilized to manage conflicts and effective two-way communication and coordination is required between them (Kim and Grobler, 2009).

2.5 Coordinating Design Changes

Coordination of design changes had been a crucial problem during the design process as well as construction process. However, there are not much effort being done to sort it out. Ahmed et al. (1992) stated the distributed and integrated environment for computer aided design (DICE), which act as a blackboard representation that integrates a global database, several knowledge modules, and a control mechanism as an example. Its function is to keep track object changes. A system is developed by Spooner and Hardwick (1993) with rules for managing concurrent changes and for identifying and sort conflict modifications. Ganeshan et al. (1994) built a system which could record the history of the design decision making process, start backtracking, and to determine the choices that might get affected when changes are made in the spatial design of residential buildings. An interesting change management model that could be used in the multidisciplinary collaborative design surrounding is proposed by Krishnamuthy and Law (1995). Mokhtar et al. (1998) introduced another system which is able to propagating design changes and tracking past changes. Although all these models is introduced, but not any single of them capture the design rationale, which is an essential requirement for properly managing design changes.

In short, researchers only had their eyes on the representation of design information and recording design rationale rather than giving their attention the management of design changes. On top of that, most of the models only designed to deal with a single design team and do not have their importance in a multidisciplinary design environment. Hence, there is a need for an effective approach to address this crucial problem.

2.6 Coordination Overlay

Coordination overlay could also be called as conflict or clash. Any situation where there's overlaying of components which is not intended is defined as conflict (Pena-Mora et al. 2003). Most of the conflicts are propagated from the evolution of a design process (Hegazy et al. 2001). The problem in design coordination is not simple, and always occurred due to lack in the communication when there is a design change that heads toward modification, which are costly and time consuming (Zaneldin et al., 2001). In the perspective of a BIM coordinator, the term 'clash' is used to refer widely to one of several kinds of dimensional conflicts detected in a BIM which they classified the clash based on the nature of its existence.

Clashes are differentiated from one another, namely hard clash, soft clash, and time clash (Mangan, 2010). However, some BIM coordinator does not classify clashes only based on their nature of existence, but also on the process used to act on them. Gijezan (2010) uses a work breakdown structure and explain 'relevant clashes' as those that edge to change orders. In this paper, the first classification is used where the clashes are based on their nature of existence.

2.6.1 Hard Clash

Hard clash refer to one building component physically yet unintentionally penetrating another building component; that is, two or more components compete for the same physical space (volume). Figure 2.2 illustrates a hard clash between pneumatic tube (purple) and waste and vent (W&V, red).

2.6.1.1 Root for Hard Clash

There are many causes for a hard clash to occur. These include design uncertainty, failing of design rules, the complexity of a design, and design error. Design uncertainty is where a designer may put a placeholder component in the model, not knowing the exact dimension for the component, leaving that to be input later (Splitter, 2012). Usually the placeholder will have a larger dimension than the exact object and this may end up causing a hard clash with other building components.

Another main cause for the occurrence of hard clash is the lack of specificity, agreement, prior to-and during design, on the development of a specific system and how it may be relative to other system. Different building system should have each of their systems assigned to remain within one or several certain volumentric layers in the building space. However, projects nowadays usually are complex in nature and always need to be delivered under time pressure. These situations edged specialty designed to work concurrently on their design development, although they lack the details needed for the system.

Clashes may be left occur intentionally by IPD members in areas of great complexity where there are no design rules could be defined (Nyugen, 2012). For instance, realizing other building system in that certain are subject to changes, the members may just place their systems in that area to show design intent, knowing clashes may occur.

Design error is also one of the roots for hard slash to surface where the placement of a building component is not wanted by the designer. However, not all the design error will end up being a hard clash as the software does not label a building component as a clash when it remain unobstructed.

2.6.2 Soft Clash

A soft clash, sometimes called clearance clash refers to components (subsystem) that are closer than a certain distance (a minimum clearance) from one another. For instance, the distance needed for two outer cylindrical surface of two pipes. A soft clash between a pneumatic tube (purple) and fire pipe (red) is illustrated in Figure 2.2.

2.6.2.1 Root for Soft Clash

A soft clash may be surface due to blocking out space surrounding the physical volume occupied by the object. In fact, the model is not modelled according to its true geometry, but with a geometry defined by the user's judgement. A soft clash is called when the blocked out space of one object overlaps with blocked out space of another. In the placeholder shoe, the reason to use a blocked out space is for reducing the modeling time at an abstract level of development (LOD). For example, the valve is represented by a conical shape instead of its real geometry.

Another reason for the definition of blocked out space is the concern of the design-construction, or operations-related concerns. Components may placed too close together that the spacing between them is not sufficient for construction access, placement of components or application of other materials and maintenance access.

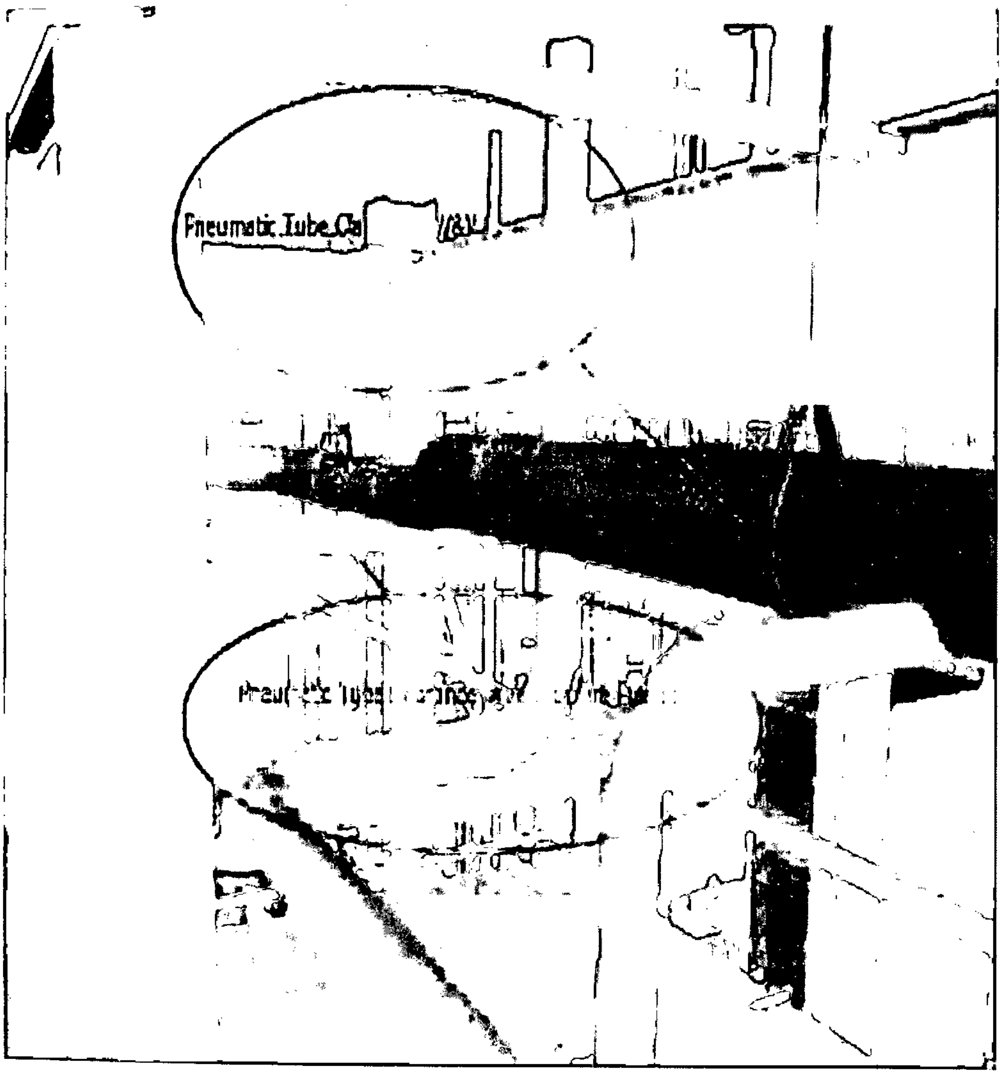

Figure 2.2 : Hard Clash Between Pneumatic Tube (purple) and Waste and Vent(W&V, red), and Soft Clash between Pneumatic Tube (purple) and Fire pipe (red)

(Source : Eric Osterling, Unger Construction)

2.7 Current Design Coordination

Although dynamic data are processed reasonably well in a single BIM with all the necessary parameters explicitly defined, changes across inter-related multi disciplinary designs that reside in a federated environment are significantly more challenging to manage. Hence, many BIM projects still rely on paper-based printouts f 2D drawings, as it is difficult to determine what has changed in the model with existing tools. This shows that the need to improve BIM-based change management system for effective coordination of multi-disciplinary models throughout the dynamic process of building design and construction.

The coordination process begins after all preliminary design drawings are completed, which involves the sizing of all components, completed engineering calculation, and sets of diagrammatic drawings. It involves many parties such as the specialty contractor from each trade (Thomas et al. 2008).

Complex or light building projects, using either the design/bid/build approach, the design/assist approach or design/build approach will require a good coordinating system. A long used method in the construction project to manage coordination related problem mainly conflicts in disciplines such as structural, architecture and mechanical, electrical, plumbing system is the over-laying of drawings from each discipline on a light table to determine and resolve the area of conflicts. Common practice is the sequential comparison overlay process evaluation (SCOPE) shown in Figure 2.3. The practice continues until all the interferences are resolved. During the process, there will be lots of negotiation between participants to determine which design needs to be revised. This method is done manually, slow, and prone to mistakes. The output of this process is a set of coordinated shop drawings which is handed to design engineer for approval.