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BIM Automation for the Design of Building Services

Avtomatizacija BIM za projektiranje gradbenih storitev

BIM A+ European Master in Building Information Modelling

Master thesis No.:

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Izvleček:

Avtomatizacija BIM pri projektiranju lahko prispeva k odpravi zamudnih opravil. V nalogi predlagana metoda avtomatizira načrtovalske izračune in modeliranje 3D, s čimer projektantu prihrani čas za druga pomembna opravila. Glavni prispevek te študije je uporaba avtomatizacije BIM za projektiranje, ki odpravlja možnosti neskladij in poveča učinkovitosti sistemov za načrtovanje.

Ne glede na velikost gradbenega projekta imajo sistemi strojnih in električnih sistemov "MEP" (angl. Mechanical, Electrical and Plumbing Systems) pomembno vlogo ne le pri končni uspešnosti projekta, temveč tudi pri prvotnih stroških in skupnem trajanju projekta. Ta študija primera ponazarja trenutno stanje zasebnega projekta v Egiptu, kot tudi izsledke raziskave, ki je bila izvedena v sodelovanju z enim izmed vodilnih generalnih izvajalcev v Sloveniji - "Kolektor Koling d.o.o". Skupina glavnega izvajalca ima obsežno znanje BIM iz prejšnjih projektov. Študije primerov so se osredotočile na posebne vrste načrtovanja avtomatizacije za projektiranje projekta MEP.

Namen tega dela je zagotoviti pregled strategij avtomatizacije BIM za načrtovanje stavbnih sistemov. Prednosti in zaključke te študije lahko povzamemo kot skupni prihranek časa, skupne prihranke pri stroških in večjo produktivnost.

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BIBLIOGRAPHIC– DOKUMENTALISTIC INFORMATION AND ABSTRACT

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Abstract:

BIM automation for design can contribute to the reducing of time and cost for Design. The proposed method automates design calculations and 3D drawing, saving up designer time for other important tasks. The main objective of this paper is automating the design in BIM to decrease the chance of clashes and increase the efficiency of design systems.

Whatever the scale of the project, mechanical, electrical, and plumbing system have a significant part in the cost and total duration of the project. This case study illustrates the current situation of the private project in Egypt, as well as the findings of the research, conducted in collaboration with one of the leading general contractors in "Slovenia" “Kolektor Koling d.o.o”. The general contractor team has extensive BIM knowledge from previous projects. The case studies concentrated on specific sorts of automation design for MEP project construction.

This work intends to provide an overview of BIM automation strategies for building service design. The advantages and conclusions of this study may be summarized as total time savings, overall cost savings, and higher productivity.

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LIST OF ACRONYMS AND ABBREVIATIONS

BIM	Building Information Modelling
MEP	Mechanical, Electrical, and Plumbing System

CHAPTER 1: INTRODUCTION

1.1 Background and Motivation

Engineering Design is always focused with creating solutions to a specific set of constraints and model parameters. Although development rarely begins with a new start, fresh solutions are frequently found (Maier and Störrle, 2011). According to the findings of the process study, the newly added off-site coordination tasks made it more difficult to coordinate of MEP systems than the traditional approach (Jang and Lee, 2018).

MEP is an essential component in the design setup and layout Construction project. It acts as an important process of Connect various components and the system is functioning and ready for operation. Practitioners in many industries MEP adjustment is one of the crucial and difficult duties in the construction process.

There is a lot of scope for continued development. MEP coordination exists between several participants, especially designers, prime contractors, and industry subcontractors. Then there is the voting process includes device search and connection routing all building system elements that comply with standards of other discipline, construction, and operation (Lu and Wong, 2018).

BIM technology fixed and enhanced the traditional MEP design with numerous options coordination concerns handled and enable the 3D BIM model designers who visualize scale, distribution, and routing of different construction systems. BIM also enables seamless with the integration of the MEP system into the architecture structural shell. Spatial interference quickly identified in a 3D environment, but this is not possible easy to identify with traditional 2D-based adjustments. Reduction of actual on-site rework. Also, BIM software such as Autodesk Navisworks.

BIM designer prepare the MEP model depending on the provisional workshop supplied by a professional subcontractor. Coordination meeting operated via the general contractor team and the BIM designer; all professionals are in responsibility. 3D adjustments are carried out in accordance with coordinated BIM model. Although, specialty the subcontractor only ensures that the proposed routing is adhered to. When it comes to design, location and functionality are sufficient the requirements of this system, it cannot guarantee everything systems combined with each other fit building. Spatial adjustment MEP in progress to avoid this, system elements are rerouted or relocated.

However, Integration BIM for the entire procedure for coordinating It is precise. and unautomated, so it needs a lot of manual adjustment work. Have the current edition well organized an automated solution for MEP adjustment. Automate your needs by developing MEP with Revit application programming

(Singh, Sawhney and Borrmann, 2015).

MEP is an optimization guideline that is linked with design production tools Rule-based routing capabilities, design duration, adjustments are greatly reduced. Therefore, improved design efficiency and accuracy, Reduced number of collisions, saved many designs, Adjustment time. Therefore, BIM's data quality assessment contributes to the development of automated processes (such as rule checking processes) and proposes automated and workflow.

The main purpose of this thesis can conclude in decrease designer repetitive tasks and increase efficiency of the design. This thesis attempts to improve the automated MEP design system and implement integrated BIM tools.

1.2 Research Objectives

This paper presented a methodical way to designing MEP systems. According to a BIM Global Adoption Survey (Succar and Kassem, 2015), BIM has three phases: modeling, collaboration, and integration. When someone has full control over one phase and moves on to the next, the efficiency and opportunities for innovation begin to grow. The first level of digital modeling has evolved much faster than the second and third levels. This is true when collaboration and integration are becoming increasingly important in BIM applications such as drafting, specifications, and quantification. Motivations here can fall into one of two categories: First, we will focus on the problem of MEP design system. Next, we will improve the automated MEP design system and investigate in the quality of BIM model.

1.3 The partner Company

The dissertation was created in cooperation with “Kolektor Koling d.o.o” The company is in “Logatec-Slovenia” as well as operating as a global supplier and main contractor for 60 years. Kolektor Koling has been integrating BIM in design processes. The case study developed with Revit and other BIM software.

1.4 Methodology Overview and Thesis structure

This study follows a methodology that is broken down into a series of steps that must be followed.
To achieve the set goals. These steps include:

The first part discusses the primary issues with MEP design adjustments, as well as the remedies identified in the literature. The second section discusses the challenges in MEP design. The next part discusses a case study that includes built-in BIM functionality. Finally, discussions and conclusions are offered, as well as recommendations for further study. This design coordination technique focuses on the details of information. Interaction and dissemination that help design teams improve their designs.

Chapter 1: Introduction: Explain the main problems of MEP design in construction and their possible solutions.

Chapter 2-Literary Studies: Contains literature that supports understanding of selected topics. Contains a run literature review that defines the terms and concepts used in connection with MEP design. This chapter describes the challenges of MEP system in the building with traditional modular design. Find out the key issues associated with pre-tuning your MEP system with BIM and the various new techniques and tools available to designers.

Chapter 3-Framework: This chapter outlines the theoretical procedures of design and automated design process. To provide the reader with knowledge of how to customize the framework to meet the project's requirements, we will introduce the concept of each step. This chapter outlines the structure of the problem and then implements of the projected technique. Describes the process of the design, provides the framework for parametric analysis, and performs computational analysis from BIM project models to automated MEP design. This allows you to create efficient designs that save time and enhance quality. The last section discusses the process of optimizing the BIM environment as well as the actions necessary to finalize and expound on the created design.

Chapter 4- The case studies: Describes the framework and adapt it to the real word.

Chapter 5-Conclusion: This chapter outlines the research and its results and suggests further development of the topic. It explains the conclusions of the study and identify how it was developed. In addition, list the model limits and recommendations for further development and improvement.

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CHAPTER 2: LITERATURE REVIEW

2.1 Overview

This research provides a study of BIM-based to automation design and coordination. BIM study is established on the design coordination through characterizing the design process evaluating the literature and making design recommendations. We also recommend the Dynamo tools for assistance the automation of MEP design and coordination.

This chapter contains a run literature review that defines the terms and concepts used in connection with MEP design. This chapter describes the challenges of building a MEP system with traditional modular design. Find out the key issues associated with pre-tuning your MEP system with BIM and the different innovative optimization and automation strategies and technologies for cost and time savings for the design stage and construction stage.

2.2 BIM concept

The concept of green building was initially put out by Chuck Eastman of Carnegie Mellon University in 1975. Building modeling was initially introduced by “Robert Aish “in his essay published in 1986. To define BIM, Autodesk formally applied to (the American Institute of Architects) in 2002(Mathews, 2013).

BIM models may be characterized as digital representations of real-world elements like architectural design and functional elements like structural analysis, energy analysis, or a variety of simulations that include semantically rich data. Software that supports BIM has parametric features for building items. For instance, the kinds and attributes of wooden stud elements in a model include their dimensions (length, breadth, and depth), their qualities as a material, and their placements within the model (XYZ coordinates). To effectively extract information from a given model, building models may be created with over 300 levels of detail (LOD). Using the Autodesk Revit Application Program Interface, Autodesk Revit offers a mechanism to define and export extensible and interoperable BIM model data (API). You have access to objects thanks to the object-based API's framework for transferring information (Narayanswamy, Liu and Al-Hussein, 2019).

A survey study on BIM was released in 2012 by the Office for National Statistics of England, which gathered advice from 1,000 construction engineers. The results revealed that 78% of respondents thought BIM was the future of construction projects, 31% were already using BIM in their projects, 75% thought they will be utilizing BIM technology in some projects by the end of 2012, and nearly 95% planned to utilize BIM over the following five years.

Because of the numerous claimed advantages, an increasing number of public agencies are demanding BIM as part of their contractual obligations (Shafiq, Matthews and Lockley, 2013). Even though BIM technologies are easily accessible, project participants still encounter substantial difficulties that impede and disrupt the coordination process, despite the benefits of BIM in design collaboration being well proven (Mehrbod, Staub-French and Bai, 2017).

The variety of activities supported by BIM that help to describe architectural ingredients in many aspects. (Ghaffarianhoseini *et al.*, 2017). These processes enable the development of building information models, or BIMs, which are essential to the construction of digital representations of buildings. These models are used to handle pertinent building design and project data in BIM-based processes (Succar, Sher and Williams, 2012).

The cumulative digital representation can contain information on design, construction, and operations, which can subsequently be utilized to enhance design and cooperation (Demian and Walters, 2014). It is believed that there is potential to improve the productivity and reliability of buildings by facilitating of many disciplines in BIM-based design (Azhar *et al.*, 2011).

BIM is a solid foundation for the use of computational design (Borrmann *et al.*, 2018). For instance, the BIM's capabilities might be used to evaluate sustainability concerns and come to pertinent conclusions throughout the building design process. Furthermore, the BIM might save time and money in comparison to conventional procedures (Soust-Verdaguer, Llatas and García-Martínez, 2017).

Nevertheless, it should be underlined that great consideration needs go into how and why BIM is deployed if its potential benefits are to be realized (Miettinen and Paavola, 2014). However, several governmental bodies have encouraged to use BIM (Abanda *et al.*, 2015). As a result, several research have been carried out to increase the applicability of workflows based on BIM in supporting performance-based design decisions.

However, several obstacles limit the possibility for adopting BIM to enhance building performance throughout the design phase. Interoperability is one of these difficulties that stands out the most (Singh, Sawhney and Borrmann, 2015). Here, the term "interoperability" refers to a system or tool's ability to share semantically necessary subsets of model information with other systems or (Eastman *et al.*, 2010).

ISO 19650 - Building Information Modelling explain that the BIM might represented by essentially endless dimensions. Furthermore, the standard 2D and 3D models, correspondingly indicating two-dimensional plans, three-dimensional volumetric views, elevations, sections, or any other dimensions representations the begins by explaining 4D. Four-dimensional modeling is used to connect the volumes of a real-time simulation of the project with time schedules.

(Kamardeen, 2010).The building's structure, which may be quite helpful to seek for problems interferences, conflicts, and prevent those conflicts on the building site providing better results throughout designs and increasing production at various phases of the building process.

5D, contrasted with, is defined as the capacity to combine cost data with each component of the model, saving a lot of time and making the cost-producing process easier quantity takeoffs and estimates for the construction site. then 6D, which he identified as the building's association. information model including the discipline of facilities management. Consequently, 6D BIM acts as a complete information database describing every aspect.

Additionally, most significant modifications are more challenging to implement at the end of the design process, these discipline-specific studies are frequently performed at a higher cost and with a longer turnaround time. Contrarily, BIM enables designers to create and publish documentation that automatically updates anytime the model to which it is linked changes. This is a well-known trend in the business, not just an impassioned assertion made by a fervent BIM supporter. “The MacLeamy “Design Effort/Effect curve in figure 1 provides the most straightforward means of observing and comprehending it.

Integrated Project Delivery is represented by the curve on the left in “the MacLeamy” figure as the procedures of Building Information For modeling to be effective, an integrated approach is necessary. The curves may also be easily applied to it. On the one side, the example shows that integrated treatment techniques need a large investment. and swift increase in work than the conventional method during the early design phase delivery techniques where the effort rises gradually but peaks later when creating construction paperwork is required. on the other hand, the cost of adjustments, which naturally rises with time, is greatly decreased while the capacity to implement such changes is higher because of the earlier rise in the effort required while implementing integrated design.

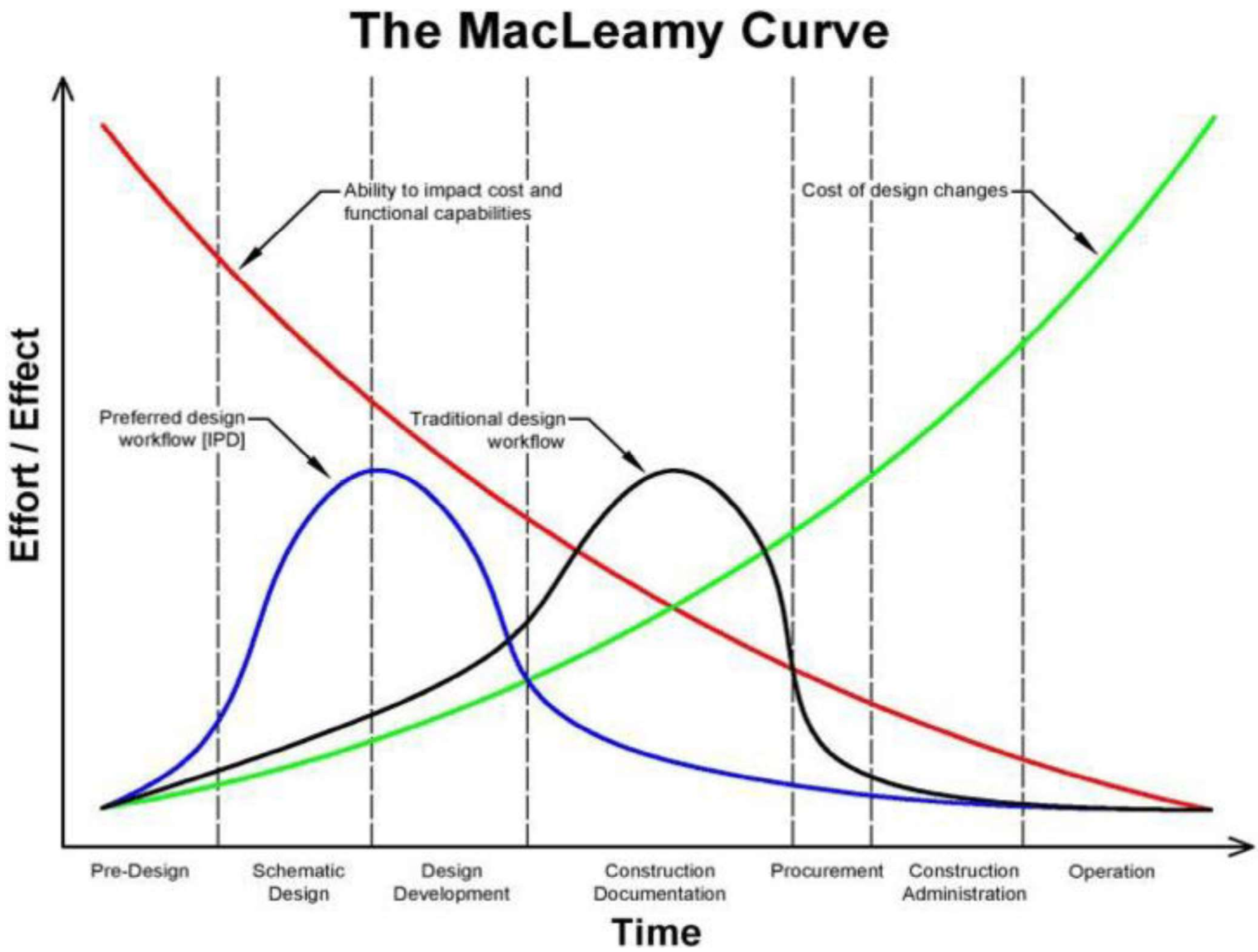

Figure 1: the MacLeamy diagram

2.3 Interoperability

Due to the obvious availability of many authoring software tools, data transmission is a major challenge in the construction industry's digitization. Every piece of software uses the native file type, which can be challenging to manage special in case all participants are not utilizing so same program procedure. The presence of the Industry Foundation Class (IFC) aids significantly in file sharing.(Choi, Choi and Kim, 2014).

The interoperability of the systems and tools used to accomplish the planned procedures is a significant issue in the utilization of BIM for performance-based design (Oduyemi, Okoroh and Fajana, 2017). To put it another way, performance-based design utilizing BIM necessitates the capacity to share critical information across the many systems and tools needed for calculations, simulations, analysis, and other procedures. Approaches based on partially or completely automated processes, such as generative (Abrishami et al., 2014), rely on the interoperability of numerous tools of this type. As a result, in BIM-based processes, a lack of interoperability might restrict the investigation and development of design concepts.

Further information on IFC and gbXML is needed to understand interoperability issues and the common file format used for estimating building costs is (IFC) (Kamel and Memari, 2019). Table 1 outlines Several of the most popular renditions of IFC, which is important to know.

Table 1: IFC versions (Building SMART- 2022)

Version	Name (HTML Documentation)	ISO publication	Published (yyyy-mm)	Current Status
4.3.dev	IFC4.3.dev	Final version expected mid-2022; published by ISO in 2023	Continues updates	Under development
4.3.RC4	IFC4.3 Infra/Rail deliverable	-	2021-07	Under voting by SC
4.0.2.1	IFC4 ADD2 TC1	ISO 16739-1:2018	2017-10	Official
4.0.0.0	IFC4	ISO 16739:2013	2013-02	Retired
2.3.0.1	IFC2x3 TC1	ISO/PAS 16739:2005	2007-07	Official
2.2.0.0	IFC2x2	-	2003-05	Retired
2.1.1.0	IFC2x ADD1	-	2001-10	Retired
2.1.0.0	IFC2x	-	2000-10	Retired
2.0.0.0	IFC2.0	-	1999-10	Retired

2.4 BIM standardization

Building Information Modeling has already started to be included into several nations' legislation regarding tendering procedures and current industry standards.

BS 1192 and PAS 1192 standards, which were formerly issued by the BSI and which used in the UK. IFC standard "Industry Foundation Classes," is another important international standard related to BIM. Building SMART, is a BIM information standardization international organization, upholds this standard, which is governed by ISO 16739:2013, as a product-neutral data collection for collecting of information about the building throughout life cycle of building.

There is another stander in BIM “COBie “(Construction Operations Building Information Exchange) which is a significant worldwide standard that is worth highlighting which is electronic records regarding for the building must be gathered and given to the owner and the facility managers (Andersson *et al.*, 2016).

2.5 MEP design Framework

(Wang *et al.*, 2016) MEP coordination process must be integrated. The framework in the figure 2 it is made up of five MEP models in the layout design process for the complete MEP, with varied degrees of detail and four sequential adjustment processes. The model describes the various tuning processes during the development of the MEP design.

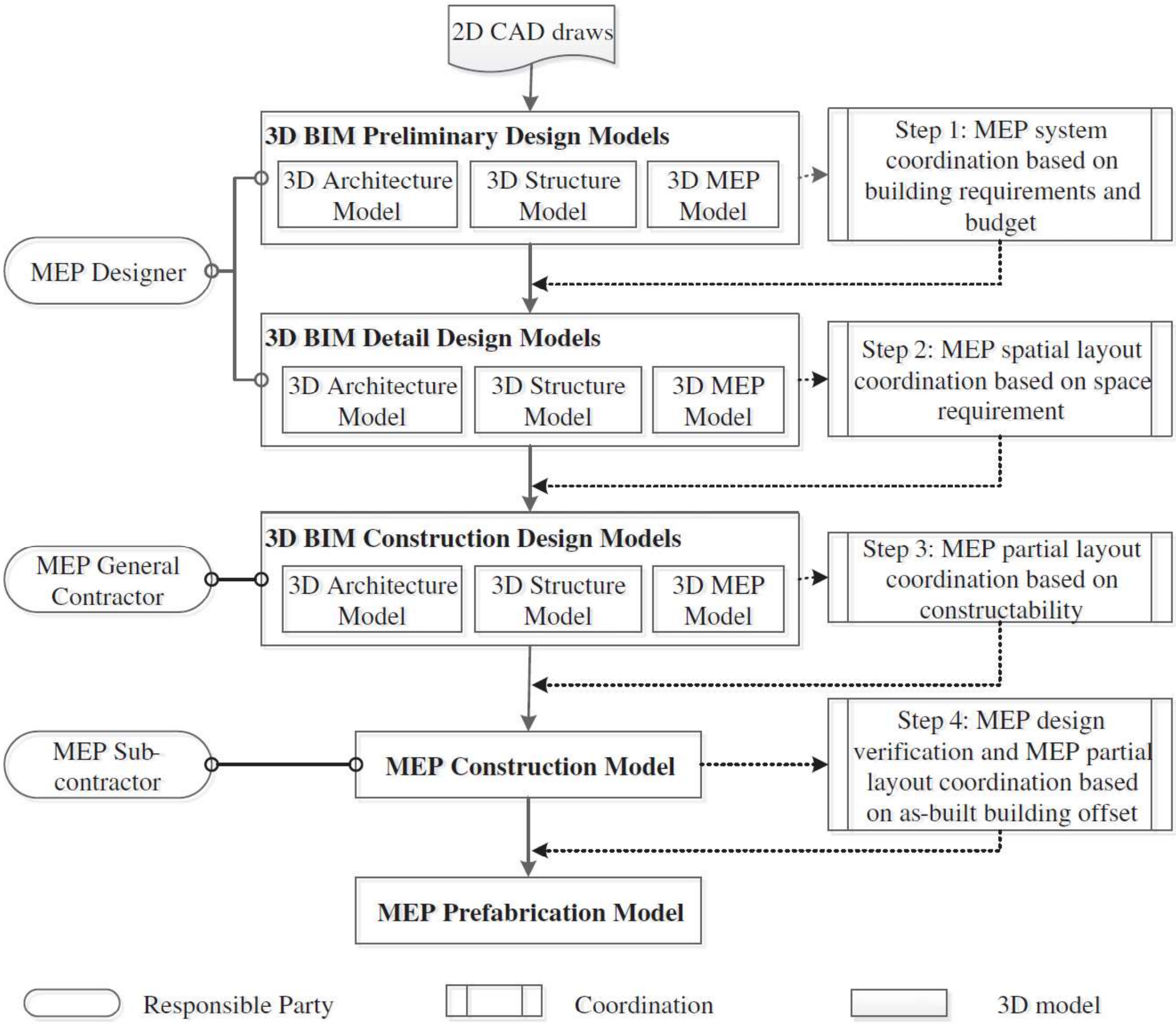

Figure 2: Framework for MEP design Wang (Jun, et al. 2016)

Figure 3 provides a unified conceptual framework for implementing the five BIM functionalities. This framework covers the complete lifespan of a building asset, from design through the operation. To ensure effective data collection, transmission, and analysis, the BIM functions can be connected to one another. To enable decision-making and use all data generated during the building's lifespan is synced in real-time to the BIM model (Xu, Mumford and Zou, 2021).

A BIM-based design review ought to be carried out when a BIM model has been created. Any design flaws or problems, such as incorrect assumptions, constructability concerns, and weakly resilient energy systems, can be detected. In the design phase, they create plans and criteria, and they manage the process in accordance with those set plans and criteria. BIM models may make use of an experienced database to fill in knowledge and experience gaps for certain stakeholders. (Xu, Mumford and Zou, 2021)

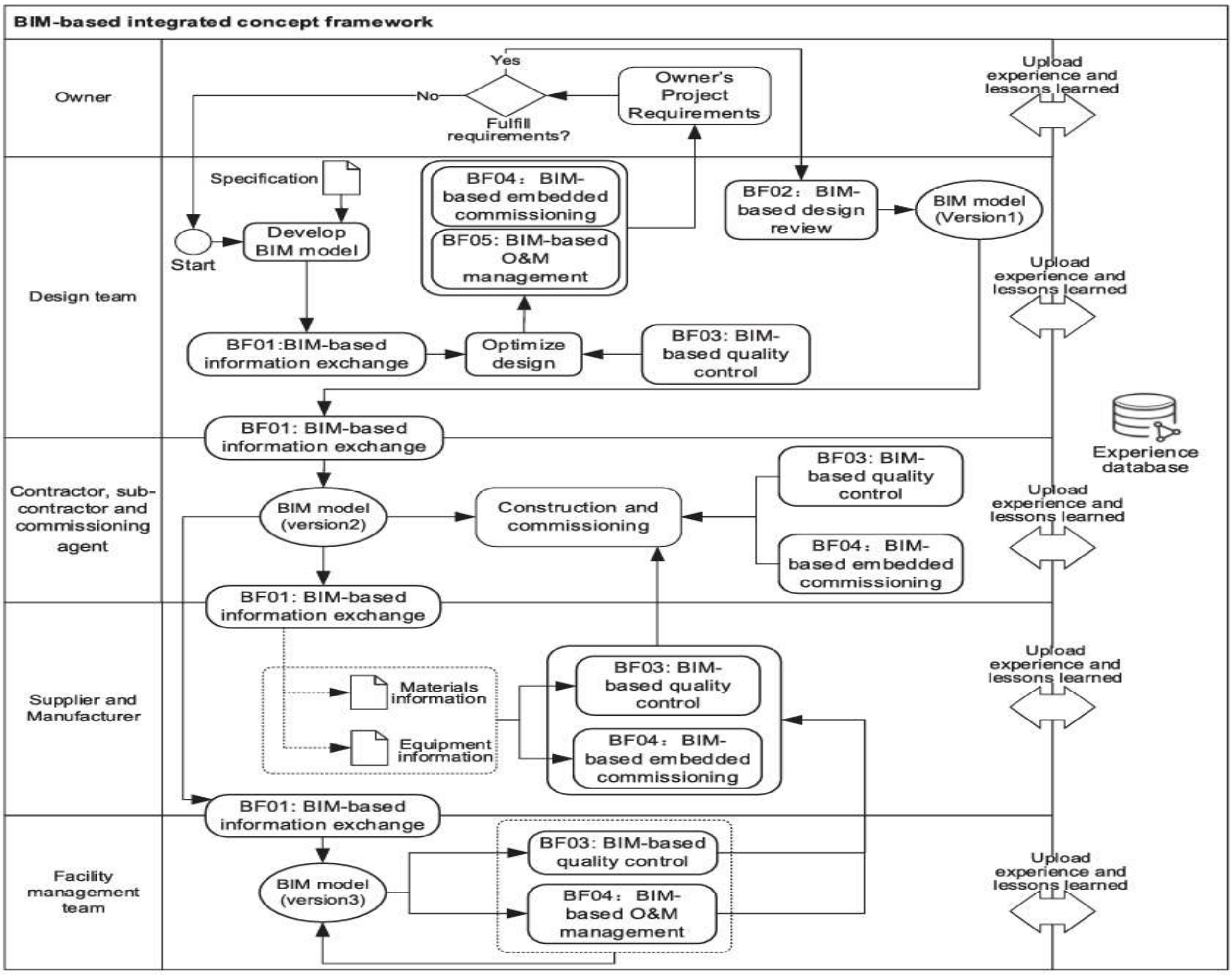

Figure 3: BIM-base integrated conceptual framework (Xu, Mumford and Zou, 2021)

2.6 MEP design system with BIM

(MEP) design frameworks research despite their importance in terms of building cost and efficiency, modular construction has gotten less attention. Design coordination between designers Lack of communication among a team, insufficient BIM expertise of design managers throughout the design stage.According to the literature, the main causes of design errors are iterative design cycles due to unexpected changes, poor management, and poor communication (Khosrowshahi and Arayici, 2012). Is related to and confuses the design workflow. There is a waste of cycle time, costs, redo, errors and more. Construction collisions include location errors where building components overlap when merging models. Resolving these conflicts is important to avoid costly redo (Won, Cheng and Lee, 2016).

MEP process BIM development may be automated to simplify the design.(Feng and Lin, 2017) propose a set of dynamo modules for the design of fire protection systems in a BIM environment, demonstrating that it will enhance design time and accuracy model development. In addition, (Hsu and Wu, 2019) System conflicts may be automatically addressed by incorporating automation and machine learning techniques into the BIM software platform.

(Wang et al., 2015) suggests a process for undertaking BIM development beginning with the preliminary design stage to the production stage to speed up the process and address clashes as they arise. BIM implementation is one of the most efficient methods for discovering the clashes in the design and resolving.

Implementation of MEP systems had been greatly improved thanks to BIM, which also rewired several inefficient practices. Workers painstakingly measured, using tapes, the construction variations between the planned and actual structures in this project. As per (Won, Cheng and Lee, 2016) When using this strategy in practice, there were three key difficulties to overcome, including:

(1) The measurement required a lot of time and effort.

(2) The measurement data's quality was poor.

(3) The construction deviation report was very vague and difficult to distinguish.

The clashes among the MEP systems are shown in figure 4 As per (Won, Cheng and Lee, 2016) Electrical and HVAC clashed effectively almost of the time, whereas HVAC clashed effectively with plumbing second part after of the time, and HVAC with HVAC least of the time. It means that almost of percent of actual collisions included HVAC in some way. The MEP designers need to focus more on HVAC design and try to find automated way to decrees the clashes in MEP.

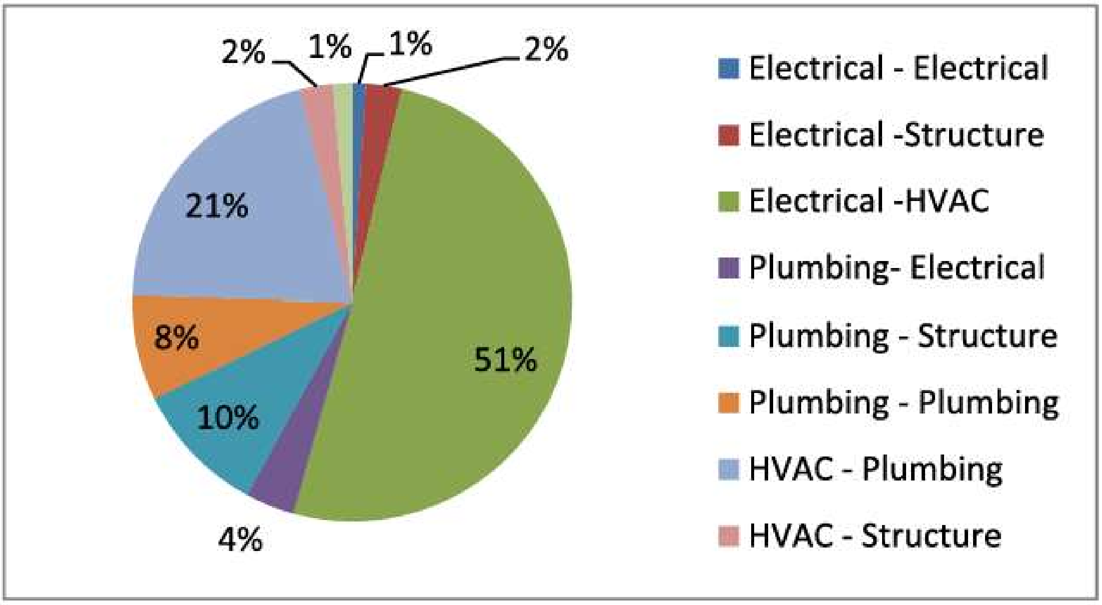

Figure 4: Effective of clashes in MEP system (Won, Cheng and Lee, 2016) .

2.7 Automation of the design in BIM

2.7.1 Computational design

computation Design while BIM is primarily concerned with the encapsulation and arrangement of information, computational design seeks to maximize the computational capabilities of current computers. Thus, computational design techniques seek to leverage computers as more than just electronic drawing boards for creating and storing representations (Terzidis, 2003).

Computational design tools' goals range from aiding to entirely automating or even complementing designers' labor, emphasizing the importance of computational design techniques (Caetano, Santos and Leitão, 2020). Computerization techniques are primarily concerned with encapsulating and arranging information.

As a result, the only information they manage is that which was first handed to them, and this information is unlikely to change in the absence of external interaction. Computational techniques, on the other hand, strive to improve the volume and specificity of information, for example, via the use of algorithms or other processes. Thus, computation is a dynamic strategy that may drive the advancement of a design, whereas computerization is a static approach (Terzidis, 2003).

Computational design techniques can help in design development by automating design operations, managing information effectively, automatically incorporating feedback from simulation results, and The way users, such as designers, interact with computational design tools differs from traditional methods. Computational design has become increasingly essential in architectural design, and its application has grown significantly, particularly in the recent decade (Caetano, Santos and Leitão, 2020). Instead, in a computational design approach, the user interacts with the digital world and the systems that generate digital representations (Terzidis, 2003).

2.7.2 Parametric design

Parametric design is one of the most frequent types of computational design. It has been proposed to assist design exploration because to its ability to minimize the time and effort required to make design modifications and assess various solutions (Caetano, Santos and Leitão, 2020).

Parametric design is a method of describing a design symbolically via the use of parameters. This necessitates the collection of relevant parameters, relationships, constraints, conditions, characteristics, and functions (Trzeciak and Borrmann, 2018), which may then be utilized to build a parametric model. When parameter values are changed, the rule-based procedure propagates the changes and develops a

new design solution based on the new parameter values. By methodically changing the parameter values, which can be done by an algorithm or some other mechanism (Yu et al., 2014).
The advantages of parametric design techniques are based on their capacity to facilitate process automation and so minimize the time spent by experts on project activities, as well as their ability to swiftly create design options that may be investigated (Sacks & Barak, 2008). The interest in parametric design techniques in building design is due in part to the fact that parametric capabilities are regarded a basic element of BIM software's (Ghaffarianhoseini et al., 2017).

It should be emphasized that parametric design can be used in many applications. Throughout the parametric design and the computational design are terms that are used interchangeably were used to support exploration by architects and structural engineers during early design work, and feedback based on both structural analysis and sustainability criteria was considered during the evaluation of alternative solutions (Röck *et al.*, 2018).

2.7.3 Generative design

The use of mechanisms that "deal with the formation of forms arising from generative rules, relations, and principles" is another branch of computational design and it is assumed above that not just form but also other design aspects are crucial for generative design. One of the key goals of generative design is to allow for the investigation of wider solution areas (Singh and Gu, 2012). This is aided in part by development with a high degree of automation and assessment of design, as well as provision of timely feedback on design choices (Hamidavi, Abrishami and Hosseini, 2020).

To do this, generative design tools aid designers by generating solutions utilizing the computational powers of computers. It is suggested that using generative design methodologies to facilitate exploration would result in more informed design decisions and, eventually, better-performing solutions Because the emphasis of generative design methodologies is often on exploration, their outputs should not be seen as final, but rather as a starting point for additional study and development to finish a (Gerber and Lin, 2014).

Similarly, to computational design, the phrase generative design refers to a broad spectrum of methodologies rather than a single specific methodology. Furthermore, because there may be some overlap between generative and parametric design (Caetano, Santos and Leitão, 2020).Solutions are developed in a parametric design method by modifying the model's parameters the another side,a generative design method, generates solutions largely via the use of a predefined mechanism or algorithm.

There are several potential implementations and uses for generative design. Gerber and Lin (2014) investigated several uses of generative design for structures, employing it to optimize designs in terms of energy consumption and financial cost by modifying construction materials and building forms. Applying of generative design methodologies in BIM workflows has also been investigated (Salimzadeh, Vahdatikhaki and Hammad, 2020).

2.7.4 Automation design

Because of the frequent necessity to handle several and competing objectives, multi-objective automation is a particularly attractive tool for building design. Typically, the outputs of multi-objective automation procedures are separated into sets of solutions. Solutions that are feasible are those that exist inside the confines of the solution space and fulfill all established constraints. These are the solutions discovered and assessed by the optimization algorithm when looking for optimal solutions(Cagan et al., 2005).

(Machairas, Tsangrassoulis and Axarli, 2014) discovered that frequent optimization objectives in building design include environmental effect, initial investment, operational cost, and comfort. This demonstrates the wide range of applications and situations in which evolutionary design techniques might be employed, which is further demonstrated by looking at some recent examples of their use in the literature.

2.8 Automation of MEP design in BIM

The automated process can be outguess compared to traditional design process, the design time can be effectively reduced almost 23 times, and the efficiency can be improved (Wang et al., 2022).

2.9 Concluding remarks

Previously established systems, methods, techniques, and tools that employ computers to help various aspects of the architectural design process, each with a purpose and environment in which they are best appropriate. This thesis focuses primarily on the automation design for the MEP in building, can generate design solutions and improve performance.

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Chapter 3: FRAMEWORK

This chapter discuss component of the framework, which is a methodology for organizing, controlling, and evaluating the automation of BIM design techniques.

3.1 Overview: aim and objectives

The suggests and the key tools, methodologies existing by this research. By examining the workflow level of the BIM process, design automation meets unique expectations for project time and cost. The following are the main objectives:

1- Automate design process using automated software.
2- Provide an automated process that may be used on a variety of projects.
3- Improving design and drawing quality and procedure.
4- Eliminating the need for long drafting hours.
5- Errors can also be easily spotted by inspecting the models.

3.2 Limitation of Case Study

Rather than a deep-level examination of one face study, the strategy in this thesis was to evaluate the research in multiple faces of study. Like:

1- To get the best performance for MEP design, use generative design to automate the ducts and pipe routing.

2- Another aspect of research is to utilize a dynamo to create automated designs for difficulties like as duct insulation and duct support as per ASHRAE code for HVAC, firefighting pipe as per NFPA code for firefighting, and drainage pipes as per international plumbing code.

3- To solve the clash, use the most up-to-date BIM tools.

4- Validate the model using the most up-to-date BIM tools.

It is exceedingly difficult for academics to obtain complete access to building projects, those with comparable degrees of complexity, scope, importance, and BIM progress. This because the design of a BIM project is almost always established by more than one designer, making it difficult for the researcher to obtain permission from each of them. Because of the difficulty in getting this authorization, the researcher was work on the project with an Egyptian designer and carry out the study with the contractor in Slovenia.

This case study illustrates the current situation of the private project in Egypt as well as the findings of a research conducted by one of the leading general contractors in "Slovenia" (Kolektor Koling). The general contractor team has extensive BIM knowledge from previous projects. The case studies concentrated on a specific sort of automation design for MEP project construction.

3.3 Methodology of framework for automated design

In this study, the strategy of a framework for automated design is based on four groups, as illustrated in figure 5, which we may include in the following:

1- Input data

2- Standard and Specifications — Chapter 3 has further information.

3- Process

4- Outputs — Chapter 4 has further information.

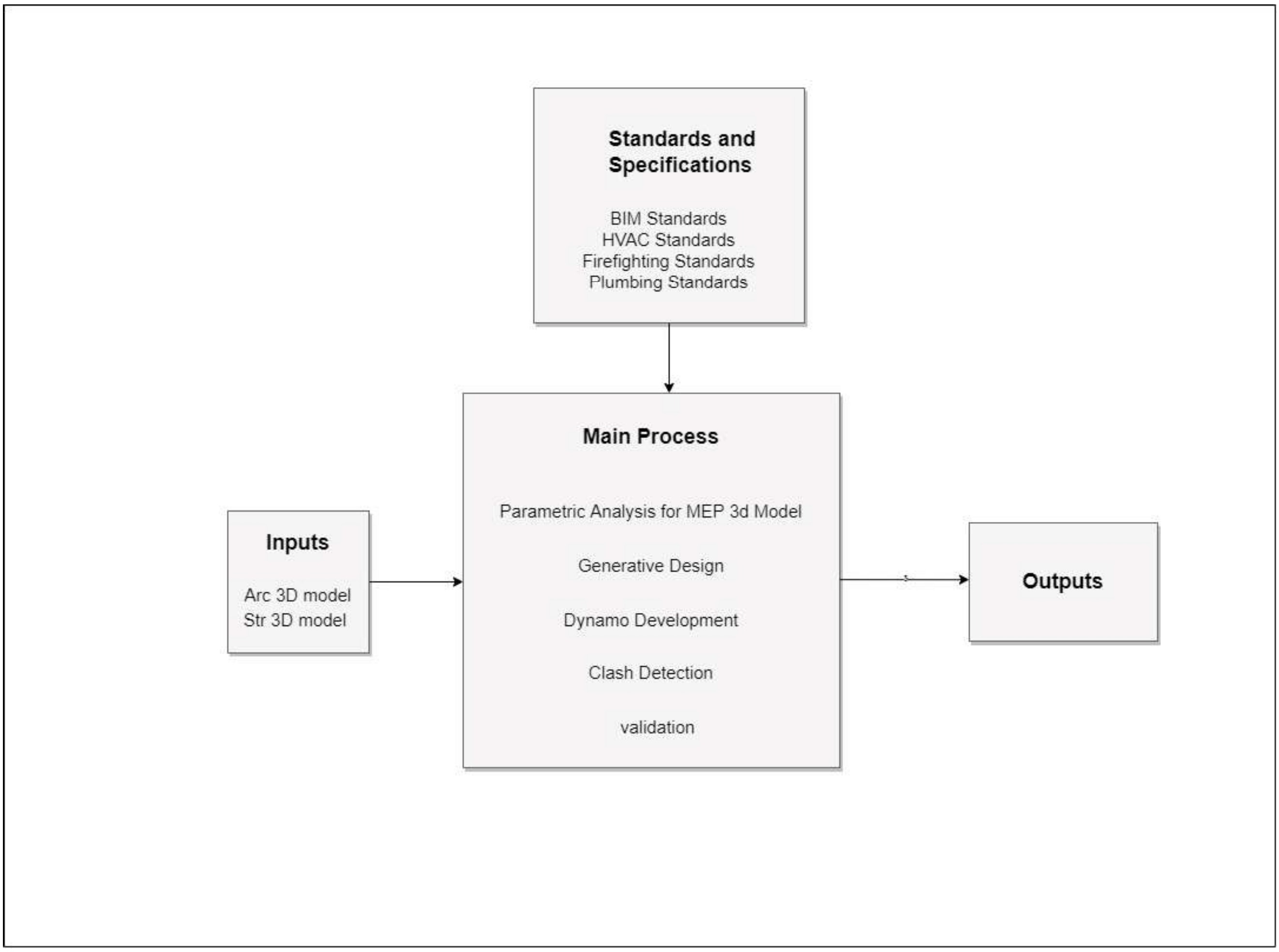

Figure 5: The proposed methodology of Framework for automated design

3.3.1 Input data

The input information is necessary for the BIM model design:
1- The architectural 3D Revit model, comprising floor plans, ceiling plans, and MEP service space needs, as well as information on tenant utilization of each area.
2- Revit structural 3D model, including floor and wall framing systems.

3.3.2 Standard and Specifications

3.3.2.1 BIM Standard

There are various current British Standards for BIM. Any member of the BIM team must adhere to this standard to complete the project in accordance with BIM criteria. Some of these standards include:
The ISO 19650 series of standards.

The ISO 19650 standards are international standards which analyzes all information, building modeling. Using standards to structure information helps to increase interoperability, allowing people and technology to connect information.

Figure 6 and figure 7 illustrates the information management relationship between parties and teams:

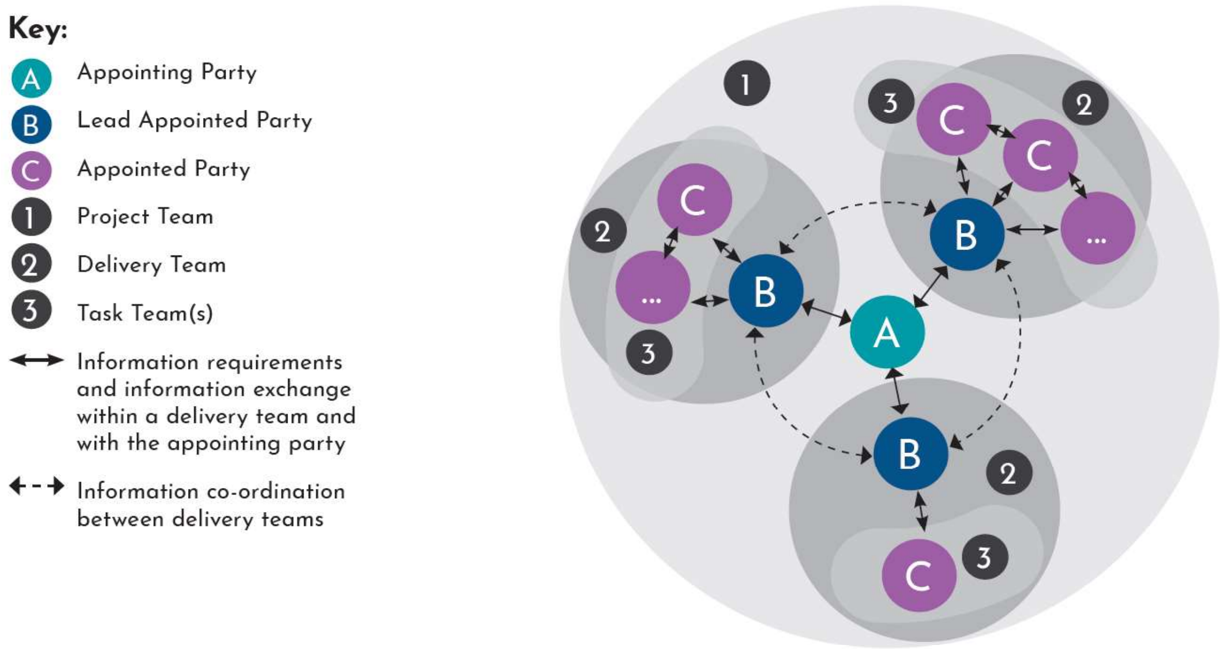

Figure 6: information management relationship" ISO 19650-2"

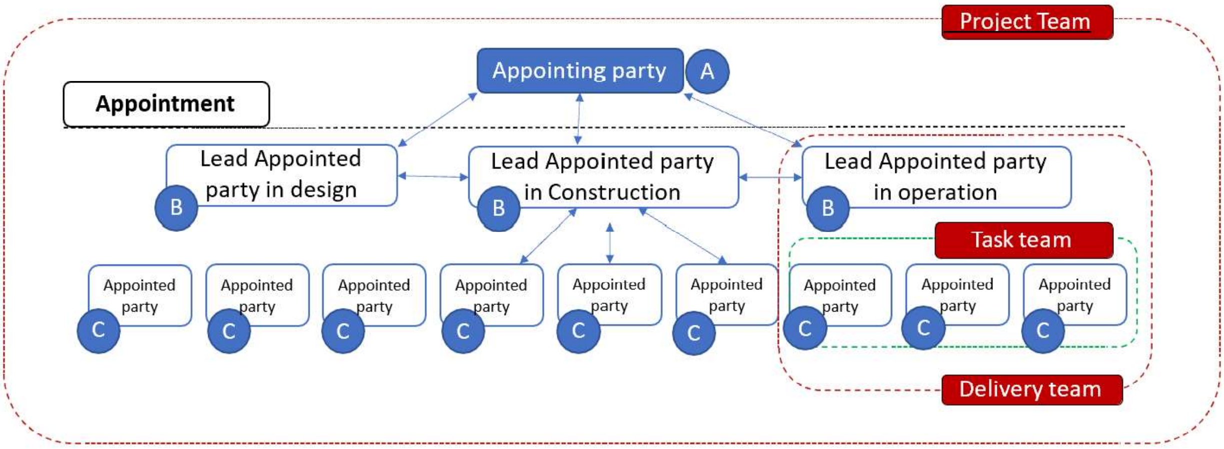

Figure 7: Hierarchy of the information management relationship between parties and teams, of ISO 19650-2

To implement the BIM environment, various concepts must understand and followed to meet BIM standards as defined by ISO 19560, as well as the ISO 19650 Hierarchy of Information Requirements and all ISO 19650 terminology. For example, OIR and PIR recognize as per shown in figure 8, which tasks must be completed and at what level of detail, and BIM use is required as per owner to deliver the project as per owner requirements, such as, coordination, cost estimation (quantity take-off), facility management , and sustainability (LEED) evaluation,

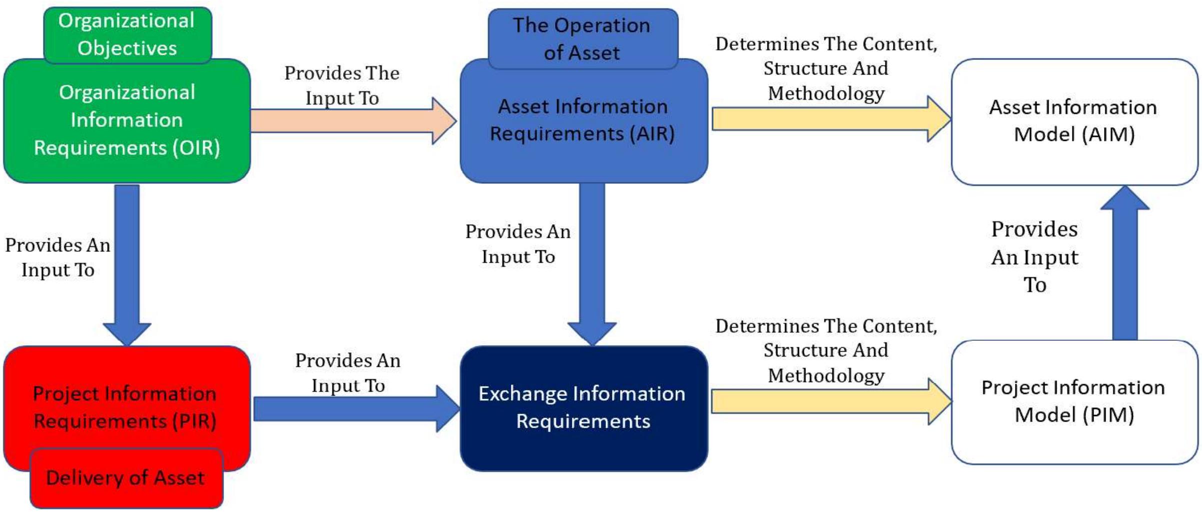

Figure 8: Information Requirements of ISO 19650-2

A BIM lead engineer or a BIM manager is responsible for following up on all aspects of the BIM life cycle which shown in figure 9, and the three stages of the BIM life cycle:

1- Procurement

2- Planning

3-Production

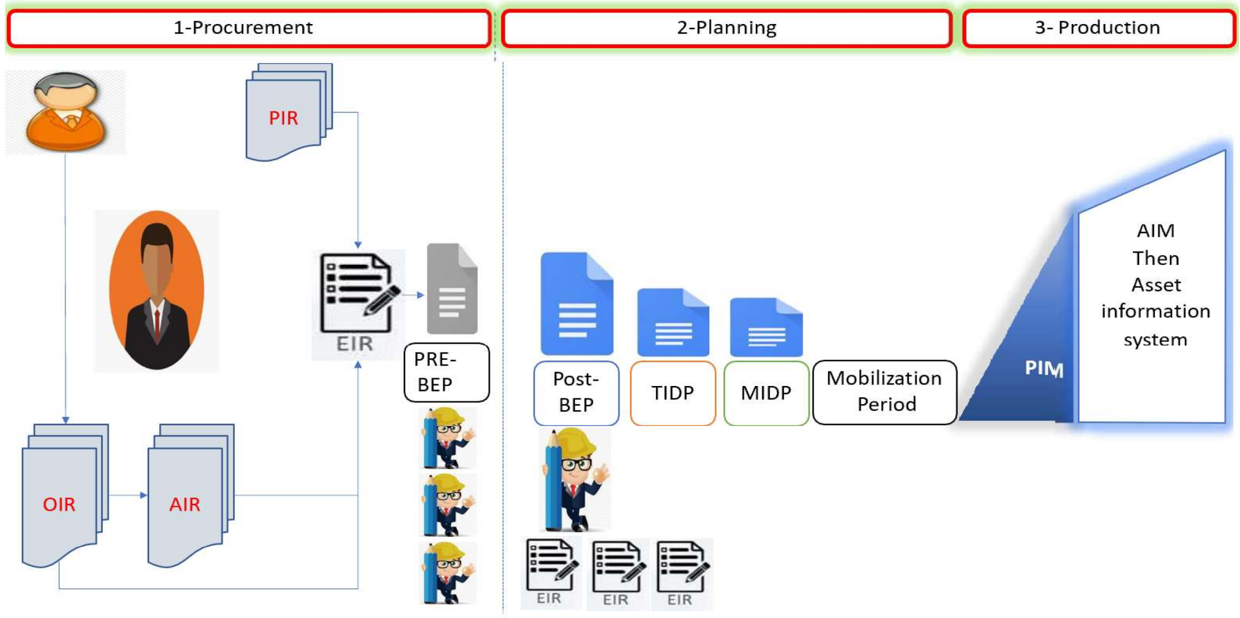

Figure 9: ISO 19650 life cycle for project as per ISO 19650-2

BIM and common data environment (CDE) are two complementing technologies utilized throughout a building's life cycle. figure 10 illustrates the common data environment (CDE) which is a tool that allows all project members to access and share all essential information (including BIM models, drawings, specifications, and documents) in a centralized repository. BIM is the methodology that promotes greater collaboration among all stakeholders involved in a BIM project. By centralizing all project data, you ensure that all project participants can cooperate more effectively, have access to the most recent versions of files, and eliminate mistakes and duplication of effort. By utilizing a CDE and incorporating BIM into that system, project teams may collaborate more effectively, accelerating the digital transformation of the organization.

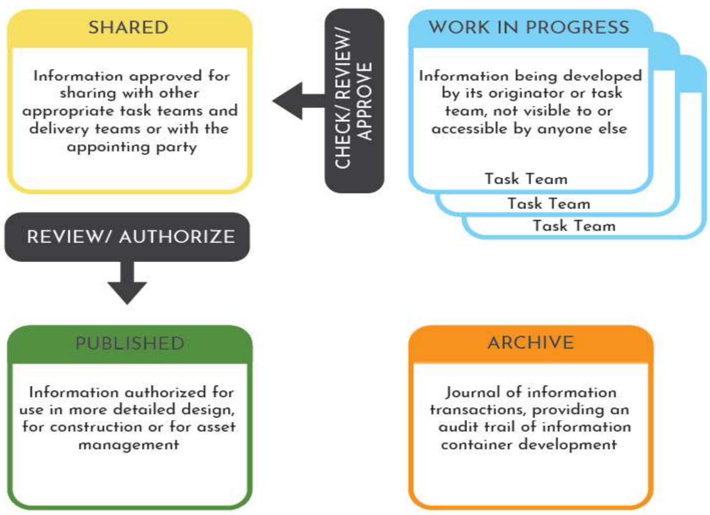

Figure 10: CDE concept as demonstrated in ISO 19650

3.3.2.2 HVAC Standard

(ASHRAE) is "The American Society of Heating, Refrigerating, and Air-Conditioning Engineers" was created in 1959.This standard specifies the functions and least criteria for both mechanical and natural ventilation systems, as well as figure 11 standard 62 ventilation and acceptable indoor Air Quality.

TABLE 6-1 MINIMUM VENTILATION RATES IN BREATHING ZONE
(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values			Air Class
						Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		
	cfm/person	L/s·person	cfm/ft^2	L/s·m^2		#/1000 ft^2 or #/100 m^2	cfm/person	L/s·person	
Correctional Facilities									
Cell	5	2.5	0.12	0.6		25	10	4.9	2
Dayroom	5	2.5	0.06	0.3		30	7	3.5	1
Guard stations	5	2.5	0.06	0.3		15	9	4.5	1
Booking/waiting	7.5	3.8	0.06	0.3		50	9	4.4	2
Educational Facilities									
Daycare (through age 4)	10	5	0.18	0.9		25	17	8.6	2
Daycare sickroom	10	5	0.18	0.9		25	17	8.6	3
Classrooms (ages 5–8)	10	5	0.12	0.6		25	15	7.4	1
Classrooms (age 9 plus)	10	5	0.12	0.6		35	13	6.7	1
Lecture classroom	7.5	3.8	0.06	0.3		65	8	4.3	1
Lecture hall (fixed seats)	7.5	3.8	0.06	0.3		150	8	4.0	1
Art classroom	10	5	0.18	0.9		20	19	9.5	2
Science laboratories	10	5	0.18	0.9		25	17	8.6	2
University/college laboratories	10	5	0.18	0.9		25	17	8.6	2
Wood/metal shop	10	5	0.18	0.9		20	19	9.5	2
Computer lab	10	5	0.12	0.6		25	15	7.4	1

Figure 11: Table showing cfm per sq. ft and per person values (ASHRAE, 2013)

HVAC duct construction standards "SMACNA" as per shown in figure 12 which illustrates the duct support.

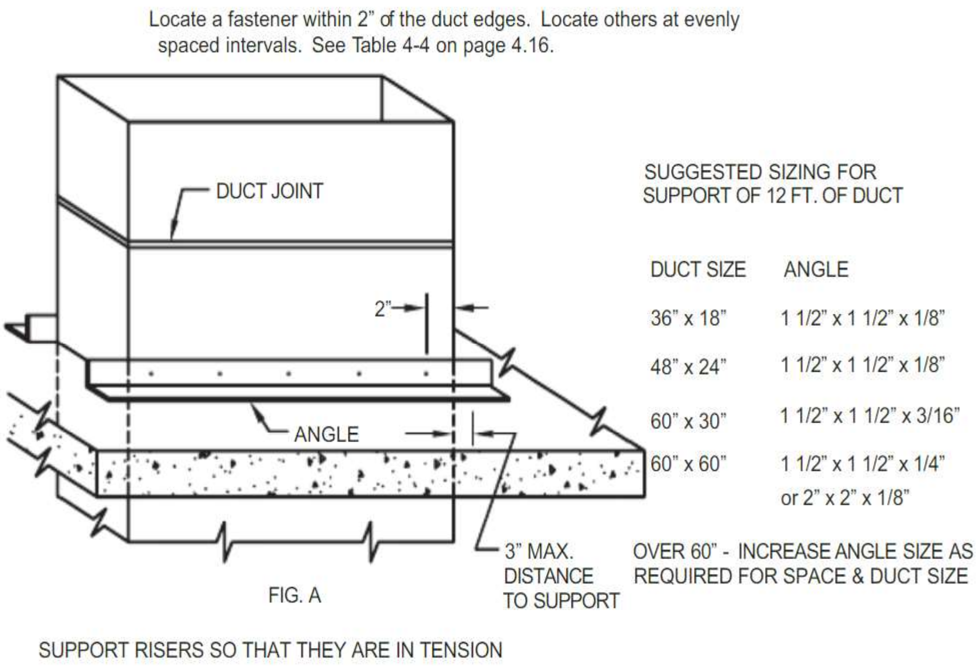

Figure 12: HVAC Duct Construction Standards

3.3.2.3 Firefighting Standard

NFPA 13 is a standard for the design and installation of automatic fire sprinkler to avoid fire and figure 13 illustrates the NFPA pipe size schedule for extra hazard.

Table A.22.5.4 Extra Hazard Pipe Schedule

Steel		Copper	
1 in.	1 sprinkler	1 in.	1 sprinkler
1¼ in.	2 sprinklers	1¼ in.	2 sprinklers
1½ in.	5 sprinklers	1½ in.	5 sprinklers
2 in.	8 sprinklers	2 in.	8 sprinklers
2½ in.	15 sprinklers	2½ in.	20 sprinklers
3 in.	27 sprinklers	3 in.	30 sprinklers
3½ in.	40 sprinklers	3½ in.	45 sprinklers
4 in.	55 sprinklers	4 in.	65 sprinklers
5 in.	90 sprinklers	5 in.	100 sprinklers
6 in.	150 sprinklers	6 in.	170 sprinklers

For SI units, 1 in. = 25.4 mm.

Figure 13: NFPA 13 standard (NFPA, 2016)

3.3.2.4 Plumbing Standard

The IPC establishes minimal standards for plumbing facilities and figure 14 illustrates a chart that assists designers in sizing plumbing pipes in accordance with IPC.

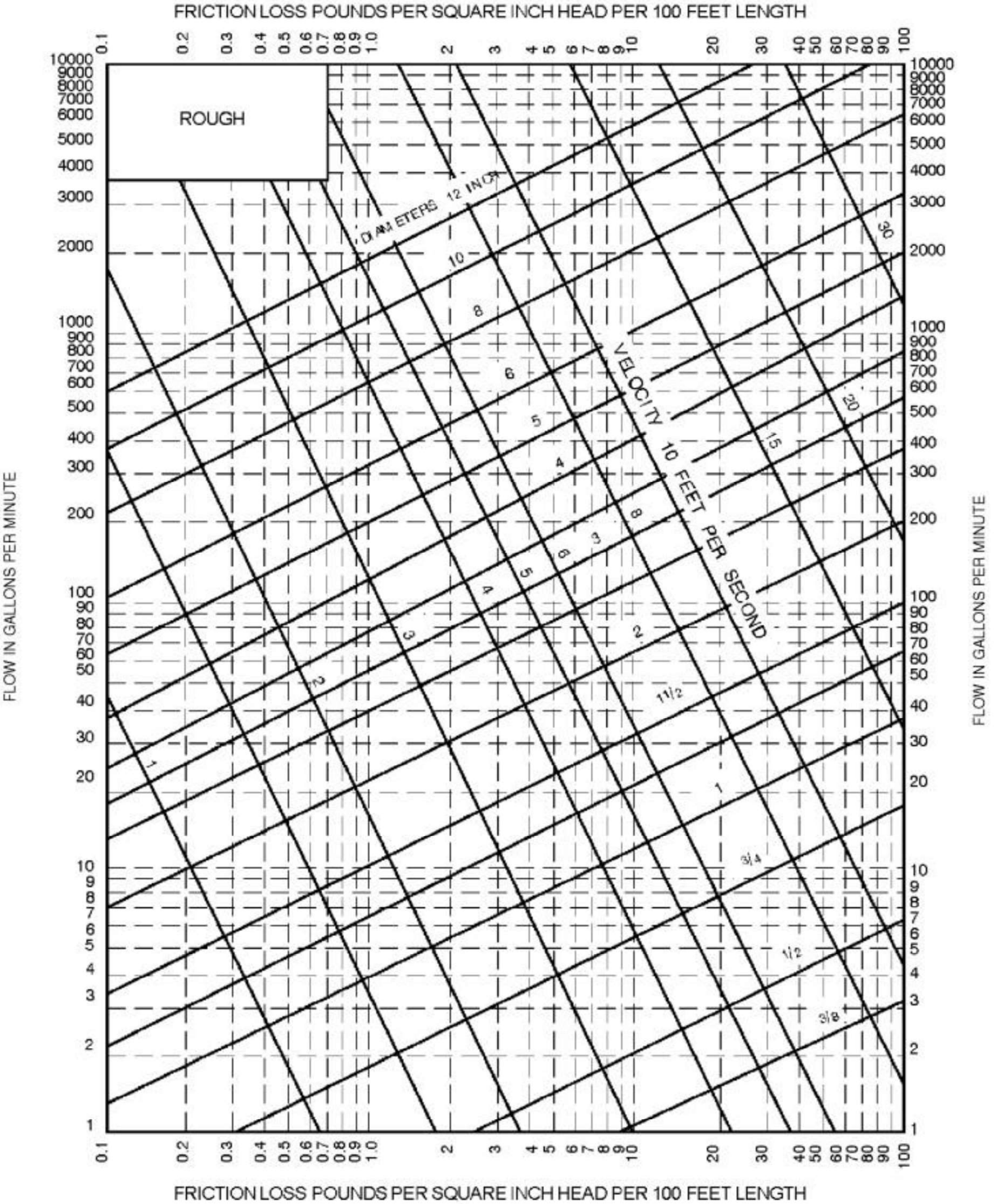

Figure 14: Plumbing pipes sizing accordance to IPC (International Code Council, 2018)

3.3.3 Process

Proceed by creating the 3D model in Revit for MEP, which involves the HVAC, fire protection system, plumbing system. As well as the duct sizes and materials for fabrication and all other MEP disciplines.

3.3.3.1 Parametric Modeling

The method of Parametric modeling enables the geometry of the building model to modify as the dimensional changes. To update the characteristics of a parametric model, feature-based modeling tools are widely used (Fu, 2018).

3.3.3.2 Generative Design

A design exploration approach is generative design. Designers insert design criteria, as well as features like as performance or space requirements, materials in software of the generative design.

Figure 15 illustrates a rough outline of the generative design process, which includes acquiring objects as inputs and geometry, feeding them through the generative design algorithm and evaluation stages, and finally presenting them through the generative design interface for design visualization and analysis.

It is really very difficult to roundtrip that choice back into Revit, so we ended up simply bringing it back to the BIM automation rather than depending on generative design to link all of those systems. Revit systems might be tricky when it comes to reconnecting all those connectors. eventually used generative design to uncover the answer and then depended on humans to implement it, giving them full control over the design process.

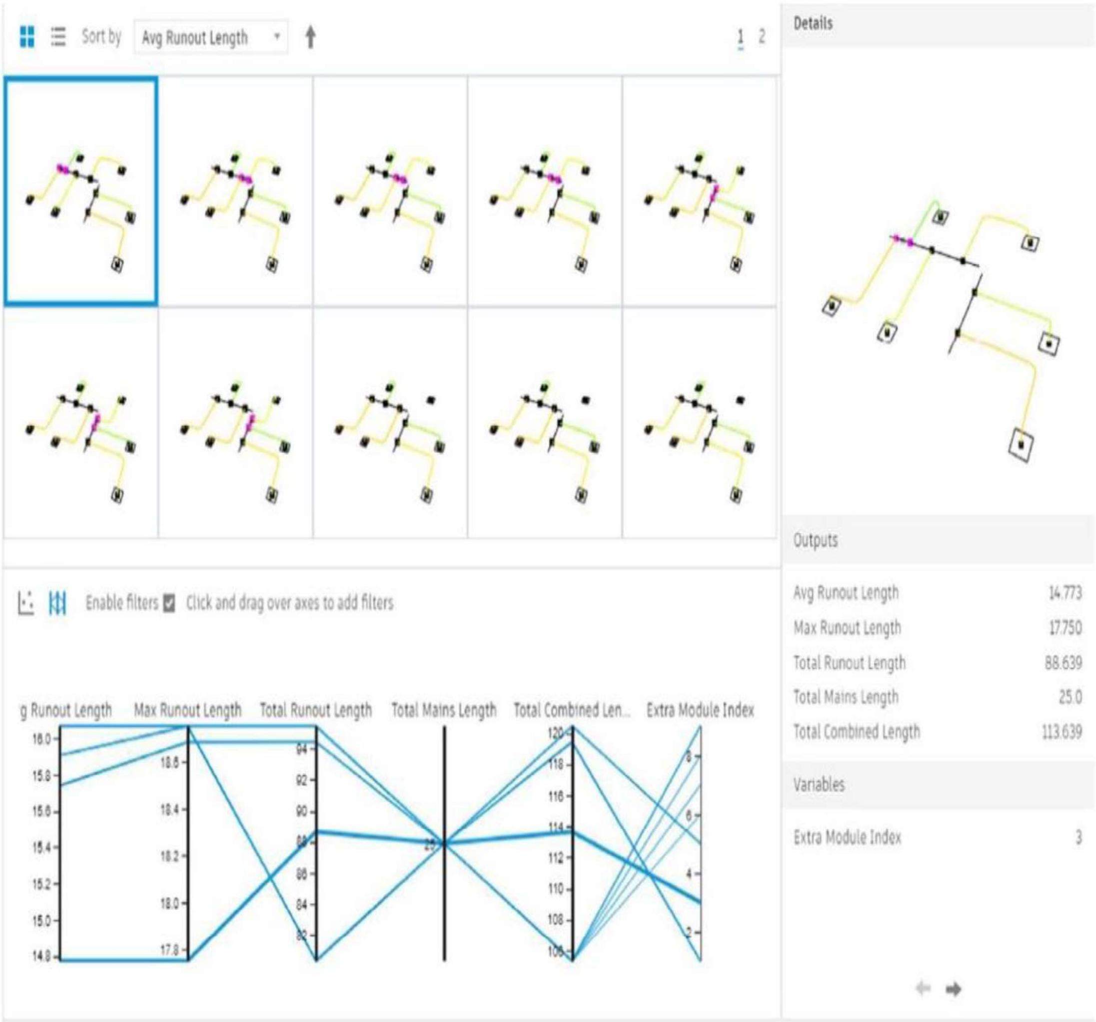

Figure 15: The generative design process

3.3.3.3 Parametric Design (Dynamo Development)

The Dynamo parametric analysis suggested algorithm to make judgments at each stage, and figure 16 illustrates an example of a dynamo interface and node connection to solve one problem.

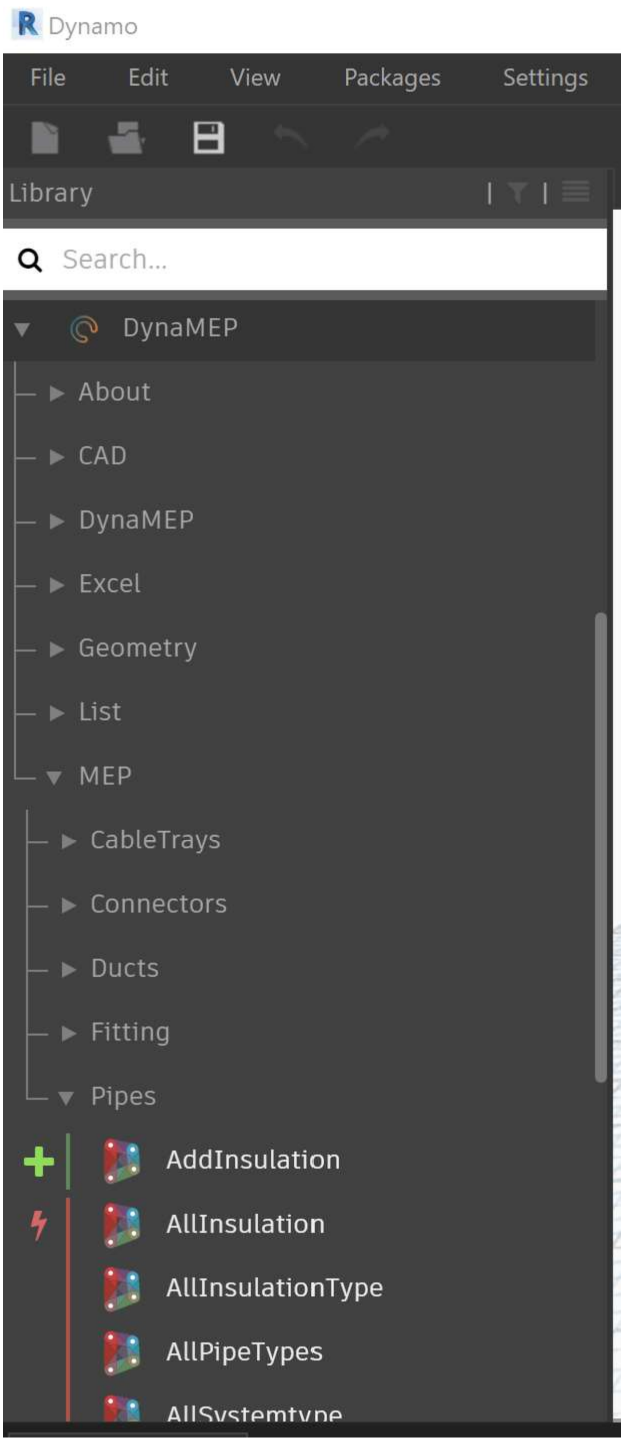

Figure 16: Example of Parametric Design (Dynamo Development)

3.3.3.4 Clash Detection

Building construction is a diverse process. MEP design system are critical impact on the project. Solutions to automate and improve project delivery are being with BIM technologies evolve will be used to streamline the coordination in the BIM process. Therefore, design accuracy and effectiveness increases, while clashes frequency decreases, saving significant design and coordination time.

Software of the clash detection facilitate visual comprehension, each system and subsystem are color coded as per shown in figure 17. Geometry or rulesets are used to discover clashes.

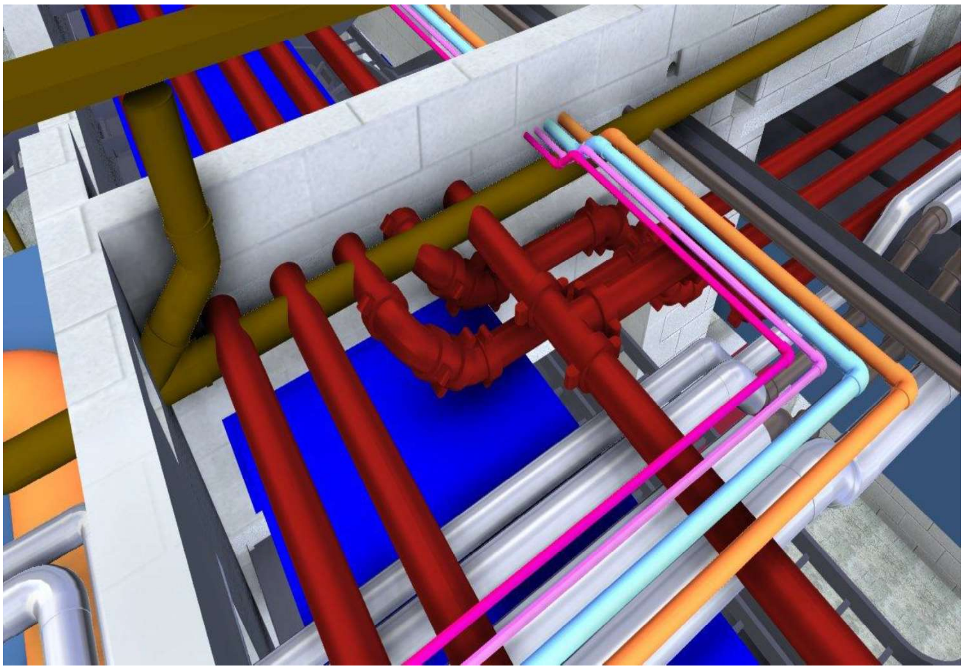

Figure 17: clash in systems in model

Practitioners frequently challenged to relate to design challenges. Several occasions when the inability to identify design coordination concerns resulted in time-consuming errors and inadequate of collaboration among participants, which contributes to an ineffective design process.

The traditional BIM-based coordination of MEP design system approach with 2Ddesign system, which takes time and requires multiple steps of collaboration to creating final drawings. To minimize coordination timeframes, the traditional approach at the commencement of design and coordination, should be adjusted to reflect common rules produced by all trades.

Furthermore, it is difficult to totally replace the traditional procedure to automate the process. Engineers continue to undertake the coordination for MEP in 2D drawings as illustrated in figure 18, to assist them in analyzing the space available for MEP systems and identifying zones to obtain agreed norms before design.

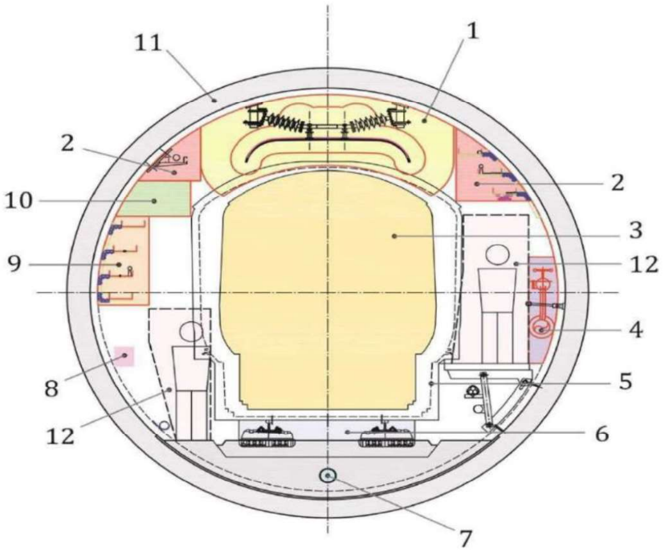

Figure 18: Illustration of the traditional process for coordination of tunnel cross-section systems in a rail project

According to (Lu and Wong, 2018), develops an algorithm capable of rapidly assessing the available area for MEP systems and assisting designers in selecting the zone to figure out for MEP systems. The number of conflicts and coordination iterations is greatly decreased using the technique depicted in figure 19 when compared to traditional BIM-based procedure.

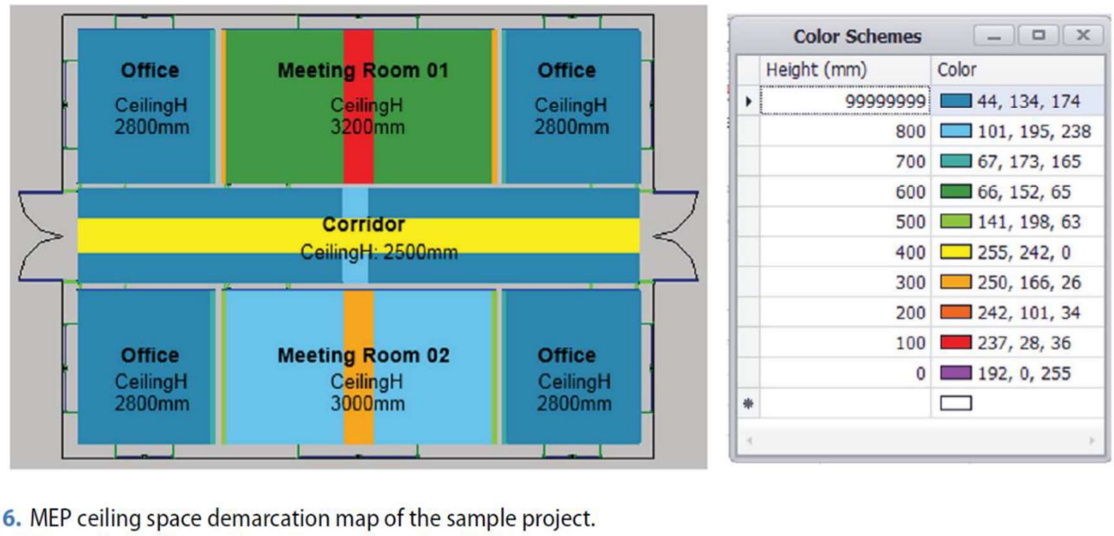

Figure 19: Illustration of the automate process for coordination in building (Lu and Wong, 2018)

BIM integration tools for conflict detection which used to detect incompatibilities between various non-proprietary applications (software from various companies). Revisions are in the program that generates the clashing section of the model. For example, if all the models are merged into a BIM modeling program such as Revit and conflict detection is conducted with Navisworks, any error made by the structural engineer will engage the structural Engineer to make the necessary changes to incorporate into Revit. Navisworks and Solibri are examples of clash detection software.

3.3.3.5 Validation of Model (Quality Planning & Quality Control)

Checking and modifying your designs prior to delivery at various project phases ensures that the geometry and data in your model are of great quality, avoiding design issues such as those shown in figures 20 and 21.

Quality-assured models are consistent with rules and BIM standards, and detecting problems early saves you both time and money. Consistent and tested models ensure that you may be proud of your work and be regarded as a provider of high-quality designs. Solibri example of checking and validation software.

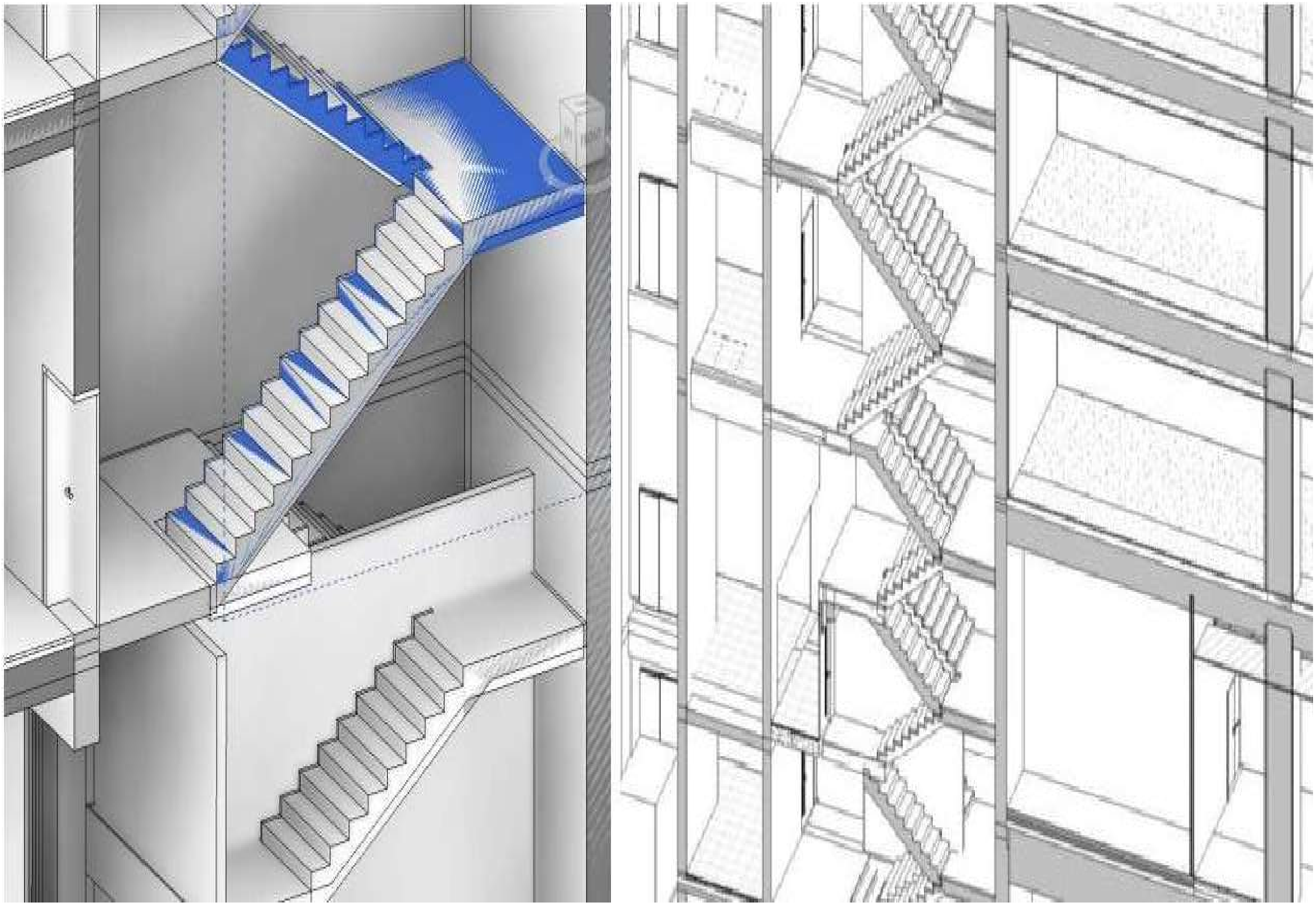

Figure 20: Fatal mistake in the design

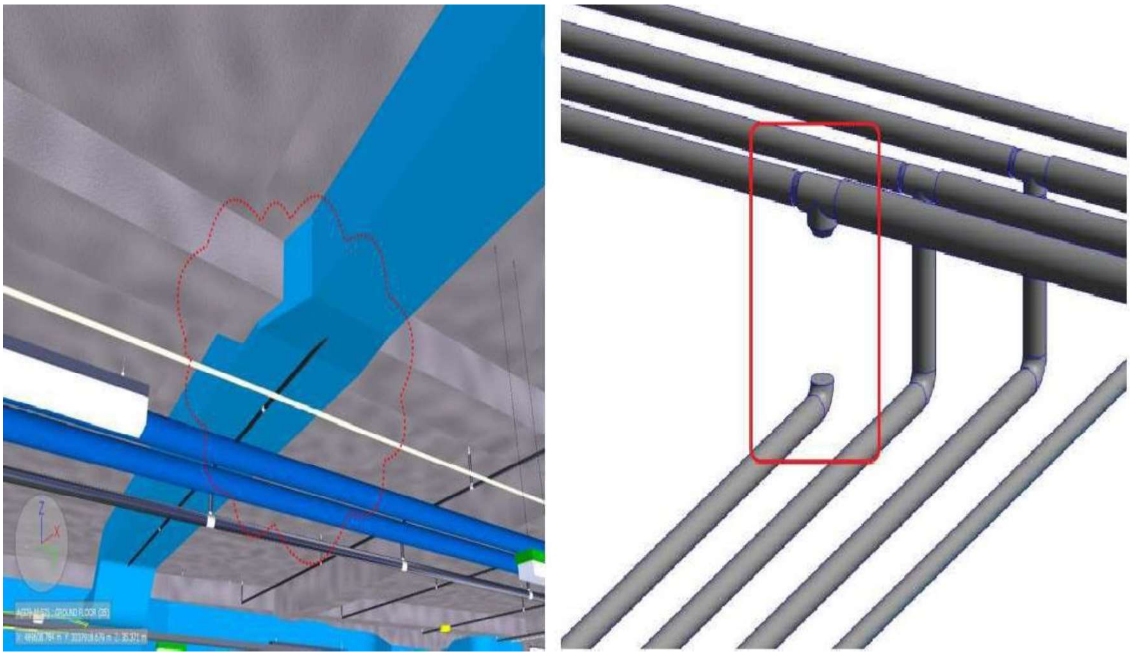

Figure 21: Clash and missing elements in systems in the design

3.3.4 Outputs

All Deliverables from the framework will be explained in the next chapter of the case study. These deliverables are beneficial in describing all the ingredients of the expected from the framework, such as the automated design process of individual models of design like the HVAC model, firefighting model, and electrical model, and the result of coordination between all models and validation of all models.

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Chapter 4- STUDY CASE

This section explains the suggested frameworks may contribute to exploration and optimization across the building design process, as well as how automated design techniques can be combined with a BIM-based workflow.

4.1 Input data

The case study inputs include architectural and structural 3D models for "MEDICAL CONFERENCE CENTER" Design & Planning for King Khalid University building generated in Revit as those shown in figures 22 and 23.

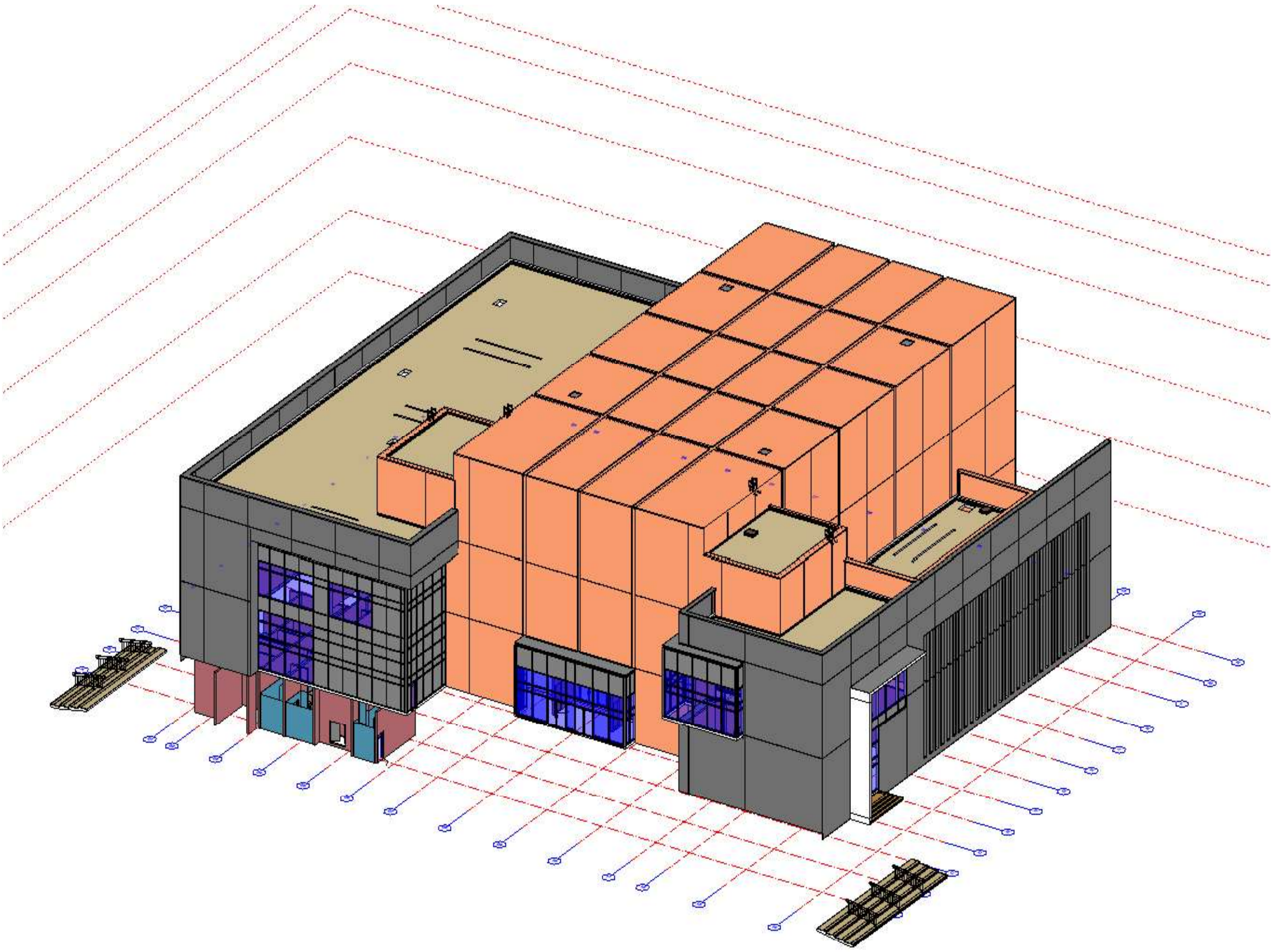


Figure 22: Case study BIM Modeling for Architectural works.

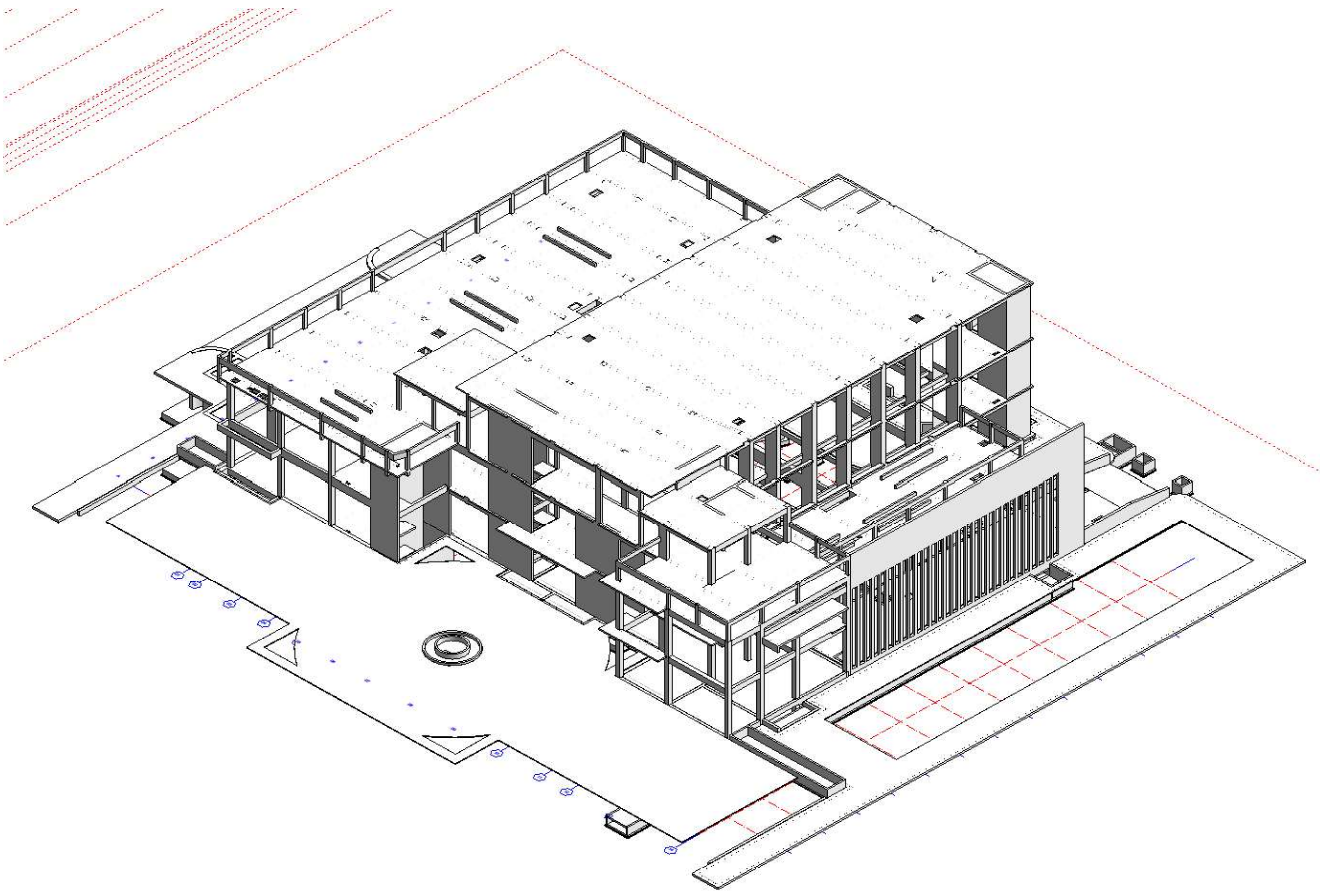


Figure 23:Case study BIM Modeling for structural works.

4.2 Standard and Specifications and BIM requirements

To start work on this case study in compliance with BIM standards, the planned first phase methodology is to gather data on the interested parties' information requirements in accordance with the BIM standard (ISO 19560), as shown in figure 24.

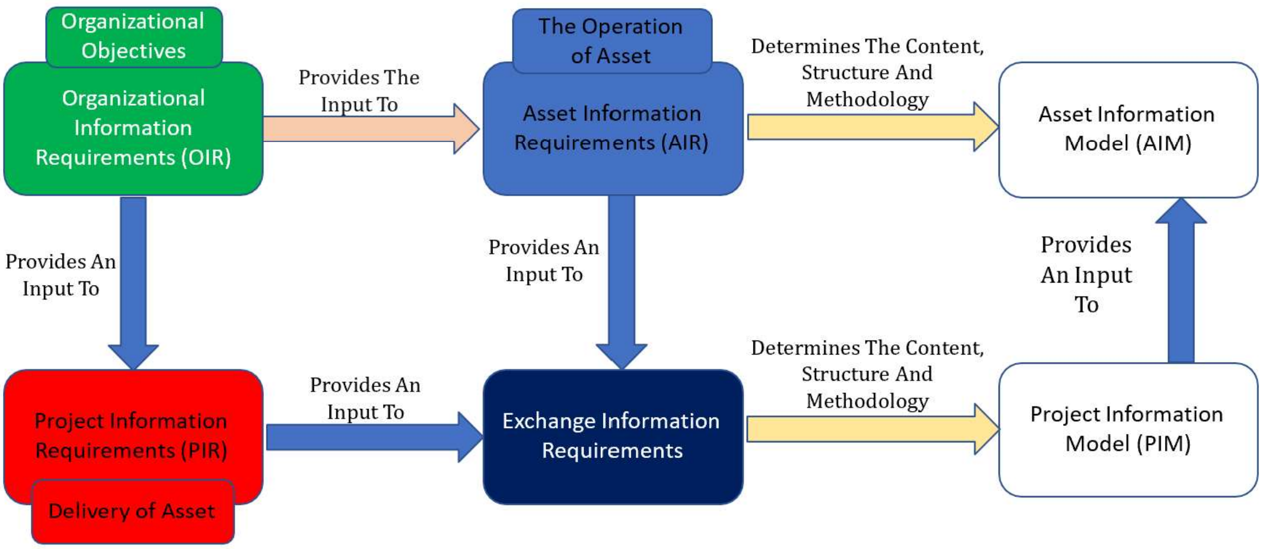


Figure 24: Information Requirements of ISO 19650-2 (OIR & AIR & PIR) have sections completed by appointing party.

The (OIR) (AIR) which are define the information required for the organization to support an operation activity and the (PIR) represented the project objectives, existing project information, important decision points, and the Appointing Party's expectations for project completion and Provide Project’s Information so that clients or employers can define clearly what they want and when under the BIM uses as per shown in figure 25.

X	PLAN	X	DESIGN	X	CONSTRUCT	X	OPERATE
×	PROGRAMMING	×	DESIGN AUTHORING		SITE UTILIZATION PLANNING		BUILDING MAINTENANCE SCHEDULING
	SITE ANALYSIS	×	DESIGN REVIEWS		CONSTRUCTION SYSTEM DESIGN		BUILDING SYSTEM ANALYSIS
		×	3D COORDINATION	×	3D COORDINATION		ASSET MANAGEMENT
			STRUCTURAL ANALYSIS		DIGITAL FABRICATION		SPACE MANAGEMENT / TRACKING
			LIGHTING ANALYSIS		3D CONTROL AND PLANNING		DISASTER PLANNING
			ENERGY ANALYSIS	×	RECORD MODELING	×	RECORD MODELING
			MECHANICAL ANALYSIS				
			OTHER ENG. ANALYSIS				
			SUSTAINABILITY (LEED) EVALUATION				
			CODE VALIDATION				
×	PHASE PLANNING (4D MODELING)	×	PHASE PLANNING (4D MODELING)	×	PHASE PLANNING (4D MODELING)		PHASE PLANNING (4D MODELING)
×	COST ESTIMATION (5D MODELING)	×	COST ESTIMATION (5D MODELING)	×	COST ESTIMATION (5D MODELING)		COST ESTIMATION (5D MODELING)
	EXISTING CONDITIONS MODELING		EXISTING CONDITIONS MODELING		EXISTING CONDITIONS MODELING		EXISTING CONDITIONS MODELING

Figure 25:BIM Uses for the case study as per PIR

The organization which owned this project in this case study is the ministry of education (Saudi Arabia). This project Consists of the university of Bisha in Saudi Arabia and the case study for one building of this project which is “MEDICAL CONFERENCE CENTER” building.

The scope of this study is appointed party (Kolektor Koling- Slovenia) as per hierarchy of the information management relationship between parties and teams, of ISO 19650-2 which illustrate in framework, the responsibility of the appointed party in BIM use requirements is (design authoring - design reviews - 3D coordination) for MEP works in Autodesk Revit and working (CDE) while the" lead appointed party" is (Arabisc -Egypt) create an automation design for this project as per framework methodology.

4.3 Process

As per the process in proposed in framework methodology:

- ✓ Parametric Modeling
- ✓ Generative Design
- ✓ Parametric Design) (Dynamo Development)
- ✓ Clash Detection
- ✓ Validation of Model (Quality Planning & Quality Control)

4.4 Outputs

4.4.1 Parametric Modelling

BIM incorporates the parameters and data of the design that characterize a in a graphical 3D model, which is known as parametric modeling. In this study, using the Revit application to design MEP as per shown in figures 26,27 and 28.

While Revit is a strong modeling program utilized in the construction industry, and its capability can fulfill all design changing demands. The full BIM project model required for MEP design which involves human input from the user. Before using this technique, the 3D models for architectural structural, other current MEP systems.

The initial phase in this research process is inputs analysis. The architectural design, which specifies the room partitions necessary for the MEP design. Furthermore, the limitations are as follows:

1. The structural component location

2- MEP elements that may interfere with one another.

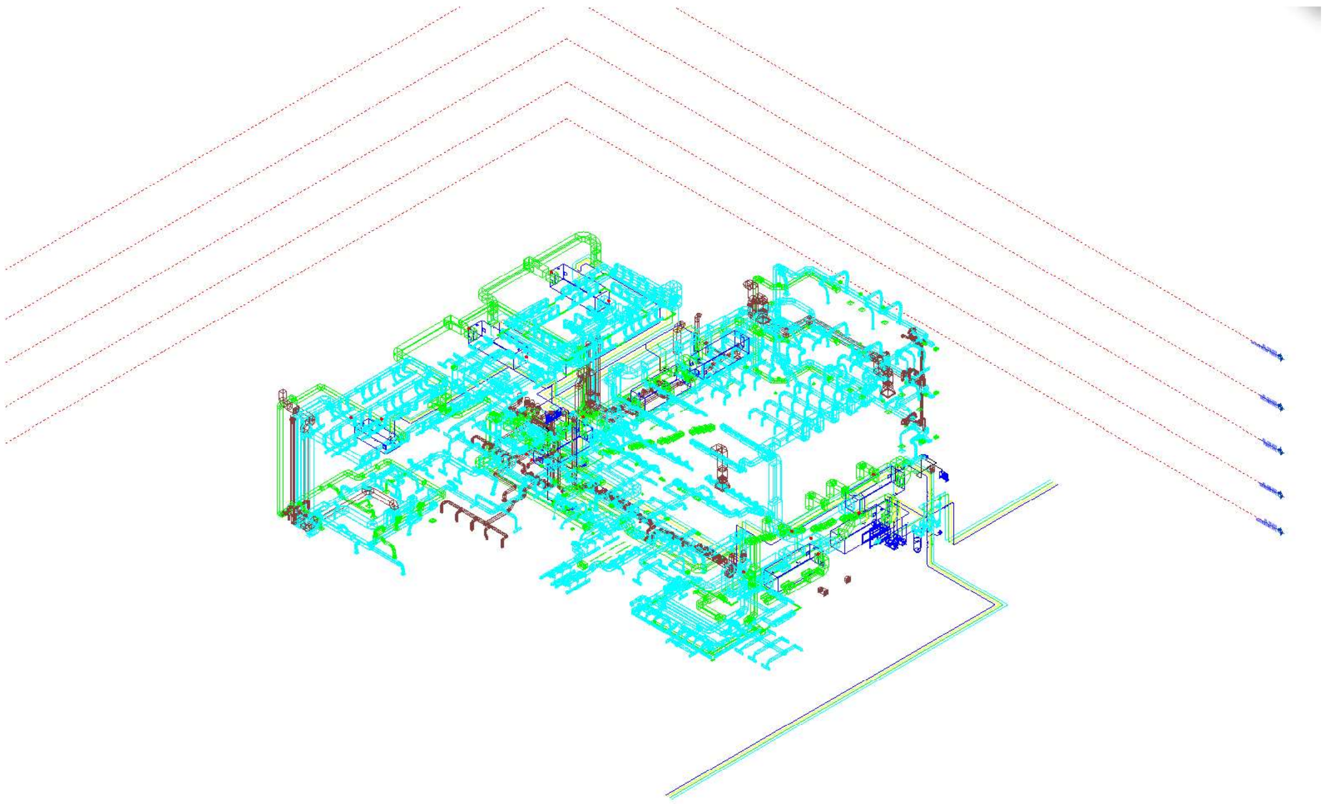


Figure 26**:** BIM Modeling for HVAC works

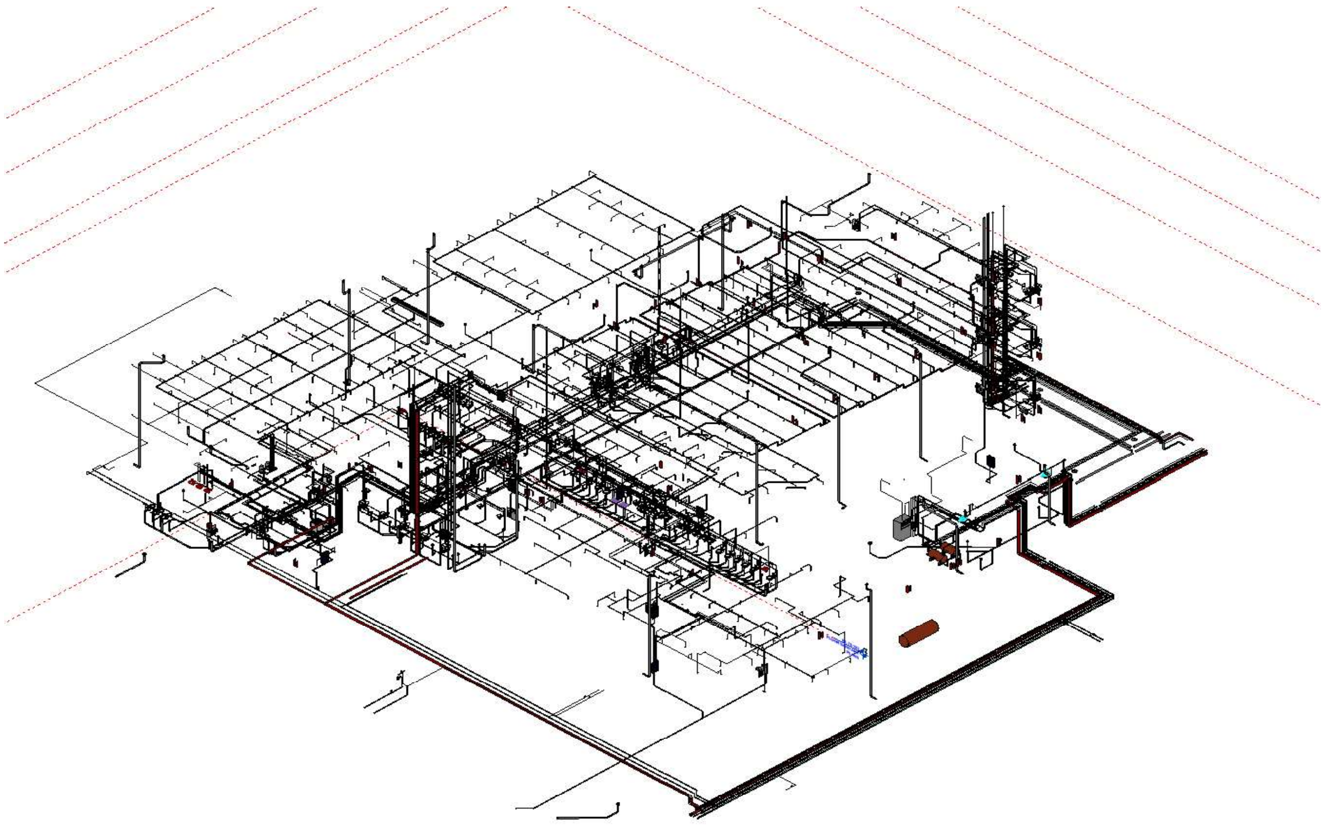


Figure 27**:** BIM Modeling for Plumbing and firefighting works

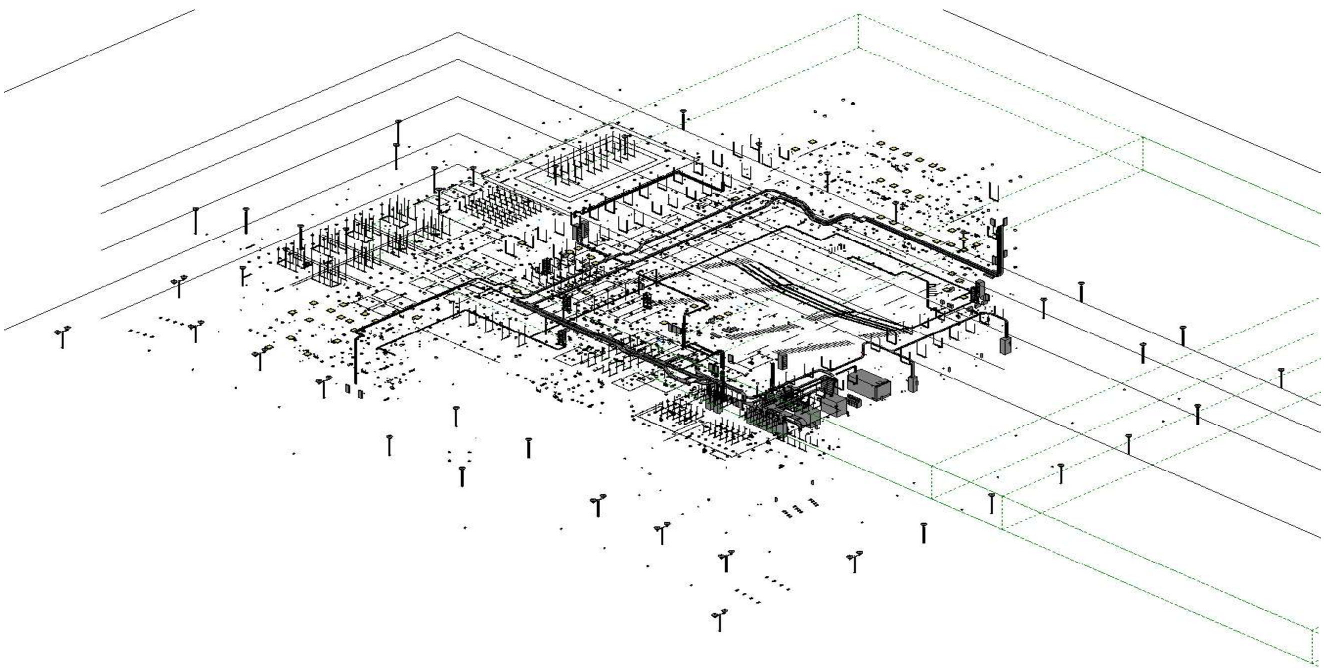


Figure 28**:** BIM Modeling for Electrical works.

4.4.2 Generative Design

BIM automation used in this case study to modify the design and make designs more successful with a little more designer. With a distinct link into a final stage, the scripts that run in parallel. Instead of combining them into one massive script, and let humans participate in the process and make decisions.

For this case study, the generative design process comprises gathering items and geometry as inputs, feeding them through the generative design algorithm and evaluation phases, and finally displaying them through the generative design interface for design visualization and analysis.

4.4.2.1 Generative design for duct distribution in HVAC model

Figure 29 illustrates a rough outline of the sorting by overall duct length, we may iterate through a few possibilities to see which one is the best in terms of total combined length. Some are quite close, which is where engineering judgment comes into play. This helped us conclude that the first module in that line would provide us with the optimal length.

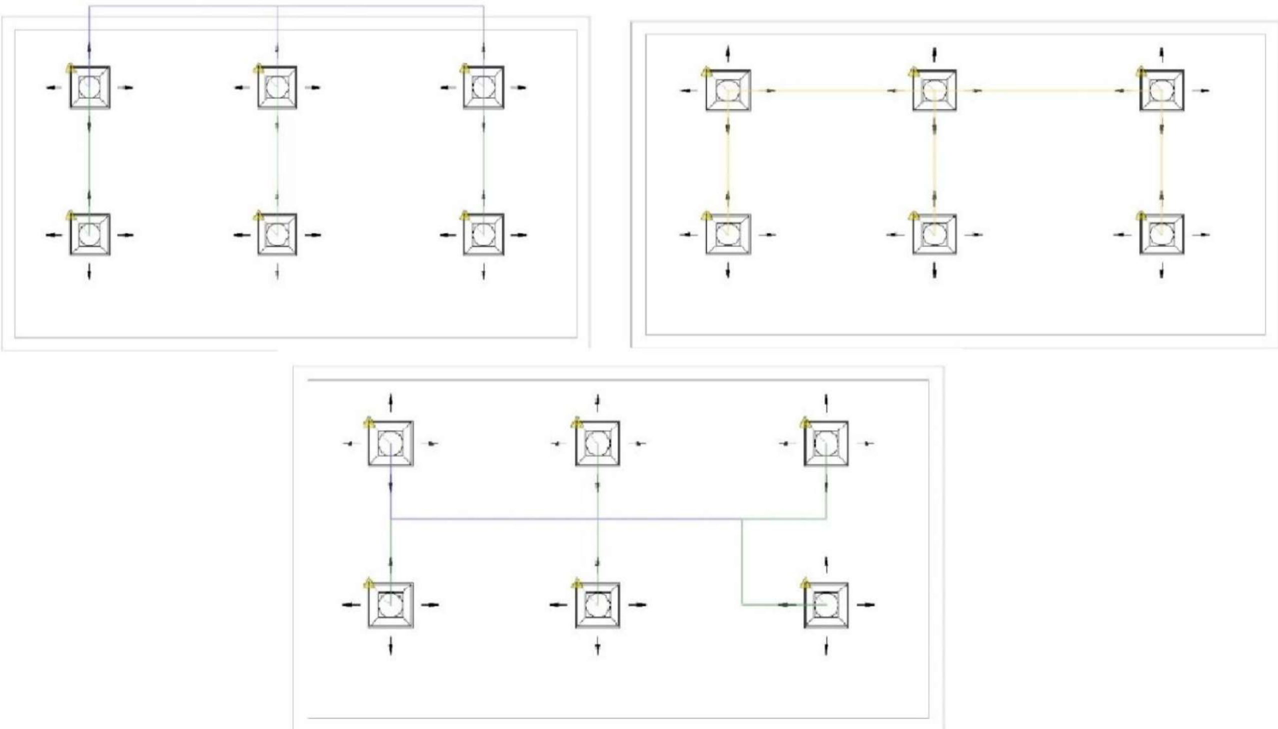


Figure 29**:** Generative design duct distribution in HVAC model

4.4.2.2 Generative design for pipes distribution in firefighting model

Figure 30 illustrates a rough outline of the sorting by overall pipes length, we may iterate through a few possibilities to see which one is the best in terms of total combined length. Some are quite close, which is where engineering judgment comes into play. This helped us conclude that the first module in that line would provide us with the optimal length.

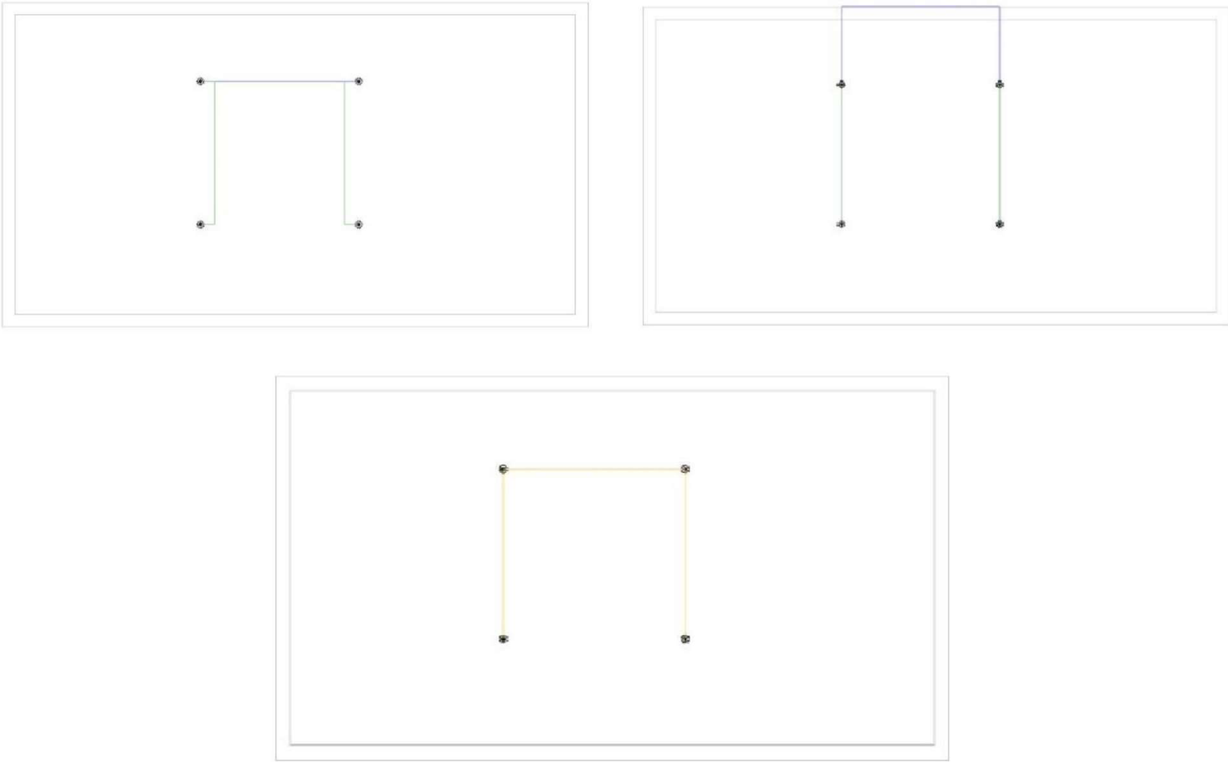


Figure 30**:** Generative design for pipes in firefighting model

4.4.2.3 Generative design for pipes distribution in plumbing model

Figure 31 illustrates a rough outline of the sorting by overall pipes length, we may iterate through a few possibilities to see which one is the best in terms of total combined length. Some are quite close, which is where engineering judgment comes into play. This helped us conclude that the first module in that line would provide us with the optimal length.

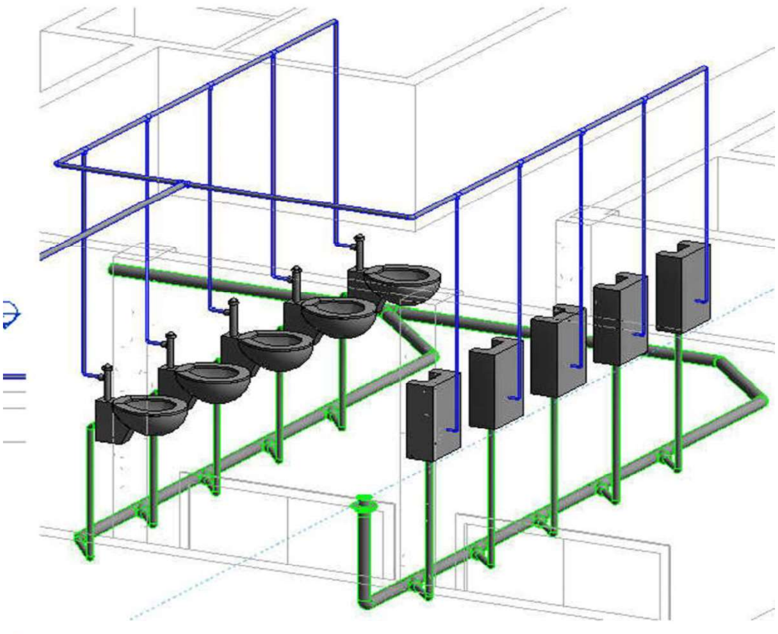


Figure 31**:** Generative design for pipes in plumbing model

4.4.3 Parametric Design (Dynamo Development)

Algorithm thinking, usually starts from the end to find a way to create the Algorithm to solve the problem. to start to build an algorism to solve problems. in this case study, the problem is creating the automatic insulation for all ducts for all projects to save time and cost.

- ✓ Plan of the model depending on algorithmic thinking what we decided before so we will check the nude requirement to work (duct – insulation – thickness) so we have three parameters we need to start to model it as parametric
- ✓ Choose all duct and duct fittings which we need to make insulation as per figure 32.
- ✓ Check the selection by making appears the graphic for all what we selected as per figure 32.
- ✓ As per code, the thickness must be 1 inch for indoor or 2 inches for outdoor ducts. the 1 inch selected because this is indoor ducts as per figure 33.
- ✓ The result of use the dynamo after running the Algorithm presented in figure 34 and saving the time and cost for engineer.

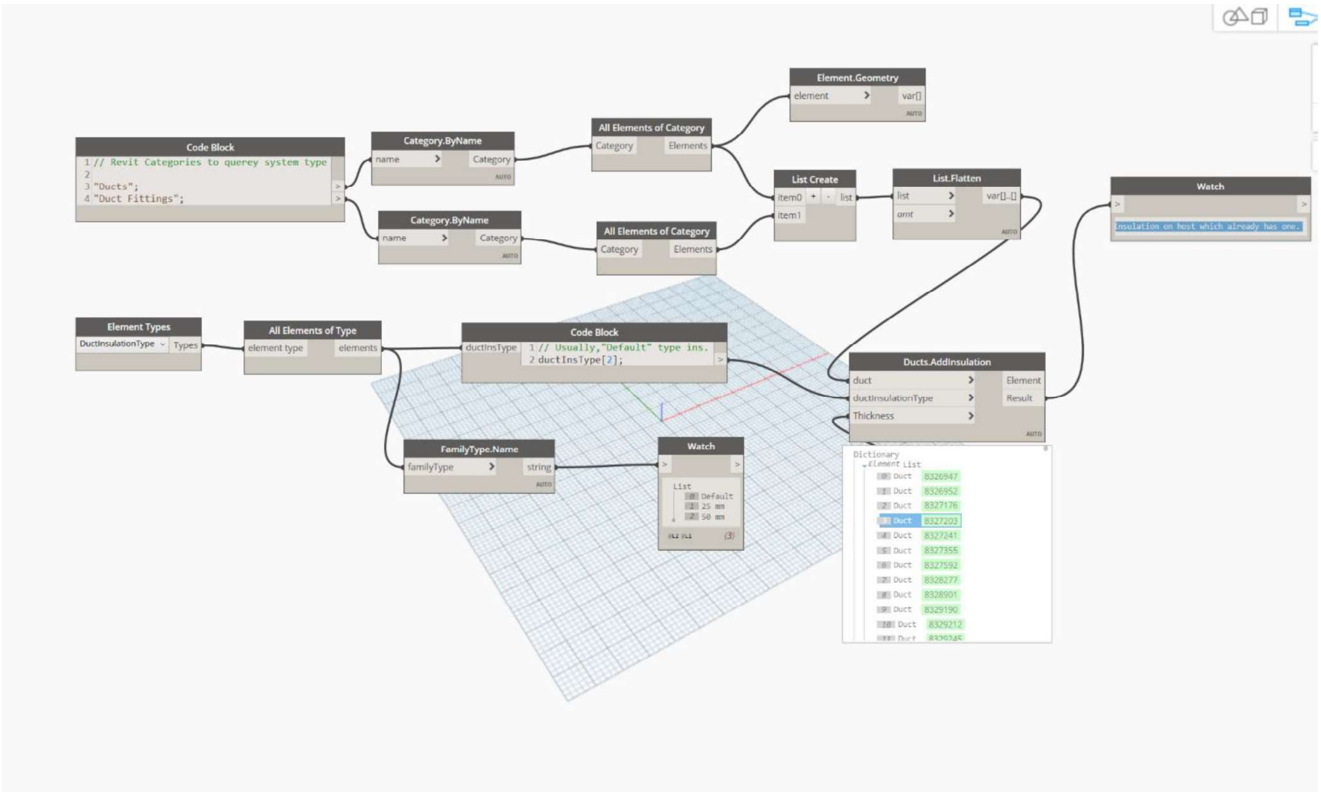


Figure 32: – Section of ducts and insulation types

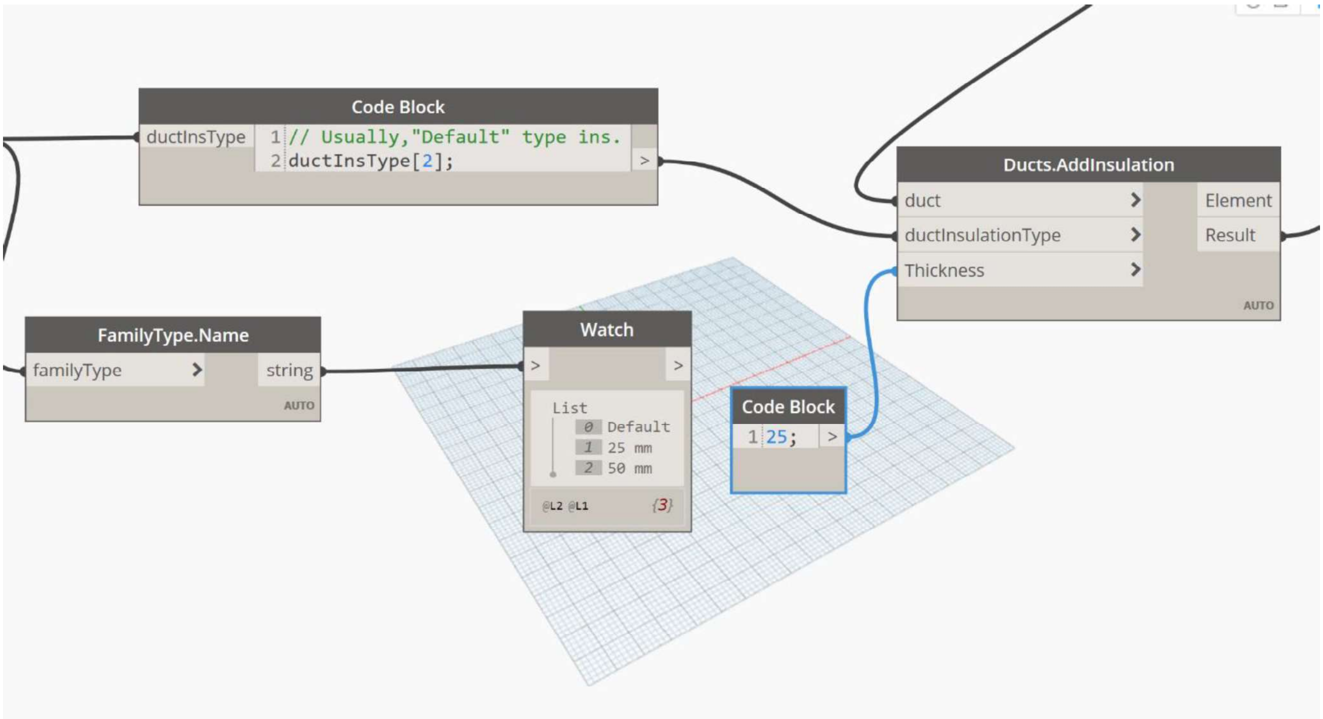


Figure 33: – Thickness of insulation selected in dynamo as per code

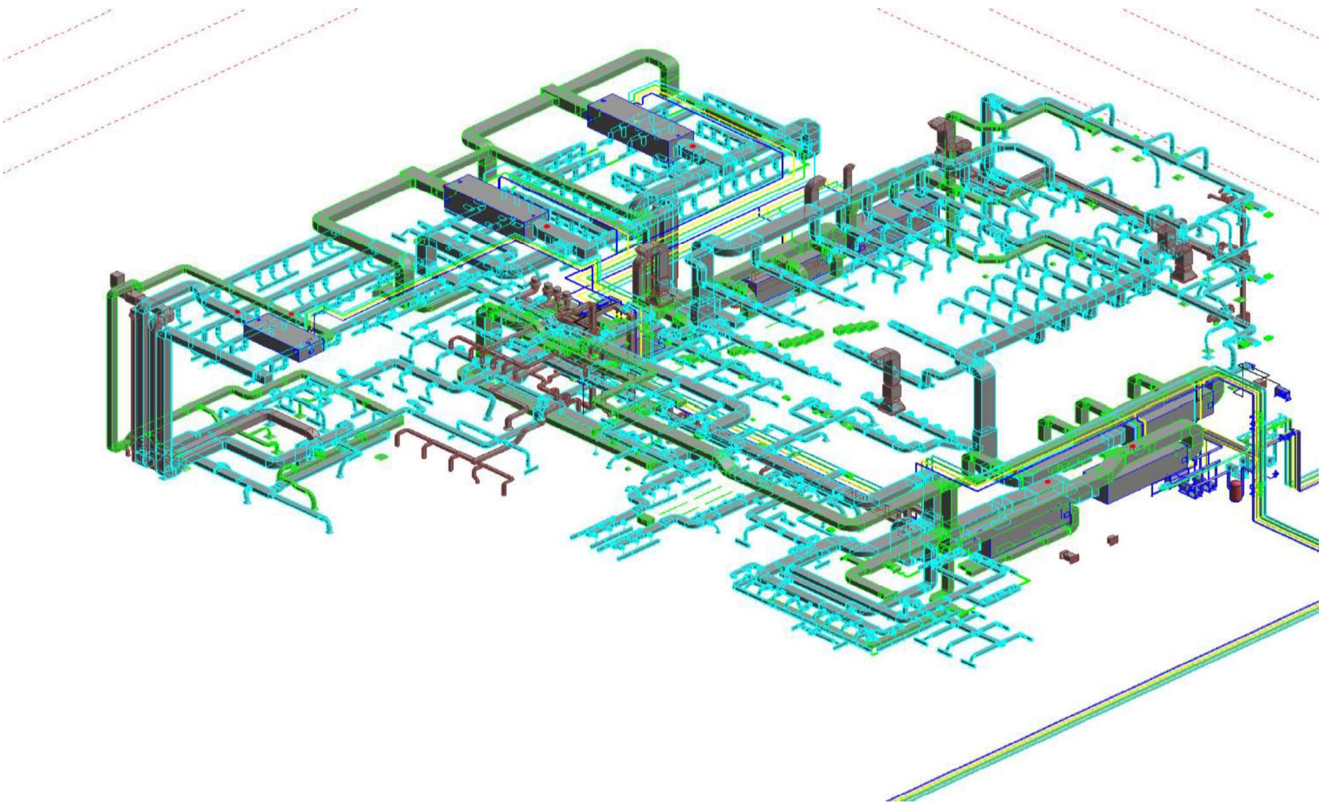


Figure 34**:** The ducts and fittings after insulated

4.4.4 Clash Detection and validation of Model (Quality Planning & Quality Control)

The Arch. and MEP model imported to the (Solibiri software) to checking and create BCF and collaboration between two models as shown in figure 35.

The interoperation data format, IFC being the most prevalent and best-known, provides for the resolution of old concerns that are frequent in data exchange, hence eliminating interpretation issues as well as take-over challenges.

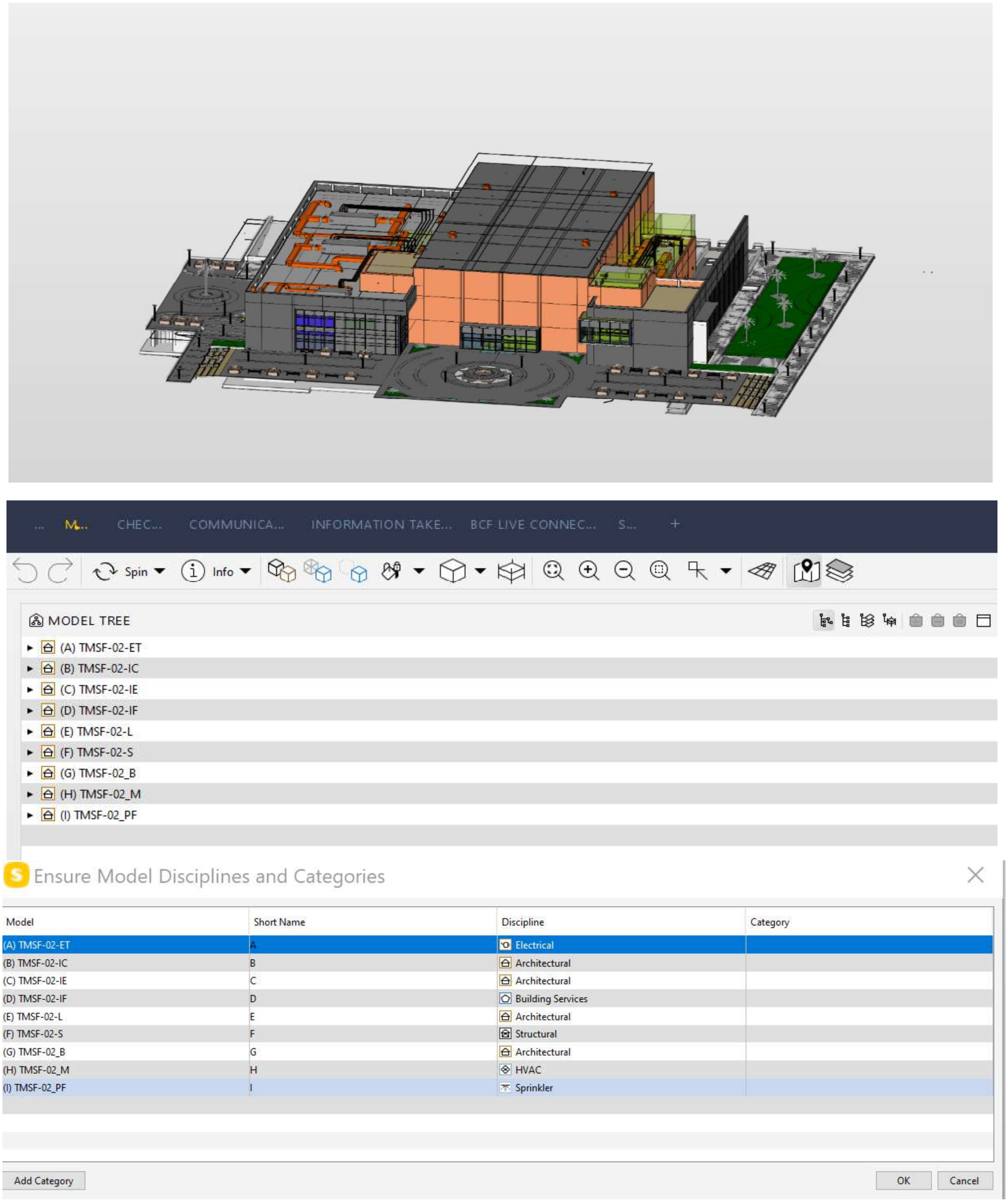


Figure 35: Showing the Definition of each model.

The checking been performed in the BIM Coordinator and BIM validation -MEP role with a " verification" of the information relating the parametric items typical of virtual models will also be undertaken in BIM system as per shown in figure 36.

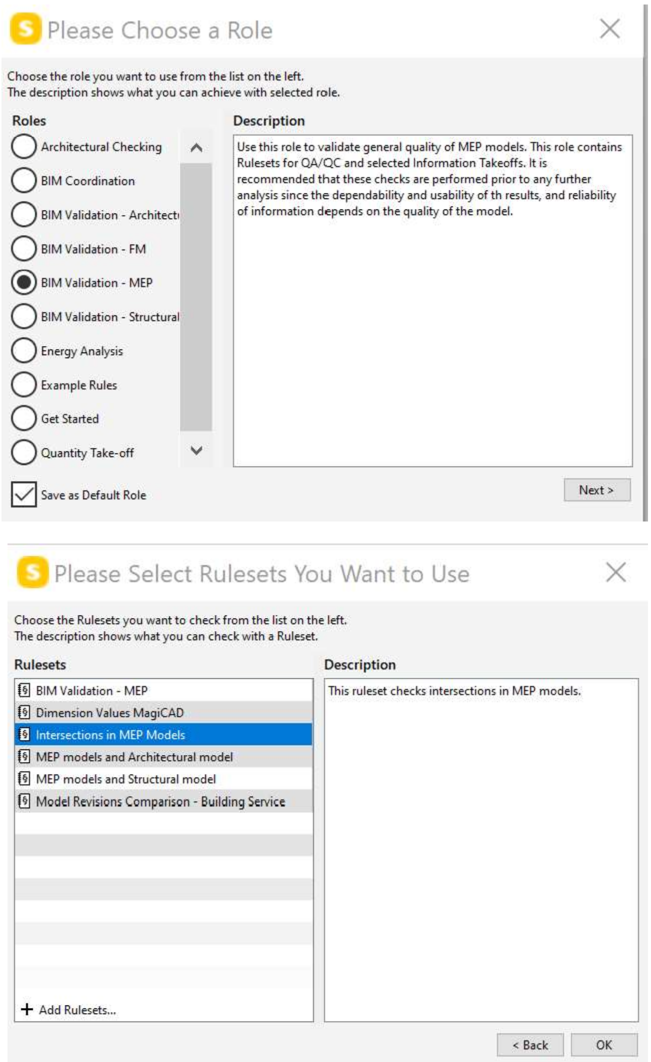


Figure 36: Showing the Role of the checking as a coordination and BIM validation -MEP role.

In intersections between architectural components the ruleset checks all intersections between components of the Arch. and MEP Models. IN practice, this manifests as regulatory and project request conformance verification, as well as frequent planning verification of what is anticipated of Clash Detection as per shown in figure 37.

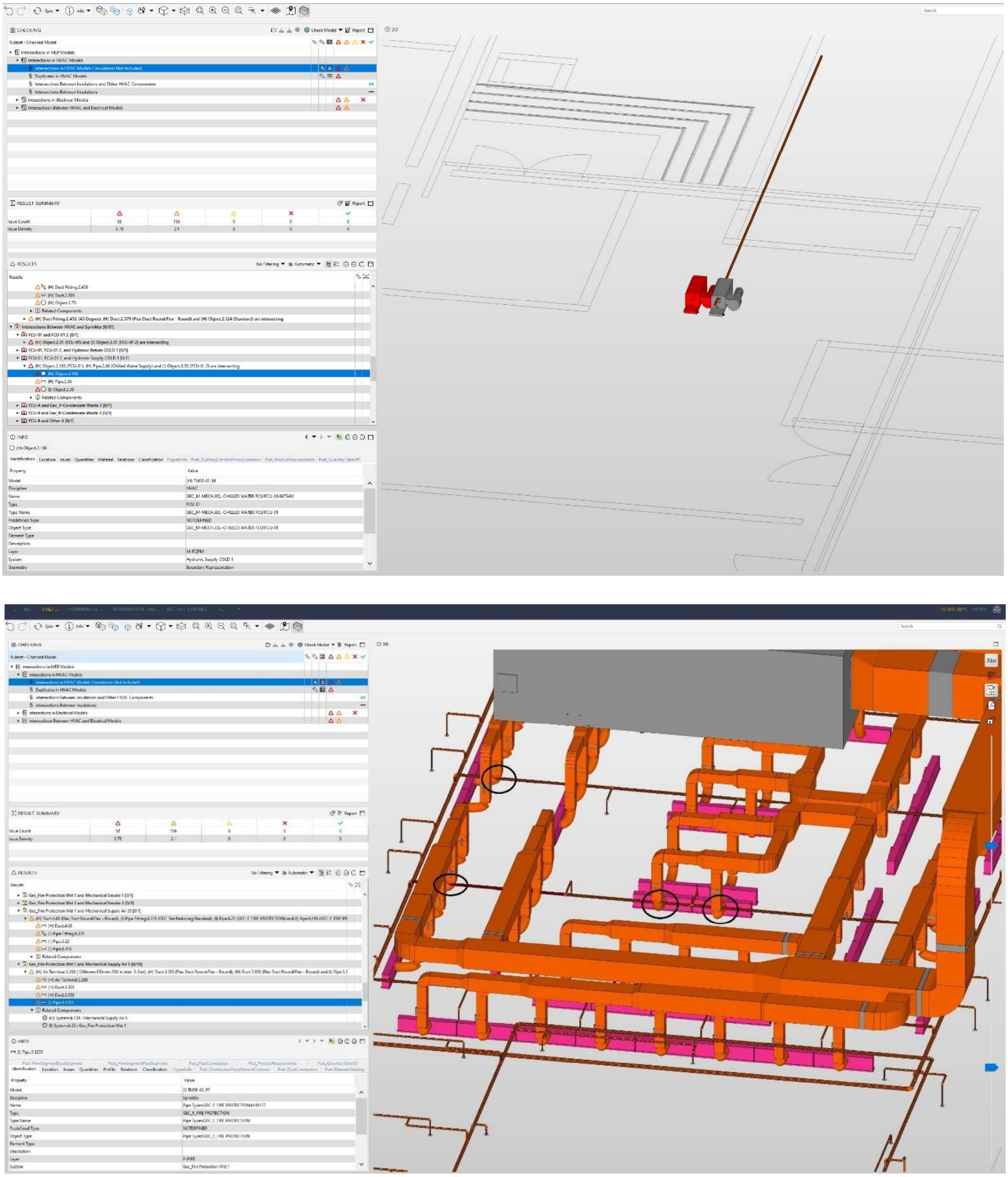
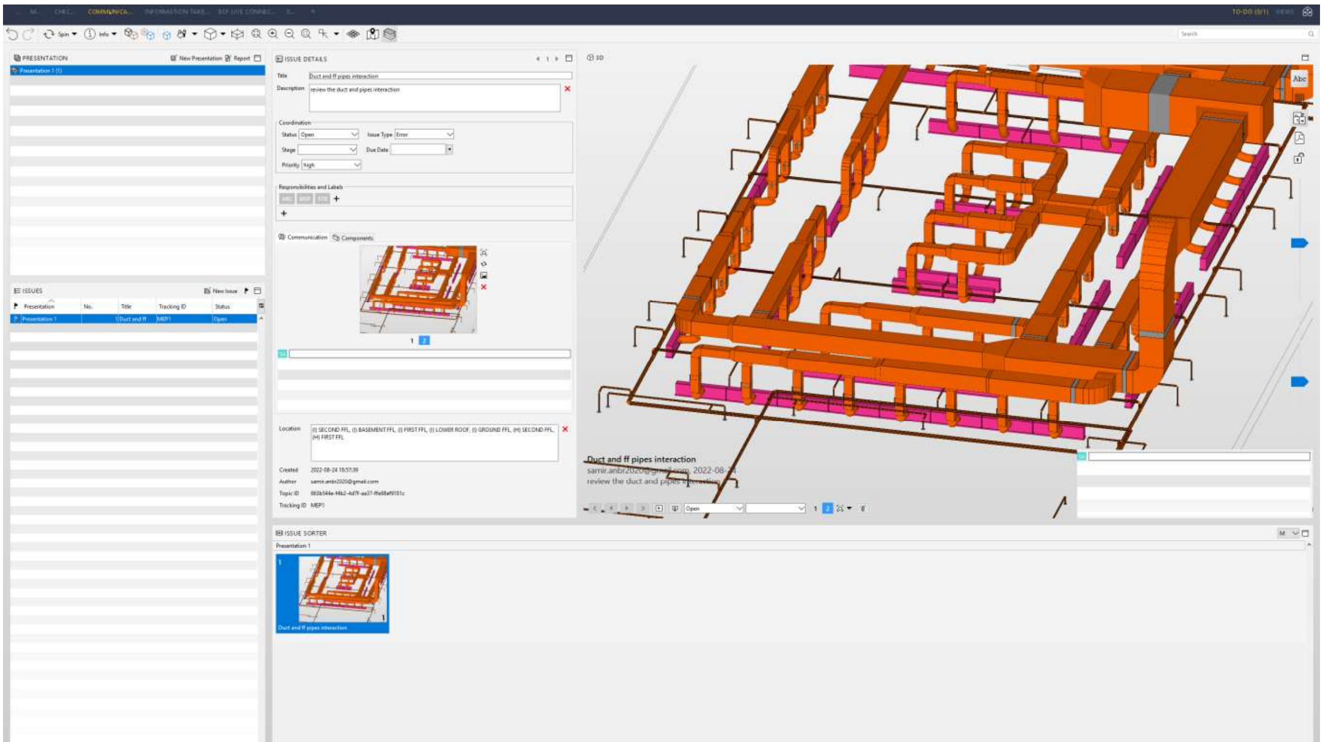
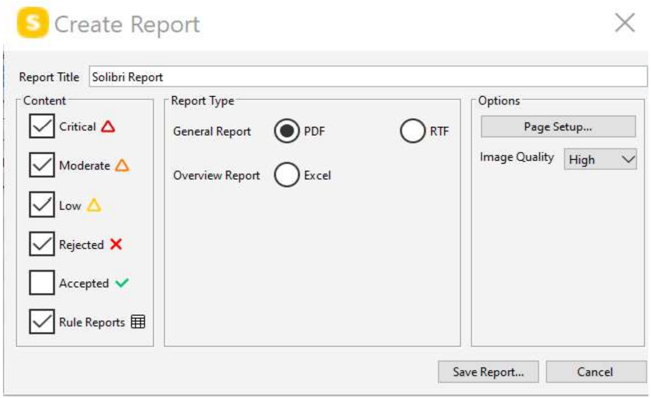
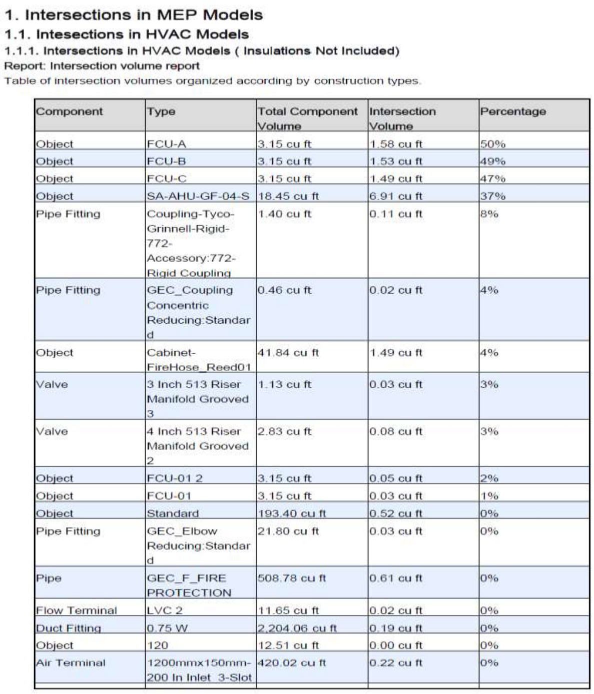


Figure 37: Showing the checking results.

The communication of information validation will involve the final phases of a design throughout the development lifecycle, making it the most crucial components of the BIM system as per shown in figure 38.







1. Intersections in MEP Models

1.1. Intesections in HVAC Models

1.1.1. Intersections in HVAC Models (Insulations Not Included)

Report: Intersection volume report

Table of intersection volumes organized according by construction types.

Component	Type	Total Component Volume	Intersection Volume	Percentage
Object	FCU-A	3.15 cu ft	1.58 cu ft	50%
Object	FCU-B	3.15 cu ft	1.53 cu ft	49%
Object	FCU-C	3.15 cu ft	1.49 cu ft	47%
Object	SA-AHU-GF-04-S	18.45 cu ft	6.91 cu ft	37%
Pipe Fitting	Coupling-Tyco-Grinnell-Rigid-772-Accessory:772-Rigid Coupling	1.40 cu ft	0.11 cu ft	8%
Pipe Fitting	GEC_Coupling Concentric Reducing:Standard	0.46 cu ft	0.02 cu ft	4%
Object	Cabinet-FireHose_Reed01	41.84 cu ft	1.49 cu ft	4%
Valve	3 Inch 513 Riser Manifold Grooved 3	1.13 cu ft	0.03 cu ft	3%
Valve	4 Inch 513 Riser Manifold Grooved 2	2.83 cu ft	0.08 cu ft	3%
Object	FCU-01 2	3.15 cu ft	0.05 cu ft	2%
Object	FCU-01	3.15 cu ft	0.03 cu ft	1%
Object	Standard	193.40 cu ft	0.52 cu ft	0%
Pipe Fitting	GEC_Elbow Reducing:Standard	21.80 cu ft	0.03 cu ft	0%
Pipe	GEC_F_FIRE PROTECTION	508.78 cu ft	0.61 cu ft	0%
Flow Terminal	LVC 2	11.65 cu ft	0.02 cu ft	0%
Duct Fitting	0.75 W	2,204.06 cu ft	0.19 cu ft	0%
Object	120	12.51 cu ft	0.00 cu ft	0%
Air Terminal	1200mmx150mm-200 In Inlet 3-Slot	420.02 cu ft	0.22 cu ft	0%

Figure 38: Showing the checking results reporting.

Upon completing all clash detection or bypassing it, the model will proceed to final validation to ensure all systems are in optimal orientation and BIM validation process is approved as per shown in figure 39.

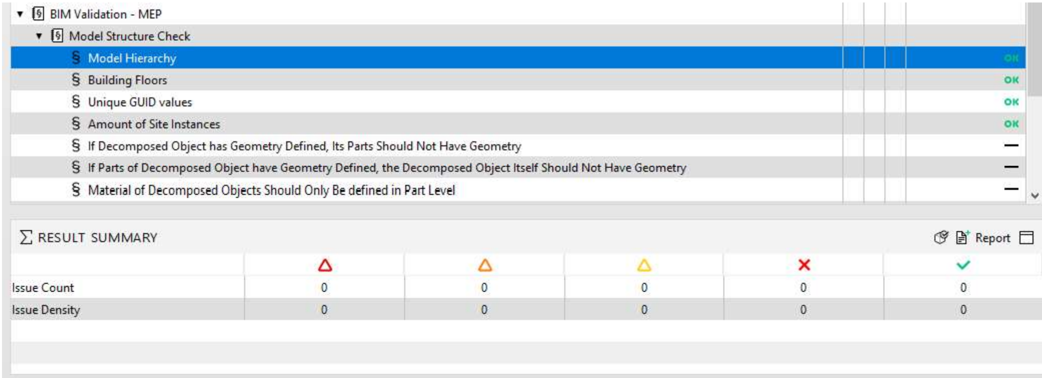


Figure 39: Showing the BIM validation process is approved.

4.5 Results and discussion

According to this case study, there are numerous methods for BIM automation design difficulties to affect the efficiency of MEP design and coordination.

BIM automation for design can help to reduce the number of time-consuming activities. The proposed method automates design calculations and 3D model, saving up designer time for other important tasks. The automation of BIM for design is the important objective of this study which reduce the chance of clashes and enhance the efficiency of design.

The concept of using BIM automation techniques for generative design and using dynamo script or using the specific rule in " Solibri" can be easily adapted for most projects with simple instructions and increased productivity.

Chapter 5- CONCLUSION

5.1 Research Contribution

This thesis provides an overview of BIM automation strategies for building service design. The advantages and conclusions of this study may be summarized as total time savings, overall cost savings, and higher productivity.

Whatever the scale of the project, MEP systems have a critical part in the design, the budget, and the period of the project. This case study illustrates the current situation of the private project in Egypt as well as the findings of research conducted in collaboration with one of the leading general contractors in "Slovenia" “Kolektor Koling d.o.o”. The general contractor team has extensive BIM knowledge from previous projects. The case studies concentrated on a specific sort of automation design for MEP project construction.

BIM automation design helps designers evaluate design possibilities rapidly and save time. Design and drawing automation can help to eliminate time-consuming chores. The suggested approach automates design calculations and 3D drawing, allowing human labor to be redirected to more vital activities.

This work's significant benefit is the use of automation BIM design to decrease the probability of construction disputes and boost design system productivity.

5.2 Research Limitations

Rather than a deep-level examination of one case study, the strategy in this thesis was to evaluate the research in multiple faces of study. Like:

1- To get the best performance for MEP design, use generative design to automate the ducts and pipe routing.
2- Another aspect of research is to utilize a dynamo to create automated designs for difficulties like duct insulation and duct support as per ASHRAE code for HVAC, firefighting pipe as per NFPA code for firefighting, and drainage pipes as per international plumbing code.
3- To solve the clash, use the most up-to-date BIM tools.
4- Validate the model using the most up-to-date BIM tools.

That is a limitation of this thesis that contributes to ensuring that the model is applicable to implement on the project site with the least amount of clash and the highest quality to meet the BIM target of reducing the cost and time of design and construction while maintaining the greatest quality.

It is exceedingly difficult for academics to obtain complete access to building projects, particularly those with comparable degrees of complexity, scope, relevance, as well as BIM design. This is because the design of a BIM project is almost always established by more than one designer, making it difficult for the researcher to obtain permission from each of them. Because of the difficulty in getting this authorization, the researcher was work on the project with an Egyptian designer and carry out the study with the contractor in Slovenia.

5.3 Future Works

Further research is necessary to evaluate the effectiveness of these automation techniques and to develop more of the developed automation software and Add-ins and unify the method of working for those tools to be able to work with any software.

These automation techniques will assess a greater variety of decision variables to provide the designer with the ideal option based on their requirements, as well as determine the optimal compromises between material, size, quality, and construction time for all components in the design process, as well as implementation in construction site duration to decrease clashes and validation time, all these techniques sustain and increase quality, time, and cost efficiency.

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