A Cast Study to Investigate an Affordable Cloud-based Server for Worksharing to Benefit Academia & Small Businesses

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Abstract
Real-time collaboration of multiple digital models is vital for successful construction projects using Virtual Design and Construction (VDC) or Building Information Modeling (BIM). Real-time collaboration allows users to workshare within a multidisciplinary team to co-author multiple smart digital models for better efficiency. This can be done in two ways, either using a physical server (Local Area Network/LAN server) or cloud-based server (Wide Area Network/WAN server). Such cloud-based servers are A360, C4R, Collaboration for Revit, or BIM360Design collaborate, etc. However, above-mentioned cloud services come at a significant price, making it challenging for academia and small businesses to perform real-time collaboration using BIM/VDC models. To find an affordable alternative, an attempt was made as part of the Virtual Design and Construction (VDC) course offered by the Construction Science and Management Department (CSM). For this case study, a popular and free (Google) cloud server was tested as a WAN server to host four multidisciplinary collaborative VDC central models for five users across five different geographic locations and time zones. The study rendered successful results to establish a real-time collaborative workshare environment; hence, can significantly benefit academia and small business

Key Words: Real-time collaboration, affordable VDC cloud server, VDC, and BIM models

Introduction
To enhance the hands-on experience for the CSM students, the VDC course was set up to simulate like a smaller size (less than ten employees) Architecture, Engineering, and Construction (AEC) firm. The goal was to use the similar technology and tools available to a small AEC firm for a real construction project at an affordable cost.

This process started with programming a small commercial building (physician's office) and creating several VDC collaborative models. Two popular modeling software, Autodesk Revit and Navisworks, were chosen to construct the VDC models and as an analytical tool to promote worksharing and real-time collaboration. The goal was to participate in real-time editing from multiple dispersed locations where each user would immediately be notified about the model changes made by the other users. Autodesk Revit is designed for such collaborative worksharing around a vast-range of geographical locations and time zones (Bwail, 2017); however, this is not possible without a physical or cloud-based server (Autodesk® Building Information Modeling, visited 2020) such as A360, C4R, or BIM360 design, etc. Current pricing for Autodesk's recent cloud server, BIM360Design collaborate, is $945/year/user (Autodesk, 2021) for both academia and professionals. Therefore it is hard for educational institutions or small AEC firms to avail such cloud-based software and, or server due to the high initial investment (Kim, 2012) and slow Return on investment (ROI) that can be as long as one year (Bwail, 2017). Therefore, the team focused their energy on investigating an affordable alternative to the central cloud server for the VDC collaborative worksharing. However, it was soon discovered that although few attempts were made towards establishing an alternative and affordable cloud-server, none are available at present. The team soon started to experiment with Google Drive as an alternative to host the digital central models, along with another Google add-on as a Virtual

private network (VPN) connector between the local machines and the central Google Drive. Fig. 1 shows a symbolic representation of how LAN and WAN servers work.

Figure 1: LAN and WAN server
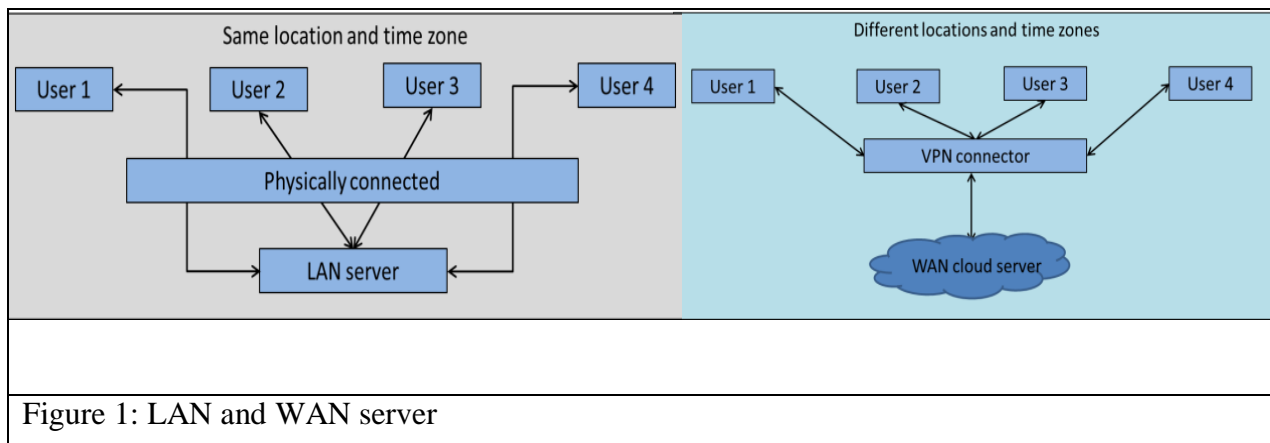
Literature Review

The authors conducted a broad literature review to identify journal articles that investigated cloud-based VDC/BIM technologies. They focused on 'title/abstract' search using keywords such as BIM server, cloud server, cloud computer, Revit Workshare or Collaboration, etc. Authors initially cumulated 51 publications containing above-mentioned terminologies. However, as cloud computing is relatively new in the AEC industry, soon, the information gap became evident in the limited number of publications. Below, the authors have short-listed some publications that had a significant influence on this case study:

Lou, et al. (2020) conducted a comprehensive summary of the status quo of BIM data exchange methods, including file-based method, cloud-based method, and three local data exchange methods comparing the advantages and disadvantages of each method. They recommended enhancing the capability to deal with large Industry Foundation Class (IFC) files while promoting integrating BIM with the blockchain method.

The most relevant study was done by Munkle et al. (2016), focusing on a low-cost IT platform that enabled the BIM model-based collaboration on a real-world case study. They explored a low-cost platform using SharePoint, Google Drive, and Dropbox for hosting extranets to enable the sharing of a live-central-integrated model between geographically separated design teams; however, they faced quality assurance and coordination challenges.

Karl Van Nieuwenhuyse shared his experiences regarding a new cloud-based desktop platform named Cloudalize (Groep, 2015) for Autodesk Revit collaboration. According to Nieuwenhuyse, Cloudalize allows users to 'rent' virtual workstations making heavy on-site workstations obsolete. Therefore this process helped in increasing time and cash outlay efficiency.

Chong et al. (2014) compared 42 comprehensive cloud-based functions such as email, calendars, online storage, document editing, website editing, video chatting, messaging, etc. They identified Google Apps, Microsoft Office365, and Box Enterprise are suitable for general cloud applications, whereas Autodesk, BIM360, BIMServer, and BIM9 are suitable for BIM applications. However, they also acknowledged that current cloud-based BIM software might not be appropriate for small construction firms.

Author Stefan Boeykens (Boeykens et al., 2012) demonstrate the importance of BIM collaboration in academia and conducted a manual four-semester-long case study using ArchiCAD, Revit, and Solibri viewer.

Zhang and Issa (2012) compared different frameworks for cloud computing, mainly focusing on the AEC industry. Their study hinged on Revit Server, Revit cloud, and STRATUS, along with Advance2000 and Amazon servers. The paper evaluated different levels of cloud computing and its benefits to organizations.

Case Study Goals

Following the literature review, the authors aimed the following goals:

- Creating a central space for cloud-based workshare to access simultaneously or as needed to promote real-time workshare, editing, and collaboration
- Following the complete work process involving design, modeling, scheduling, quantity take-off and clash detection of the VDC models
- To bring five different participants into a single workshare platform using only free software
- The team of five users functioning as a small AEC firm

Methodology

The methodology depended on creating workshare VDC model, transferring them to Google drive and testing real-time collaboration. The study started with brainstorming to identify the required program areas for the physician's office project, as listed in the following paragraph. Once the team finalized the program areas, they moved on to create the digital models using Autodesk Revit. This process demanded significant time depending on users' prior knowledge of Autodesk Revit. Fig. 2 shows a diagrammatic workflow diagram for methods used.

Programmed areas

The following program areas were included in the physician's office project

- Waiting area (300 ft^2)
- Two examination rooms (80-100 ft^2)
- Break room (100 ft^2)
- Office (200 ft^2)
- Storage (100 ft^2)
- Test room (200 ft^2)
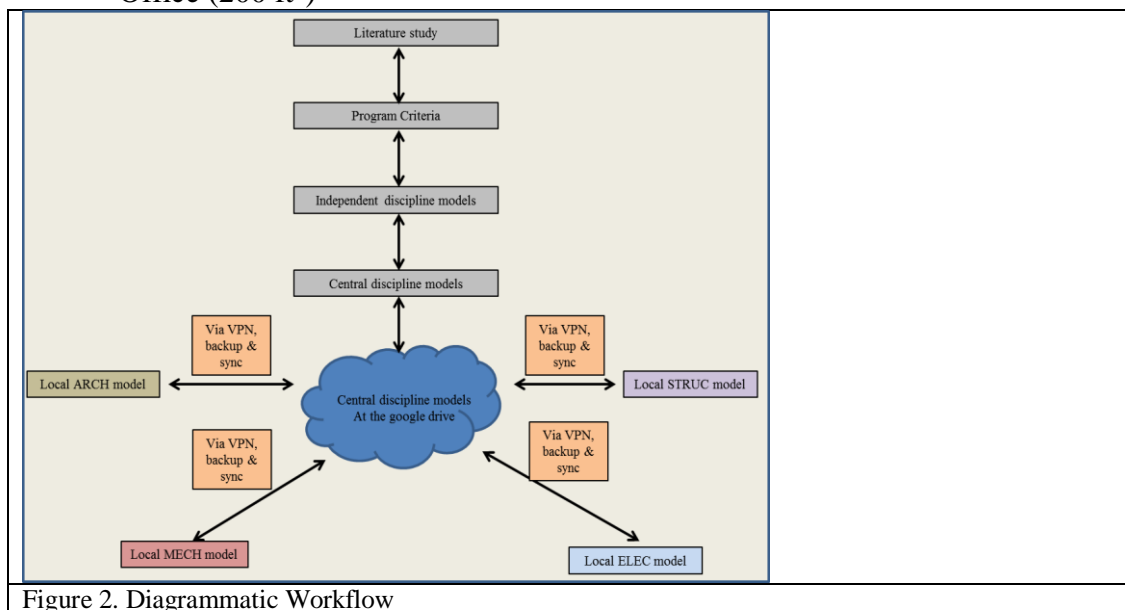- Bath room / change room (150 ft^2)

Figure 2. Diagrammatic Workflow

The Challenges

The users were located in three different states (Alabama, Florida, and Tennessee) within the United States. Students performed as employees at a small-sized AEC firm where multiple users worked on the Revit files at the same time/location and also separately. It was crucial to follow Revit's workflow standard to avoid any loss of work and seamless collaborative real-time worksharing.

Collaborative worksharing for Revit involves creating a master-model, also known as central-model, by activating worksets. The central model preserves complete information for all worksets and elements in the project and also acts as a distribution point for all updates made to the synchronized local models. End-users

then create local files from the central files to work simultaneously on the same project. This method requires the Revit central files to be located in a server accessible to all involved. This can be done in two ways (Bwail, 2017); either by using a LAN network server where all team members can access or a cloud-based WAN server using a VPN connector.

When using the WAN server with the VPN method, the file location is vital, as Autodesk Revit looks for a specific file path for data exchange between the central and local files. This path must remain same throughout the project, as accidental change of the file path can result in lost communication and connection between central and local files. Therefore, the team aimed to create a seamless integration between the central and the local files so Revit will identify the Google Drive path identical for all users.

The Step by Step Process

Step 1 - The first step was to create a multidisciplinary team consisting of four students and the course instructor. Four disciplines were Architecture (ARCH), Structural (STRUC), Mechanical (MECH and PLUMB), and Electrical (ELEC) and each student focused on their discipline models.

Step 2 - Autodesk Revit was selected as the workshare platform. Each user individually downloaded Revit to their local machines using their academic accounts. They soon started to design and model their individual models. At this stage, the different discipline Revit files, namely ARCH, MECH and PLUMB, ELEC, and STRUC, were created. These models were non-workshare models transmitted and linked using a portable thumb drive. This process soon created confusion due to duplicate, outdated, and, or out-of-sync models, and the need for central collaborative space became evident.

Step 3 - The team looked at Google Drive as a WAN server due to its large storage space. However, it was quickly discovered that using one user's personal Gmail account and sharing that Google Drive with other users did not result in the needed editable workshare environment. Therefore, as an alternative, a new Gmail account was created, and all users logged into the new Gmail account on their local machines using the same login credentials. This allowed equal editing and saving access to Google Drive for all users. In addition, users also downloaded Google's 'Backup and Sync' app (free) to connect the Google Drive to their local machine as a VPN connector. This allowed each user to work from their local machines and seamlessly save to Google Drive directly, a process that is very similar to Autodesk's cloud server.

Step 4 – After step three, the different discipline files (ARCH, MECH and PLUMB, ELEC, and STRUC) were taken into the workshare environment by activating worksets and saving them as central files. All individual users then created a local copy using the central file. The central and local files (sized from 8 to 15MB) were saved in Google Drive, which could be accessed using the Backup and Sync app from the local machines. As part of the BIM Management Plan (BMP), the team also established workflow rules such as naming convention, saving intervals, and additional communication methods to inform each other about important updates. Special attention was given to naming conventions to clearly identify the central and local files, disciplines, users, and versions. Each user had ownership of particular discipline files to avoid accidental corruption of other central files. Fig. 3 and Fig. 4 contain the three and two-dimensional floor plans, and individual discipline models are shown in Appendix A.
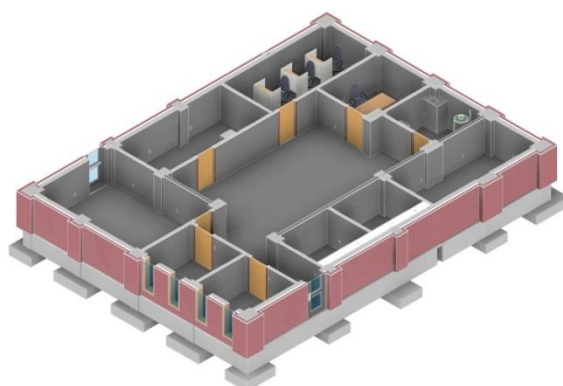
Figure 3: 3D floor plan

Step 5 - Once this path was established, collaborative workshare became seamless, where all users could see the changes made in real-time. The collaborative model is shown in Fig. 5
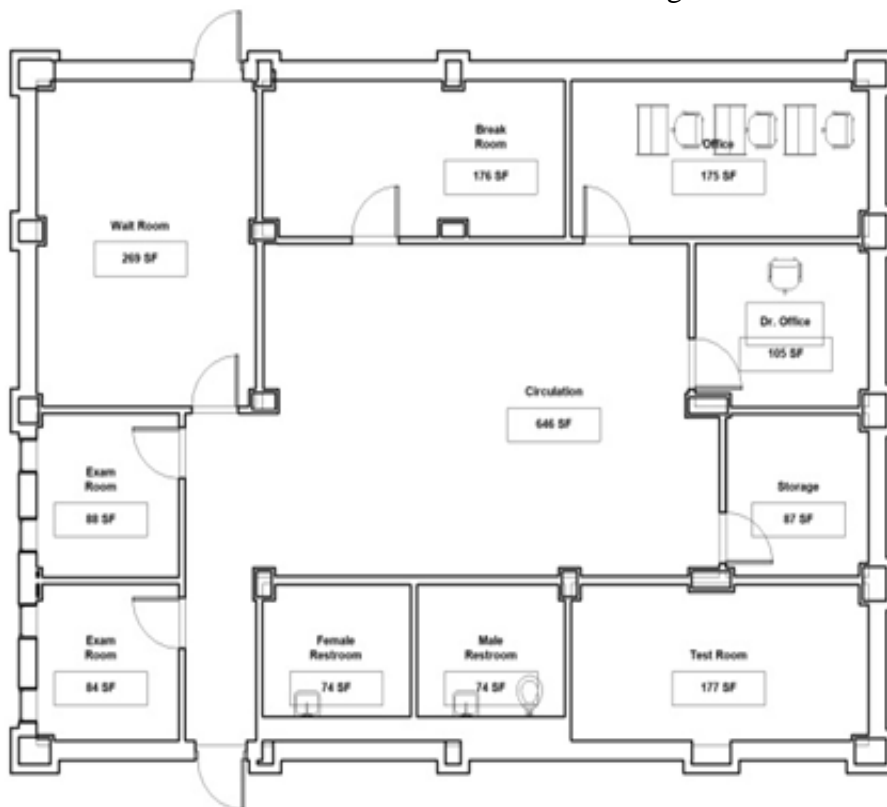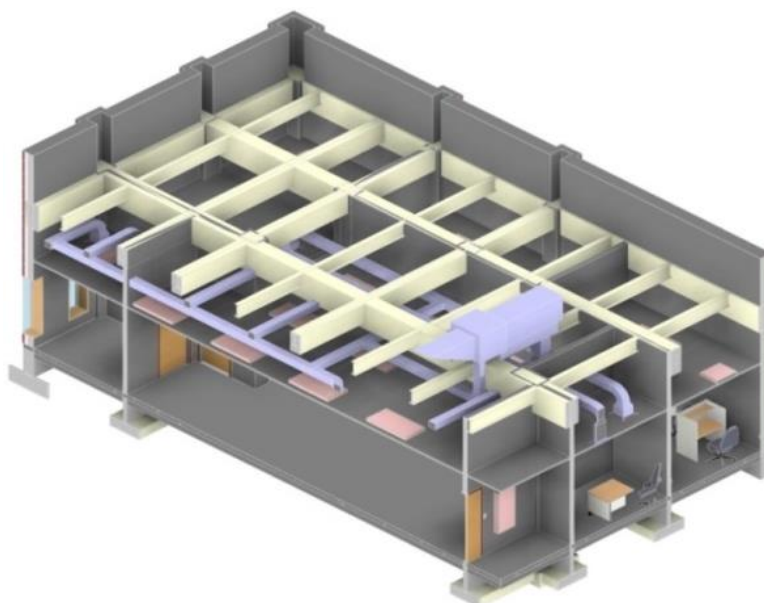

Figure 4: 2D floor plan

Figure 5: Collaborative model

The Tools Used

Fig 6 contains the various tools used to establish the alternative cloud server space.

Autodesk Revit as multidisciplinary modeling tool

Google 'Backup and Sync' as VPN communicator between users local machine and Google cloud server

Autodesk Navisworks for 3D design/constructability review

ZOOM for meetings, discussion, or decision making

Google Drive as cloud server

Personal phone services along with GroupMe chat for communication

Fig 6: Tools used

The Results

This study rendered successful results. The team could edit and co-author four discipline VDC models in real-time using only free software and a cloud server. This study also established Google Drive as an alternative to BIM360 for real-time collaboration, which can render significant cost reduction with multiple benefits. The potential benefits of the process are noted below:

- Only freely downloadable software were used
- It was a seamless and simplified process, thus reducing the learning curve
- Although a smaller group of users was involved in this study, it can be tailored for a bigger group due to the flexibility of the process
- One-time and quick setup for Google Drive as the cloud server

At the same time, the team also noticed few future opportunities for improvement, as noted below:

- The process did not generate automated communication as BIM360 would. Therefore, the team needed to communicate using their phones or GroupMe Chat whenever important edits were made.
- Uploading and downloading was depended on internet speed. However, it was not considered to be a related issue to the cloud server worksharing.
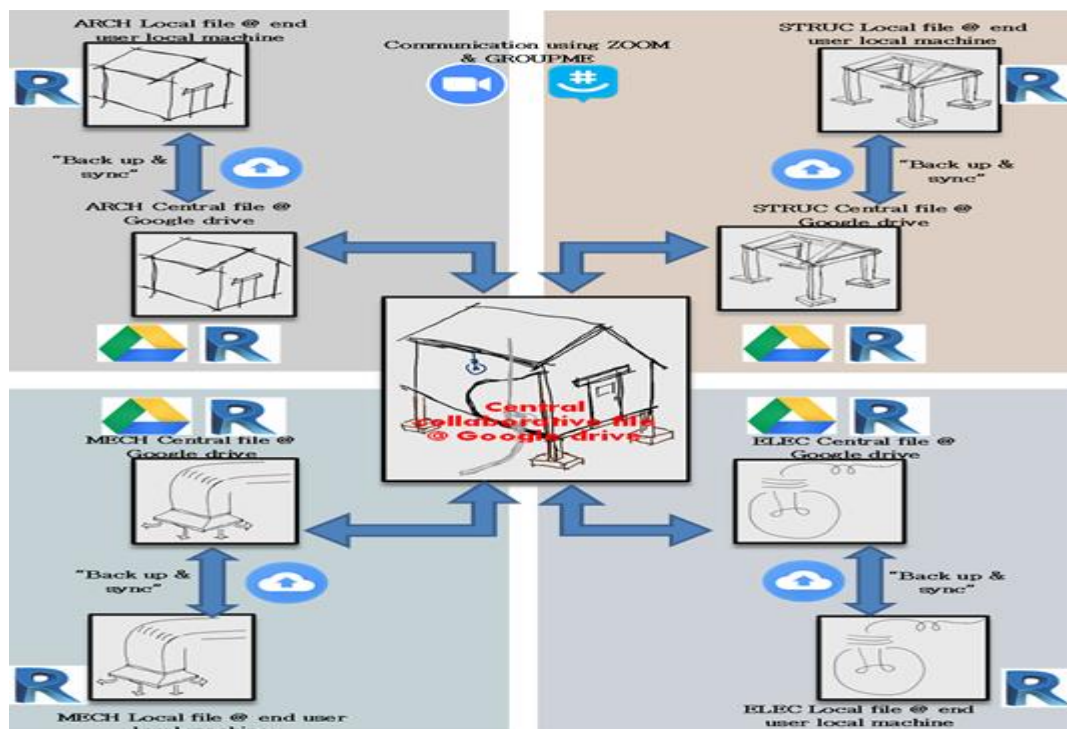
The Process

Fig 7 demonstrates the workflow diagram for easier understanding of the process. Figure 7: Workflow Diagram
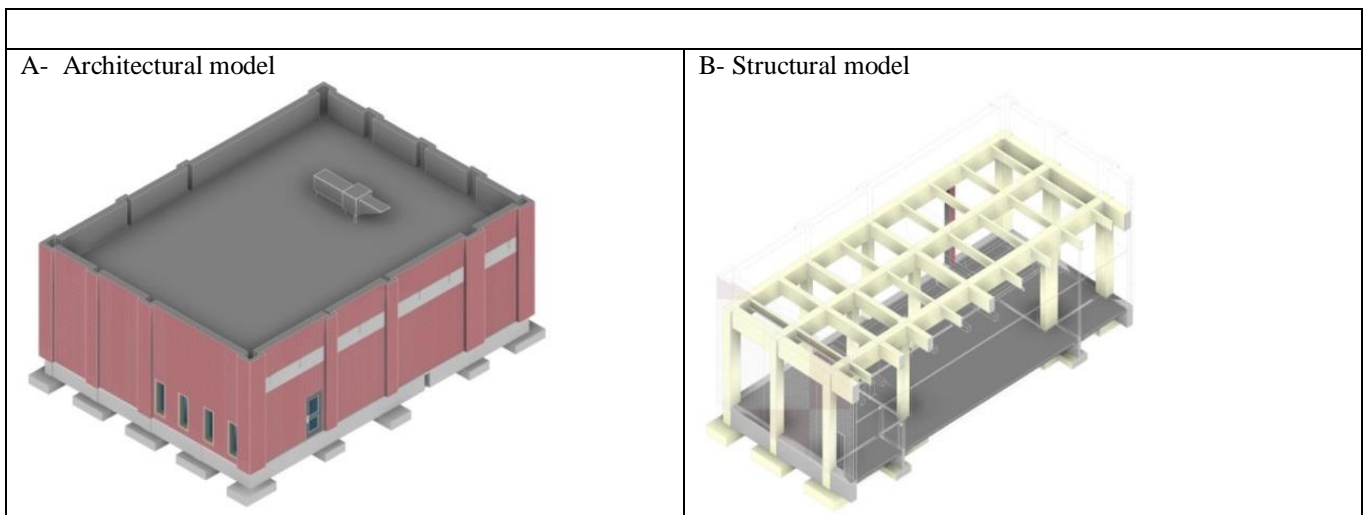
Conclusion

This research proved that Google Drive could be utilized as an affordable alternative to the expensive cloud-based server to perform similar worksharing functions suitable for academia and small business. This may render significant economic benefits to the smaller AEC organizations, making BIM/VDC affordable for all. Additionally, this research also showed that a course can be designed to simulate the digital work environment of a small AEC firm, thus providing vital work experience to the students.
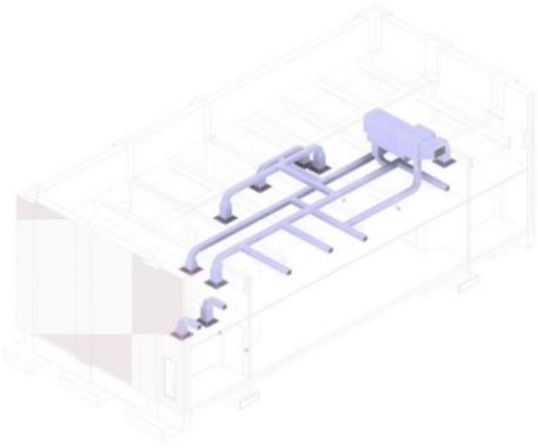
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Appendix A

| A- Architectural model | B- Structural model |

C-Mechanical model	D-Electrical model