FACILITY MANAGEMENT USING BUILDING INFORMATION MODELING

A CASE STUDY OF JINNAH POSTGRADUATE MEDICAL CENTRE (JPMC)

By

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ABSTRACT

The nature of buildings is getting more complex with increased number of parallel processes ultimately leading to an increased number of facilities and components with amplified amount of data and information. Handling and management of this information is challenging and solutions to this problem are often not effective. Building Information Modeling (BIM) has established its ground in the design and construction phase overall. The operations and maintenance phase which entirely consists of management of facilities management data and information remains unexplored under BIM. Pakistan is yet to adopt BIM in its construction industry. Effective facility management requires the necessary pre-requisites which include a platform for communication, a detailed database and a model for visualization. In this project, the main objective was to develop a comprehensive database for a facility manager and develop an integrated Model of a health facility along with its mechanical, electrical and plumbing (MEP) models. The database creates a central link between the model and information of the components and facilities placed. Analysis of this proposed solution was carried out by surveys and interviews of well-established health facilities in Islamabad.

This is to certify that the

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Has been accepted towards the partial fulfillment

of

the requirements

for

Bachelors of Engineering in Civil Engineering

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DEDICATED

TO

OUR

PARENTS

&

TEACHERS

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LIST OF ABBREVIATIONS

FM	Facility Management
BIM	Building Information Modeling
AEC	Architecture, Engineering and Construction
CMMS	Computerized Maintenance Management System
IFC	Industry Foundation Classes
CAFM	Computer-aided facility management
MEP	Mechanical, Electrical, Plumbing
FMS	Facility Management System
ERP	Enterprise resource planning
HVAC	Heating, Ventilation and Air Condition
LOD	Level of Detail/Development
MWO	Maintenance Work Order Schedule
Cobie	Construction Operations Building Information Exchange
AHU	Air Handling Unit
GIS	Geographic Information System
OPD	Out-Patient Department
CEM	Construction Engineering and Management
JPMC	Jinnah Post-graduate Medical Center
AC	Air Conditioner
BHU	Building Health Units

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Chapter 1

INTRODUCTION

1.1 BACKGROUND

In the modern developing world, the nature of buildings is getting more complex and delicate. The construction industry is facing a challenging time to combat this complexity. Engineers are introducing more complex designs to cater for client requirements. These designs come along with the introduction of more compound components and facilities existing in a building. The interconnection of these components and facilities is a loop that is supposed to be kept running throughout the lifecycle of the building. This is why the operation phase constitutes approximately 60% of the total life-cycle cost of a facility (Arcamete et al. 2010). A lot of processes take place during the running of a building. As a result, huge of amount of data and information is produced daily that needs to be administered by the building's facility manager.

Communication and information management are among the key areas of management operations at every stage of a construction project life cycle. One of the essential aspects of investment process management practice in the construction sector is the impact of decisions and processes that take place at subsequent stages of the life cycle of a building on its physical, functional and performance characteristics. (Araszkiewicz, 2017) Involvement of more technical and diverse personnel in these operations phase is becoming a necessity.

The design and construction phase of a building is given more importance as compared to its more significant phase i.e. the maintenance and operations phase. The lifespan of a building is determined from how well it's maintenance and operations phase are handled by the facility managers. Buildings as of today, contain multiple systems running in parallel that are connected downstream to daily used facilities integrated together as one whole entity. Hence, the role of facility manager is critical to the planning, maintaining, and managing of these complex facilities (Eric M. Wetze et al, 2015)

Facility Management (FM) is a phrase not new to this era. The term facility management dates back to 1970s emerging in North America. (Azman et al. 2014) Traditionally, FM had been performed on a manual basis, whereby paper-based work involved large records of facilities and components which were monitored by the operations manager in the few buildings that they existed. Over the years, introduction of new modeling techniques such as Building Information Modeling (BIM) allowed for better visualization and storage of data regarding components and facilities. The integration of this information with custom built software for facility management has paved the way for a new beginning in this field.

However, when this concept is taken to a larger scale, say larger buildings such as airports, medical centers etc., the quantum of components and facilities increases to a whole new level. The role of facility managers ultimately gets more hectic and critical. Due to this, often FM sector is not installed properly when such a quantum exists. Considering a medical center that involves many departments with an equally larger quantity of installed medical equipment, the amount of information that would be required for facility management of these components and facilities also increases exponentially. Running 24/7, medical facilities cannot afford any major fault, hindrance or abruption on the on-going operations. This is due to the interdependence of all systems in the building which implies that a breakdown downstream would sequentially halt all processes upstream. The criticality of such a situation infers that facility management of such buildings is to be given utmost importance and recognition. A proper and well-maintained platform for facility management would play a key role in monitoring and harmonizing the day-to-day processes of this medical facility.

Practically, in the Architecture, Engineering and Construction (AEC) industry of Pakistan, the concept of facility management is relatively new or is not being effectively taken place. Old traditional methods of FM are still being used which are time consuming and not very efficient.

1.2 PROBLEM STATEMENT

The facility management sector has not yet been established or properly explored in most of the countries including Pakistan. The problem usually lies in acquiring information at different stages that needs to be collected repeatedly and integrating them into a platform. Furthermore, it has been seen that facility management is not effectively included in the design phase as well as in the contractual elements of a project. The construction industry is less concerned on the maintenance and operation phase of the building. This is usually the cause of lack of necessary knowledge and skills as well as cost issues.

Owners are always hesitant on the implementation of FM. This is due to the pre-requisites for its successful implementation which include an as-built 3D model of the building and a facility management software to access data from the model. With the introduction of BIM, it has made it possible to perform facility management. However, integration of BIM information with a platform to perform FM analysis is often the challenge faced. Several companies adapted to producing custom-made software or plug-in tools that allow us integrate the BIM of a building. Other software includes the Cobie plugin in BIM linked to Computerized Maintenance Management System (CMMS) or Industry Foundation Classes (IFC), YouBIM, Computer-aided facility management (CAFM) and several others.

These software allow us to view and analyze information from the as-built model. However, making the model, understanding the software and applying the knowledge requires expertise that is not always readily available in the market. Therefore, a bridge should be built to narrow the gap to reach some consensus for the BIM-FM practice. (Liu 2012;)

There is a gap between design and facility management professionals regarding the knowledge and technology. Realizing the power of BIM in the facility management phase is the initial step for implementation. After which follows the determination of problems and concerns that affect good performance of facility operations and maintenance activities. (Rui et al 2016) When these problems have been addressed, BIM can then be effectively used as tool for FM. This plan has no outlook in most construction projects in Pakistan which is a major reason that owners are being hesitant on its application. Hence, the need of research and work in this field is necessary in order to put across the benefits and opportunities for the facility management sector. The unavailability of expertise in BIM as well as FM has led to this filed lagging behind in terms of its execution and its funding. Consequently, FM is a field that has been given less importance to

1.3 OBJECTIVES

- To determine the levels of facility management and their implementation.
- To develop a comprehensive 3D model (Architectural, MEP and other parallel systems) of a large complex health facility
- To develop a comprehensive database for Facility Management

Chapter 2

LITERATURE REVIEW

2.1 HISTORY

The term facility management dates back to 1970s emerging in North America. However, not much research was done in to not until the 1980s when FM gained grip in the construction industry. The proper definition of FM is still debatable. Nutt in 2000 defines FM as" the primary function of FM is resource management, at strategic and operational levels of support."(Tay et al. 2001) The IFMA in 2003 describes it as "The practice of coordinating the physical workplace with the people and work of the organization; integrates the principles of business administration, architecture, and the behavioral and engineering sciences" (Azman et al. 2014) Alexander in 2013 defines FM as: "the process by which an organization delivers and sustains support services in a quality environment to meet strategic needs." (Alexandar, 2013) These explanations exemplify that the definition of FM has evolved because of various roles that facility management plays in different parts of the world.

In the past, a manual database of major facilities was kept and updated on a monthly or more regular basis. To perform facility management, one had to use the 2D drawings and the record books. This was a slow, time consuming and vigorous process. Due to this, facility management was given less attention over the years. It remains an unexplored field in most of the countries. It is then right to say that every country having its own culture, type of organization and leadership resulted into different level of development of Facilities Management. Below is a survey conducted on the implementation of facility management in the past years of different countries:

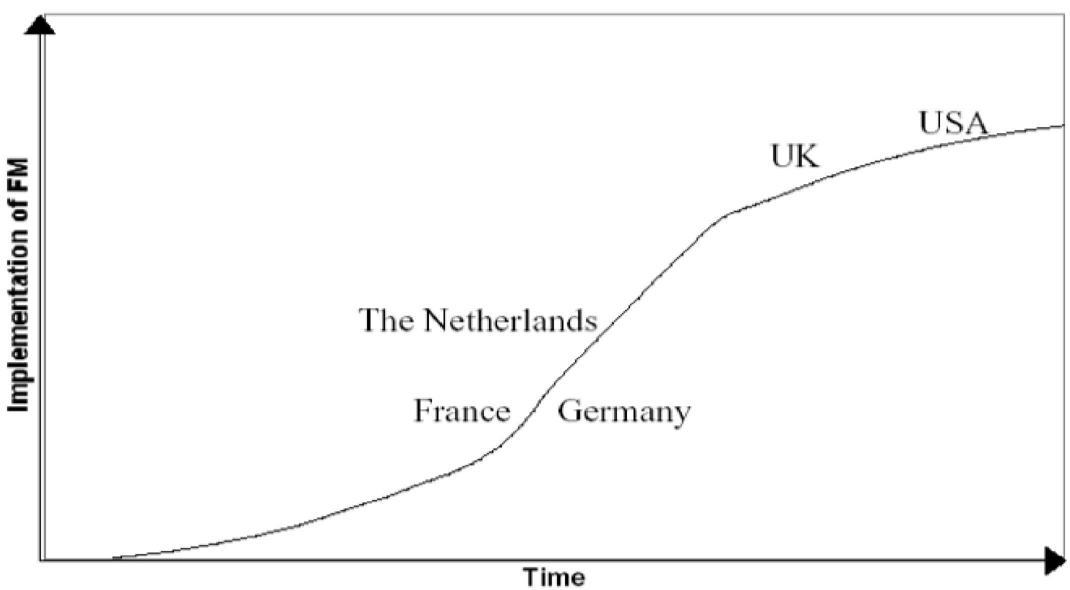

Figure 2.1: Graph showing Implementation of FM in countries

Many countries depending on their cultural and construction background stayed reluctant on the implementation however others implemented FM to its full capacity and took it forward for further research and what it has to offer.

2.2 MODULES OF FACILITY MANAGEMENT

The Facility Management System (FMS) consists of a series of software modules that allow an owner of facility manager to select module based on operational and facility management needs. Modules that may be included are described below:

a) Work Order Management:

A work order module tracks and monitors all service requests. Systems may allow for tenants or occupants to send service requests over a network or the Internet and be automatically notified on the status of the service request.

b) Asset Management:

An asset management module manages all necessary equipment data including names and models, serial numbers, location, vendor, internal cost center, warranties, performance and documentation. The company or organization may have an asset management program that is part of their enterprise resource planning (ERP) which is a business-level software platform.

c) Material and Equipment Parts Management:

A material management system tracks material and equipment parts that are moved into and out of inventory, and that currently reside in inventory. System is typically tied to and integrated with the work order system and purchasing system. The inventory system may have set thresholds for various parts and materials and automatically triggers the reorder and restocking of parts and materials through the purchasing system.

d) Procurement Management:

Procurement management automates and streamlines the procurement process for vendor services and equipment. Contractors are preapproved for specific types of services and equipment. Track contracts, key contract dates and contractor performance. Systems can also automatically requisition materials and equipment based on predetermined maintenance schedules.

2.3 AREAS OF APPLICATION

Facility Management is gaining popularity among many large organizations in recent times. Through proper facilities management you can not only control the operations of the building and cost associated with it but you can also ensure better safety and collaboration of safety professionals with the facilities management staff. The following are the applications of FM:

2.3.1 Locating building components

In order to detect a problem and to solve it, FM personnel need to trace the building components (i.e. equipment, materials and finishes). Traditionally, people have been relying on drawings or expertise to search a facility like Heating Ventilation and Air Conditioning (HVAC), water supply lines etc. in the regions where it's not vivid e.g. behind the walls or beneath the floors. We can use the as built 3D BIM models to navigate through the facilities of the building proficiently and linking them with digital viewing platforms that would increase its utility. This practice would be more effective especially in the case of emergency or when new personnel are hired who are unaware of building components.

2.3.2 Facilitating real time data access

FM staff perform a variety of tasks like replacing worn out items, maintenance of existing facilities etc., this requires access to a huge and diverse amount of data in different models. With the help of BIM, a well-established data base can be created in which all the relevant information can be stored. This not only eases the access to data but also expedites the decision making as well.

2.3.3 Maintainability

Maintainability is defined as Achieving optimum performance throughout the lifespan of facility with the minimum lifecycle cost. (Paper)It basically focuses on accessibility to the facilities provided in unapproachable areas, using sustainable materials and adopting preventive maintenance measures. Hence the 3D BIM models can be used for the maintainability operations by analyzing the actual dimensions, spatial relationships etc.

2.3.4 Creating and updating digital assets

Digital assets include information about equipment (like HVAC, plumbing etc.), information about manufacturers, specifications, operating manuals etc. These digital assets when linked with the facilities management system, operations can be carried out effortlessly. Otherwise you have to manually link all of these data with the database which is a cumbersome task.

2.3.5 Space management

Efficient space management not only enhances the utility of spaces but also has a good impact on the output of workers working in those spaces. Space management involves forecasting space requirement and managing space attributes. For this purpose, BIM can be used to not only identify unutilized spaces but also perform space analysis as well. This particularly helps in dispute resolution and insurance claims as you can visualize what your buildings looked like in yesteryears and how it looks in the present.

2.3.6 Emergency management

Emergency caused in the buildings can be manmade, due to internal disturbances and riots. For active emergency management you need data from diverse sources which must be properly organized. Using BIM, you can have real time access to data. Utilizing this the personnel can recognize the hazard areas efficiently and provide effective solutions for it.

2.3.7 Controlling and Monitoring Energy

In the United States, buildings account for 72% of electricity consumption, 39%of energy use, and 38%of all carbon dioxide (CO2) emissions (U.S. Green Building Council, 2009). Control of energy and its monitoring is another dimension of Facility Management and managers heavily rely on energy management systems. In complex buildings, where components such as diffusers, terminal boxes, thermostats and other heat emitting devices exist, facility managers must take utmost care in controlling the emission of energy.

2.4 INTEGRATION OF BIM IN FM

Although BIM can be handful for FM staff to perform better in FM, it reduces time for updating FM database by 98% (Ding et al.2009). Tremendous amount of data on facilities and components in a building is compiled and entered into the database of Computerized maintenance management system (CMMS). The issue lies of integrating this data for the purposes of facility management. In order to solve the data integration problem between BIM and CMMSs/FMSs, researchers have applied two standards, namely Construction Operations Building Information Exchange (Cobie) and IFC.

Cobie is an information exchange specification for the life-cycle capture and delivery of information needed by facility managers. The Cobie standard helps to improve the handover of asset related data via the BIM models to the facility managers and/or owners of a building. With Cobie standard, stakeholders are able to store maintenance information in BIM in a structured way, and thus in a valuable form of facility documentation (Codinhoto et al., 2013)

In addition, the IFC standard is an object-orientated 3D vendor-neutral BIM data format for geometric and semantic information of building objects. The IFC standard has been used as the generic file format for transferring information from BIM models into CMMSs/FMSs, due to the lack of interoperability between existing CMMSs/FMSs and the growing number of commercially available BIM packages (Becerik-Gerber et al., 2011)

2.5 EFFECTIVENESS OF BIM FOR FACILITY MANAGEMENT

Effective maintenance and management of buildings could significantly reduce costs associated with interoperability of a building. Research and surveys have been carried on implementation of BIM for FM in the Design, Construction and Operation and Management stage.

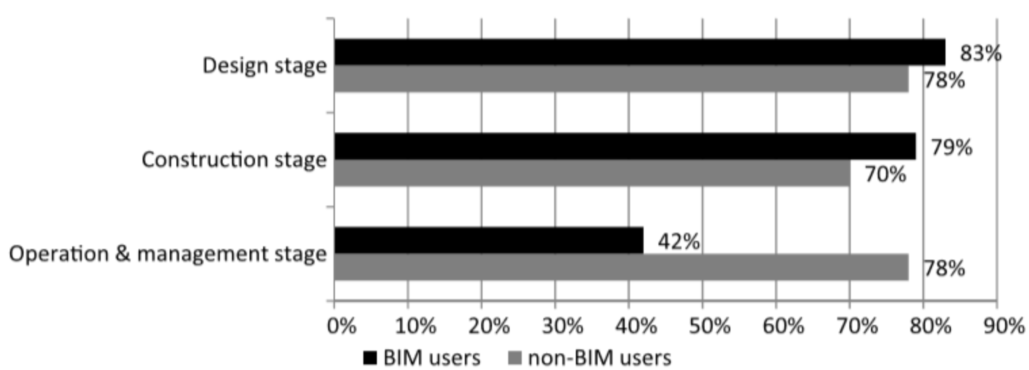

Figure 2.2: Usage of BIM & Non-BIM users at different stages

From the above graph we can notice that BIM is a preferred usually in the design stage and lesser in the later stages of the project. Facility management is part of the operation and maintenance stage and it can be seen that BIM is being used less frequently in that stage.

Furthermore, another study was carried out to see what exactly BIM users use the software for in different application areas. The results are as follows:

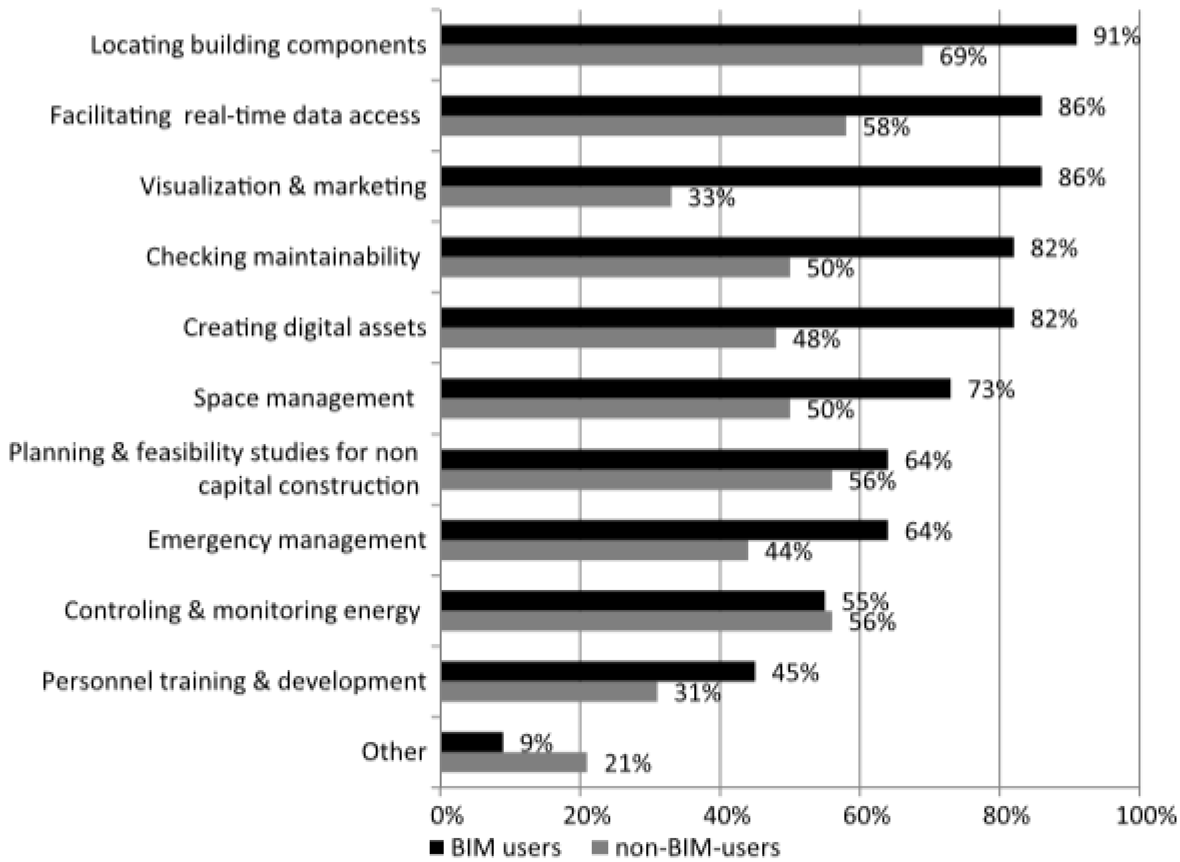

Figure 2.3: BIM & Non-BIM users in different application areas

Application area \ Case study (ID nr)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Mobile localization of building resources							▪		▪	▪
Digital asset with real-time data access	▪	▪	▪	▪	▪	▪	▪	▪	▪	▪
Space management		▪	▪							▪
Renovation/retrofit planning and feasibility studies	▪	▪								▪
Maintainability studies	▪	▪	▪							▪
Energy analysis and control		▪	▪							
Safety/emergency management		▪			▪					

Legend:

(1) Sabol [26]; (2) Aryaici, Onyenobi and Egbu [2]; (3) Neelapala and Lockheed [21]; (4) Codinhoto and Kiviniemi [5]; (5) Wang et al. [31]; (6) Orr et al. [22]; (7) Lin, Su and Chen [12]; (8) Su, Lee and Lin [27]; (9) Costin et al. [6]; (10) Fillingham, Malone and Gulliver [10].

Figure 2.4: BIM and their application areas

From the analysis above, we can notice that not all areas of applications in FM are effectively being discovered by BIM. One can come to conclude that FM is a vast field of area that needs more attention and discovery.

2.6 ROLE OF FACILITY MANAGERS

We have come to discover that facility management is a field that can be considered untouched due to the lack of its implementation fully in the building's maintenance and operations phase. As a facility manager, one should exactly know the quantum and details of his work that include:

1. Identifying the needs for systems integration and its level.
2. Evaluate costs and benefits of various approaches.
3. Present options to decision makers in a way they can understand.
4. Remain part of the integration process during installation.
5. Be involved in commissioning and maintenance of the new systems.

2.7 ROLE OF INFORMATION IN FACILITY MANAGEMENT

Facility Managers thoroughly have to understand and go through every existing component or machinery in a building in order to produce effective decision making while performing maintenance. In order to do so, complete and accurate information is a must. Information for FM includes:

- Accurate as-built models of all building components i.e. architectural, structural, mechanical, electrical, plumbing, and fire protection systems, and site plan including safety accesses among others.
- Accurate as-built model for main utility lines to the buildings;
- Accurate telecommunication representations, including proper placing and annotation of outlets;
- Labeled, annotated, and colored spaces according to FM guidelines, which should include standards for space type, description, space usage, and so on.
- Built-in schedules in the model.
- Logical object tree organization to manage the various components within the model;
- Accurate clearance requirements for mechanical, electrical, and plumbing (MEP)equipment to provide maintainability based on technical specifications

However, from several studies, it can be noted that lack of information and its quality is a major barrier for this aim. Research confirms that poor Information Quality of delivered information causes significant costs and rework for the operation phase. (Puyan et al., 2017) The BIM model will simply display information that you have fed it i.e. it will not specify details that are not provided to it. An example of this can be taken from below:

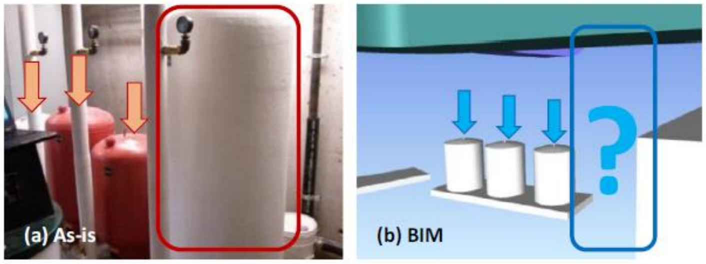

Figure 2.5: Cylinder As-built vs as-modeled

From the photo above, we can notice that in the white expansion tank in the as-is photo is not seen in the BIM model. A possible reason of this could be that the model has incomplete representation of the as-is. Another example could be as below:

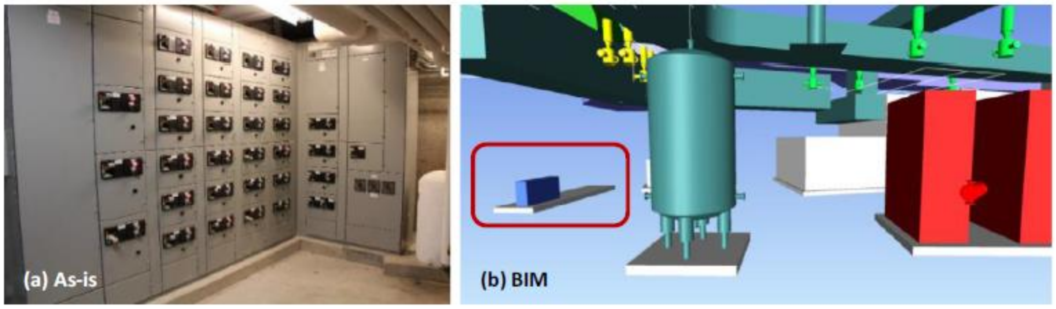

Figure 2.6: Lockers As-built vs as-modeled

From the photo, it is seen that the detailed mechanical room in the as-is is seen simply as a blue box in the BIM model. This could be due to lack of understandability of some model parts. Hence, combining these issues we can categorize the limitations of BIM model in FM as follows.

1. Incompleteness
2. Inaccuracy
3. Redundancy
4. Understandability

In order for the BIM model to work effectively for FM, the data in it should be complete, accurate, understandable and less redundant. This leads us to "Level of Detail (LOD)" of the model or "level of representation" of the reality.

2.8 LEVEL OF DEVELOPMENT of BIM IN FM

In Building Information Modeling, there are 6 levels of details as seen below:

Table 2.1: Level of Development

LOD 100 – Concept Design	The building 3D model is developed to represent the information on basic level. Thereby, only conceptual model creation is possible in this stage. Parameters like area, height, volume, location and orientation are defined

LOD 200 – Schematic Design	General model where elements are modeled with approximate quantities, size, shape, location and orientation. We can also attach non- geometric information to the model elements
LOD 300 – Detailed Design	Accurate modeling and shop drawings where elements are defined with specific assemblies, precise quantity, size, shape, location and orientation. Here too we can attach non-geometric information to the model elements
LOD 350 – Construction Documentation	It includes model detail and element that represent how building elements interface with various systems and other building elements with graphics and written definitions
LOD 400 – Fabrication & Assembly	Model elements are modeled as specific assemblies, with complete fabrication, assembly, and detailing information in addition to precise quantity, size, shape, location and orientation. Non- geometric information to the model elements can also be attached
LOD 500 – As-Built	Elements are modeled as constructed assemblies for Maintenance and operations. In addition to actual and accurate in size, shape, location, quantity, and orientation, non-geometric information is attached to modeled elements

Facility managers would usually need information to the highest level of detail however this is not always the case. Information provided by the architect may not be of any use to the Facility manager e.g. when an architect prepares the model, he would insert a generic geometry like a box to represent an air conditioner which would satisfy his needs but would not be sufficient for the facility manager. FM. users, as the end consumers of the model, thoroughly depend of the quality of modeling done.

Nevertheless, research shows that BIM has not been successfully used in a broader spectrum for the facility maintenance and operation purposes. The main explanation for this outcome is because of the difficulties that the owners have in assessing the quality of the delivered models. (Puyan et al., 2017) Many projects do not involve FM information needs in the project contract and necessities. Hence, one can't expect from one who doesn't have complete information.

Level of detailing then plays a key role for this issue. As built models will include detailing up to the maximum possible level i.e. contextual and intrinsic with dimensions, location, quantity, orientation and other non-dimensional information. We can take an example of the level of detail required for an AHU (Air Handling Unit)

Detail
Required attributes for AHUs: • *Manufacturer, Model, Fan, Capacity L/s, S.P. kPa, Motor kW, Heating Coil, Fin Series, Type, Height mm, Width mm, Rows, Capacity W, Air Entering °C, Air Leaving °C, Air S.P. Drop kPa, Water, L/s, Water entering °C, Water Leaving °C, Water Pressure Drop kPa, Steam Cap. kg/s, Steam Pressure kPa, Cooling Coil, Fin Series, Type, Height mm, Width mm, Rows, Capacity W, Air Entering (°C DB, °C WB), Air Leaving (°C DB, °C WB), Water, L/s, Water Entering °C, Water Leaving °C, Water Pressure Drop kPa, Saturated Suction °C*

Figure 2.7: Allied Properties of Air Handling Unit.

LOD 500- As built is the ultimate requirement as seen from above, with dimensions, location, quantity and other non-dimensional information required for facility managers. It can be seen that is information is vast and when taken to large buildings such as airports or hospital which include complex components and equipment, the amount of data exponentially increases. The data is supposed to be handled and managed for input into the BIM model and for FM which has not been done properly in the previous times.

2.9 FM IN LARGE CONSTRUCTION PROJECTS

The nature of projects is changing with the passage of time. Larger and more complex projects including airports, tunnels, medical centers, railways and others that have an immense number of MEP, equipment, and other components running in them. From research, it has been deduced that only the installation of MEP systems account for 20%-40% of the total construction cost and covers more than 50% of the total duration of the construction process. (Puyan et al., 2017)

Construction of MEP and other facilities includes many collaborative and parallel activities that require smooth communication and cooperation. The cost of operation management of these facilities could cost up to 60% of the total cost of the project. (Zhen-Zhong et al.,

In large construction projects, the LOD must be carefully selected in order to target the specific need of facility management sector. Generally, the facilities management on such a scale includes numerous systems of each sector, say MEP would also include 10 systems or Communications would include 5 systems and more. Each of these systems would then further contain dozens of components and modelling all of these in plentiful detail and integrating it into a single system for visualization of FM is practically impossible. This is where companies consider putting aside what detail is important and what is not. Modelling all the details would stand unnecessary.

It has also been found that in such projects, multiple contractors are involved and thus a deviation in LOD at the micro level could be a problem for facility managers. Hence, keeping all contractors on the same page is a hectic task in order to have identical LOD in all cases.

In a research carried out by Wiet Mazairac and Jakob Beetz, it had been deduced that the total number of all MEP elements in a residential or even high-rise commercial building is normally in the range of 50 thousand to 10 million in LOD 500. When the scale of the project is increased to larger projects, the same can increase to 200 thousand and 50 million. (Mazairac and Beetz, 2013) The quantum of work increases and is a huge burden on the modelling team if LOD 500 is chosen.

It can be certainly said that extracting partial model subsets would be key in effective FM and not vast-scaled FM. A segregation agenda may be followed for such cases. This would mean for important spaces such as surgery rooms in a medical facility, LOD 500 could be implemented, LOD 300 could be used for the communication system on a single floor, LOD 100 could be used for the whole plumbing(pipe) system within the building. This leads to the level of facility management required by the operating body of the building.

2.9.1 Micro Scale FM Models

In the operation and maintenance phase, repairing, regular maintenance and emergency handling would need a high level of detail BIM model as well as information of manuals, historic records and interdependence with other elements. An example of oxygen supply lines in operation theatre's that is linked to many other lines such as the electrical and the communications line. The information on interdependence of these together would be a requirement to perform any emergency in the case of oxygen breakdown. LOD 500 would be handy since it would give information on location, orientation and mainly non-geometric aspects that would allow facility managers to extract and diagnose the solution to the problem. A breakdown in the oxygen level could be a cause of another breakdown downstream in the electrical lines. Hence, as-builts models should start the practice of establishing logic chains to enrich information in micro-scale FM models.

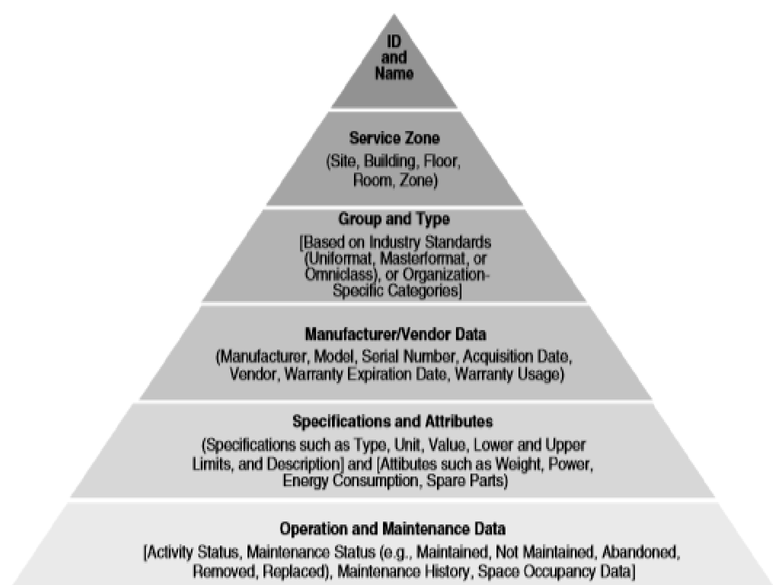

Figure 2.8: Non-geometric Properties

2.9.2 Macro Scale FM Models

In cases of routine checks and maintenance, one would not require a large set data for analysis. Hence, FM in this aspect would be restricted to a relatively lower LOD. A facility manager would choose to use LOD 300 in those sections of the building which require routine checks for example, relationships among rooms, corridors and accesses or electric and water supply systems. LOD 300 would focus more on the spatial, quantifiable and some non-geometric information for the facilities. The shop drawings in this case could be used. In Macro scale modelling, the integration of Geographic Information System (GIS) could be convenient supporting visualization of the supply chain process and emergency response. "*It is believed that BIM is used in a relatively micro level of the world while GIS on the other hand is used in a macro level.*"

Figure 2.9: Different Levels of Detail

2.10 IMPLICATIONS AND CHALLENGES OF FM

There is no clear distinction in defining the roles that who is going to maintain the database and maintaining it. Diversity in BIM and FM software tools, and interoperability issues leads to a lot of confusion and hence multiple stakeholders are working in this field. Another aspect is the lack of effective collaboration between project stakeholders, in most of the projects' design phase, facilities managers input isn't incorporated. The developing world isn't welcoming the new ideas and changes rather they are adapting to the older set patterns. In addition, the barriers in the investment in building the technical capabilities and creating human resource who have expertise in the usage of modern tools. The developed world is also missing legal framework to incorporate BIM in construction rules.

2.11 FUTURE PROESPECTS OF BIM in FM

Facility management is diverse and one can go to utmost depths of it. Such future implications possible in FM could be:

1. Gaming – BIM can be used for virtual training of operation and maintenance of personnel for testing understandability of facilities.
2. Equipment fault detection and diagnosis (Golabchi et al. 2016).
3. Augmented Reality – BIM can be connected with AR to provide overlaid geometric representation on the physical space.
4. BIM can be used in conjunction with fire safety sensors, hazardous management and Information technology (IT) management

2.11.1 Maintenance Work Order Schedule (MWO)

MWO scheduling is a new, innovative methodology that could be applied for facility management. MWO refers to the scheduling of a series of maintenance tasks to fulfil certain requirements (Weiwei et al., 2018). It involves two steps namely; prioritization and scheduling. A successful work order schedule comprises of a framework that would include integration of BIM and CMMS/FMS. This framework would automatically generate schedule for facility maintenance work orders. The stages contain:

1. Data integration – as-built model would have facility maintenance information who data is integrated between BIM and CMMS/FMS using IFC extension and Cobie
2. Failure Identification- Failure components are identified in the BIM model for visualization.
3. BIM-based sub-optimal maintenance path planning - This would involve a sub-optimal path between any two locations in the 3D BIM model
4. BIM-based automatic work order scheduling algorithm–the shortest path to the facility is then found

Chapter 3

METHODOLOGY

3.1 TOPIC SELECTION

The topic for our final year project is Facility Management using Building Information Modeling. This topic addresses the urgent need for facility management of a building of today's nature. It has clearly been understood how important the maintenance and operations phase are in the lifecycle of the building. The industry offers several new software for facility management that would enhance this process.

3.2CASE STUDY

Hospitals are the busiest of buildings, and no hospital could aid its true purpose to 'serve the humanity' unless it is equipped with imperative facilities like Medical supply lines, Air Conditioning to maintain a comfortable milieu, Medical: MRI, X-Ray machines etc. Facilities need to be managed because depreciation/ malfunction is the associated property of it. Other factors also include the 24/7 operational capacity of hospitals that don't permit interruption for normal day-to-day activities at the unimaginable cost of 'patient's discomfort'.

To implement the required objectives on pragmatic scale, Jinnah Post Graduate Medical Center was chosen as the principal site of the project. JPMC is the biggest Public Sector hospital facility of Sindh, Pakistan. Patient-Aid foundation in collaboration with Government of Sindh was constructing an eight floor Hospital complex. National Engineering services of Pakistan was serving as the consultant of the project. NESPAK is implementing Building information modelling in its design process. One step forward in the utility of BIM for facilities management besides closing the BIM of the particular project after its completion, and become the part of the archive, BIM is beyond that. Post completion analysis is an important component of BIM so that, Dos and Don'ts of project can be analyzed. New (Out-Patient Department) OPD and Surgical block was selected as the site for executing our final year project for obtaining required objectives.

3.3 LITERATURE REVIEW

After thorough and a vigorous process of reading and analyzing research papers and books, it was found that facility management has a lot to offer but is not yet being fully implemented by authorities. The technique of FM is not much popular in the industry, yet its need is increasing exponentially for the purpose of implementation of BIM and FM. This was a newly constructed building and hence all data required and assistance was provided by the firm.

3.4 DATA COLLECTION

The project was awarded to Construction Engineering and Management CEM department at NUST by NESPAK Islamabad, to dig deep into the utility of the BIM as the pilot project for the students of NUST Institute of Civil engineering. NESPAK House Islamabad, NESPAK Architectural division Karachi bridged the commination gap and the 2D design drawings were provided as soft copy (.dwg) files of architectural, structural and other systems were retrieved from

NESPAK. Further queries were noted in notepad and these queries were addressed in our four-day trip to the project site.

3.5 DESCRIPTION

The development of a BIM for Jinnah Post Graduate Medical Center (JPMC) Karachi required a different approach that could be expected from the BIM process of a new construction. The building was already constructed through traditional project delivery method with traditional practices in place. The hospital complex included Surgical and Out Door Patient (OPD) complex, where treatment of more than seven hundred outdoor patients in different departments of OPD was planned. Facilities management of such a busy hospital complex requires some innovative practices where BIM could be implemented to visualize the MEP and Medical gas supply lines in order to see behind and inside the wall. This would help to avoid the cumbersome, inefficient practice of traditional facilities management practices.
National Engineering Services of Pakistan is executing the responsibilities of the consultant for the project; besides Patient Aid foundation- the partner client of Government of Sindh. The design drawings were obtained by contacting Architectural division of NESPAK Karachi.

The process was impeded due to several challenges, the commination barriers between our group, Site team and mainly the consultant. To overcome the communication barriers and understanding the in-depth insights of the executed facility, our group paid four days visit to the hospital facility and NESPAK Architectural division Karachi. The client and Consultant were welcoming to address our issues and boosted us technically by highlighting the importance of the project. Site execution engineers and technicians briefed us about the complex and handled our questions patiently.

3.6 MAKING OF THE MODEL

The 3D model was developed using Autodesk Revit 2017. The model was developed as per the as-built drawings provided to us by NESPAK. After the full completion of the model, a database for the components and facilities was made.

The following is a brief overview, in chronological order to develop LOD 400 BIM model leading to facilities management of the Jinnah Post Graduate Medical Center, Karachi.

- Development of generic Architectural model.
- Creation of Customized Revit families.
- Development of MEP Models including HVAC and plumbing models.
- Creating the central data base of Hospital facilities and then linking the BIM for tabulating the database of the facilities of the hospital.

3.6.1 Architectural Model

3.6.1.1 Revit Families

Families in Revit are components that are needed to create a model. They include doors, windows, stairs, walls, floors, etc. A family can have many variations. They can have differences in size, building materials or other parameters. A change made to a certain family type is updated throughout the project where ever that type may have been used.

For instance, if we change the wall thickness of a wall type, all the walls with that wall type are changed automatically.
Revit provides a wide range of default families. In most cases, these families are not enough to develop a detailed Revit model. We can create our own families by the following methods:

- Edit an existing family according to our needs.
- Create a new library from scratch by choosing any of the family templates Revit provides.
- Download families online from different resources.

In our model, most of the default families were edited to suit our modeling needs e.g. walls, windows, doors, stairs, etc.
Some families were downloaded from online resources such as 'Autodesk Seek' and 'Revitcity'.

3.6.1.2 Grid Establishment:

The first task to make the model was to establish a grid, in the bounds of which the building was to be completed. The vertical lines of the grid were named in alphabetic order and the horizontal in numeric order. The horizontal and vertical lines of the grid would intersect each other at the point of any column in most of the cases and at the extreme boundary points in other. The advantage of making the grid at the start of the model was that there was no use of scale afterwards. The grid lines effectively determined the boundaries of rooms etc.

3.6.1.3 Floor Levels

The heights of the floors were accordingly incorporated in the parametric model. These floor levels were used as a base for importing the CAD files onto them.

3.6.1.4 Importing CAD files

NESPAK provided 2D files were imported to serve as the drafting pad for 3D modelling process.

3.6.1.5 Placement of columns

First and foremost, architectural columns were placed on the intersection of all grids. The columns were connected to the upper corresponding level for the Basement level, Ground level and Mezzanine. The columns from first to six were similar and hence they connected directly from the first level to sixth.

3.6.1.6 Placement of walls

The walls were sketched as per the underlay of the AutoCAD drawing. First the outer walls were sketched and then walls that divide rooms and spaces were made. One most important point to note during placement of walls was to enable all rooms to have a separate space and two room don't coincide with each other. This was done in order to avoid Room Tagging issues later on.

3.6.1.7 Modelling Ramps and Stairs

The ramps and stairs were a challenge to build as the dimensioning of each of them was not consistent between the as-built and tender drawings. The ramps were built with the command of floor and then by modifying the sub-element, the elevation of the ramp was adjusted. Similarly, stairs were built with the simple command of stairs in Revit. Having completed this, railing was attached to the ramps and stairs.

3.6.1.8 Placement of Slab and floors

Slabs in Revit are simple and easy to make with the command of floor. The boundary of the slab was defined and then loop is completed for a single floor. Despite floors 2 to 4 being similar, there were minor changes in slab boundaries and hence all floors were placed separately.

3.6.1.9 Placement of Architectural components

Doors, windows and ventilators were the next elements to be added. They require wall hosts and are easy to place through and drag. Windows were added with a default sill height of 3 feet and ventilators were added with a default sill height of 7 feet.

3.6.2 MEP Model

Jinnah Post Graduate Medical Center Karachi boasts of very complex; state of the art and modern MEP systems. This is largely due to the fact that this facility is built for high quality cancer treatment and cyber knife treatment which required well organized but complex systems. The systems consist of all the latest components outsourced from abroad. Our concentration was on the modeling of Plumbing, Electrical and HVAC Model. The general procedure followed was linking the already developed architectural model file with the new template for the respective MEP models. The purpose of linking the architectural model with the MEP models is to provide reference for modeling of MEP elements.

3.6.2.1 HVAC Model

Since HVAC system falls in the realm of Mechanical engineers, difficulty was faced in understanding of HVAC drawings as well as process of design and placement of HVAC systems. Therefore, help was taken from experts in HVAC and also a site visit aided us in understanding the situation. After understanding of the drawings Autodesk Revit 2017 and Mechanical Template was used.

3.6.2.1.1Fixtures

The first and fore most thing that was performed in HVAC modeling is placement of all the HVAC fixtures on all the levels. Generic fixtures were placed. Main fixtures are Diffusers, Exhaust fans, Air Handling Units (AHU's), Air Conditioners, Fan Coil Units and Heat Pumps. This was done in order to enable us join the ducts and pipes with ease.

3.6.2.1.2 Duct Layout

The next step was to design the ducts as stated in the drawings. The ducts were drawn according to scale with the help of AutoCAD files.

The building had four functioning ducts.

1) Supply Air Duct
2) Return Air Duct
3) Exhaust Air Duct

The ducts were generally modelled at an offset of 13 feet. However, in case of all clashes between two ducts, the respective elevation of the duct was reduced to 11.5 feet. The sizes of the ducts were followed as provided.

3.6.2.1.3 Connections

The step consists of the connections of the ducts with their respective air terminals or AHU's. We connected the supply air ducts with the help of flex duct to supply air terminals and return air ducts to return diffusers and vice versa. The reason behind different connection was difficult to sort out at first but then we realized that if the distance between duct system and diffusers are too low then direct connection of duct cannot be happened because of the very short angle so in that case flex duct was being used.

3.6.2.1.4 Vertical Ducts

The ducts had to be connected to the AHU's placed on the first and roof floor. This was done with the help of cutting cross sections and using the elevation views. This was a hard task since it involved changing views for every instance and hence had to be done carefully.

3.6.2.1.5 Air Conditioning Pipes

The AC pipes included 2 RD and RS pipes as well as a single chilled water pipe. The RD/ RS pipes were connected at the front of the AC and were placed at an elevation of 11 feet. The Chilled water pipe was connected at the back side of the AC also with an elevation of 11 feet. The pipes had to be placed exactly in front of the AC openings in order to avoid angle failures by Revit.

3.6.2.2 Plumbing Model

A separate Revit file was used for plumbing model. Mechanical Template was assigned to it. This is due to the fact that our plumbing drawings had some mechanical components that needed to be modeled.

3.6.2.2.1 Fixtures

Plumbing fixtures included Sinks, Water closets, Flush tanks, Commode, Water Heaters, taps, Manholes and Geysers.

3.6.2.2.2 Piping Systems

The plumbing model generally involved 3 Water systems:

- Sanitary system:

This system includes of two pipes namely, Waste Pipe and Soil Pipe. The Soil Pipe was connected to the outlet of the Water closets and Flush Toilets. The Soil pipe was connected to the outlet of the sinks.

- Water Supply system:

This system includes of two pipes namely, Hot Water Supply Pipe and Cold-Water Supply Pipe. The hot water pipe was connected to the Geyser and then to the respective Sink. The cold-water pipe was connected directly to the sinks.

- Treatment Water System

This included of the treated water pipe. This pipe was connected to the taps which existed in patient ward areas and surgery rooms.

Their Material and appearance in drawing i.e. color and line pattern were assigned in their respective Type properties. Afterwards for each piping system Mechanical Settings were changed i.e. Pipe Type and their respective offset from the base of the level they are placed in.

The whole system started from Water tanks placed at the roof and led to the manholes placed at the ground.

3.6.2.3 Electrical Model

For this model, electrical template was used to further facilitate the modeling process.

3.6.2.3.1 Fixtures

Electrical Fixtures include ceiling fans, recess lights, switches, receptacles, distribution boards, main boards and others. The first and foremost step was the placement of ceiling fans and recess lights. This was then followed by the individual placement of switches and receptacles in every room. Since some rooms contained Building Health Units (BHU), receptacles had to be provided. Care had to be taken on the elevation of the switches.

3.6.2.3.2 Power Plan

Each floor was provided with a power plan which shows how the power is distributed among each room and then further to the main boards. In Revit, wiring of any kind is not shown due to the fact that the scale is relatively small. The lights and fans were first attached the switches which were then further attached to the distribution systems.

3.6.2.3.3 Distribution

Every floor consisted of a distribution room which contained the distribution boards, main boards and other distribution components. From these boards rise the vertical conduits which lead to the cable trays. The cable trays then distribute this heavy wiring and conduiting to respective rooms including the BHU.

3.7DATABASE GENERATION FOR FACILITY MANAGEMENT:

3.7.1 Adding Information

After having developed the MEP models, the major task was to attach information to allied components that would be effectively used by a facility manager. In order to do so, catalogues and information were retrieved from NESPAK and after site visit to Jinnah Post graduate Center, Surgical Ward, Karachi. This information was compiled and inserted for every component existing in the MEP models. Relevant and sufficient information had to be added in order to achieve the highest Level of Development (LOD) possible to facilitate the facility management effort.

3.7.2 Database

Revit 2017 offers an option of scheduling quantities. This option enables us to select the desired associated parameters of every component and extract them to single sheet known as a database. This sheet also includes the room ID, name and level on which each component exists. The data was then exported to excel. This was done in order to present the complex information in a more vivid and easy to use software for a leigh man facility manager.

3.8 ANALYSIS

The suitability of this database had to be justified. In order to do so, we conducted surveys and interviews with four hospitals within the region of Islamabad namely;

- Shifa International Hospital
- Quaid-e-Azam International Hospital
- Pakistan Institute of Medical Sciences (PIMS) Hospital
- Khan Research Laboratories (KRL)

The above-mentioned hospitals were interviewed and were asked to analyze our proposed solution to facility management. The questions are attached in appendix A. The analysis was done according to four defined parameters that are believed to justify the suitability of facility management process. These parameters include:

- Integration
- Quality
- Time
- Cost

3.9 FINAL REPORT

After all the process of modeling and its analysis carried out, a detailed report was generated which states in detail about what the project was all about. The literature review about FM is shared clarifying about the various misconceptions of FM and why it is important to consider FM in the earlier stage of the construction process. The report also contains the step wise process of how the project was carried out and how the work flow had been. At the end of the report the case study of Jinnah Post Graduate Medical Center, Surgical Ward was discussed giving information about the preparation of modeling and applications of tools of BIM in the real-life project and all the difficulties faced during the work flow of the project.

3.10 RESULT AND CONCLUSION

The results and information obtained from the applications of the tools of BIM were found. A comprehensive study about the applications has been given at the end of the report and comparison has been made between traditional and BIM techniques for FM.

3.11FLOW CHART OF THE PROJECT

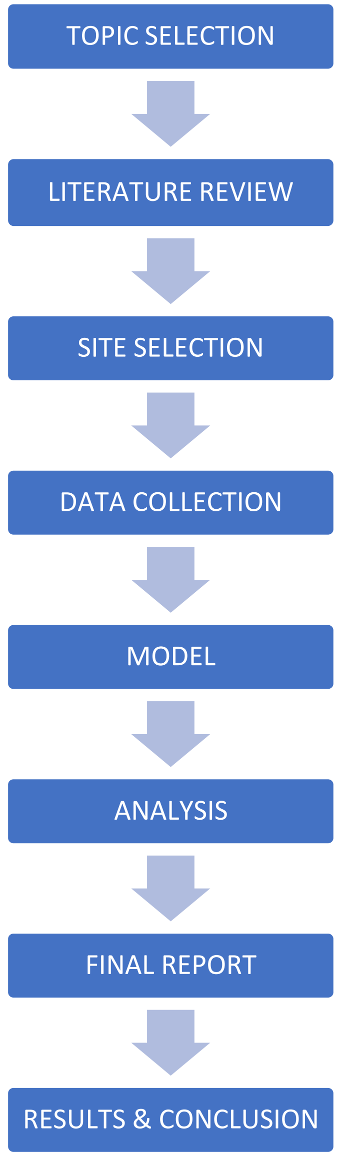

Figure 3.1: Flowchart for the Project

Chapter 4

RESULTS AND ANALYSIS

4.1 INTRODUCTION

The purpose of this project was to develop a comprehensive database for facility management and analyze on its suitability. Furthermore, the implementation of facility management using BIM had to be examined and justified. Architectural, HVAC, Plumbing and Electrical models were developed for Jinnah Post-graduate Medical Center, Surgical Ward, Karachi which is a 178392 feet squared facility with 9 floors; Basement, Ground, Mezzanine and 6 floors. These models served as a pre-requisite for the database with facility management information. This chapter includes the results of the case study which are:

- Model Views, problems and solutions:
  - Architectural
  - HVAC
  - Plumbing
  - Electrical
- HVAC schedules:
  - Air Terminals
  - Mechanical Equipment
- Plumbing Schedules
- Electrical Schedules:
  - Lighting Fixtures
  - Lighting Devices
  - Electrical Equipment
  - Electrical Fixtures
- Surveys retrieved from hospitals

4.2 ARCHITECTURAL MODEL

Jinnah Post-graduate Medical Center, Surgical Ward, a state-of-the-art design was a large in itself a complex but unique building. This building contained of two main entrances. The South entrance was the Surgical Ward entrance as shown in Figure 4.1. This entrance granted access to floor 1 to 6 and was only for patients for surgeries.

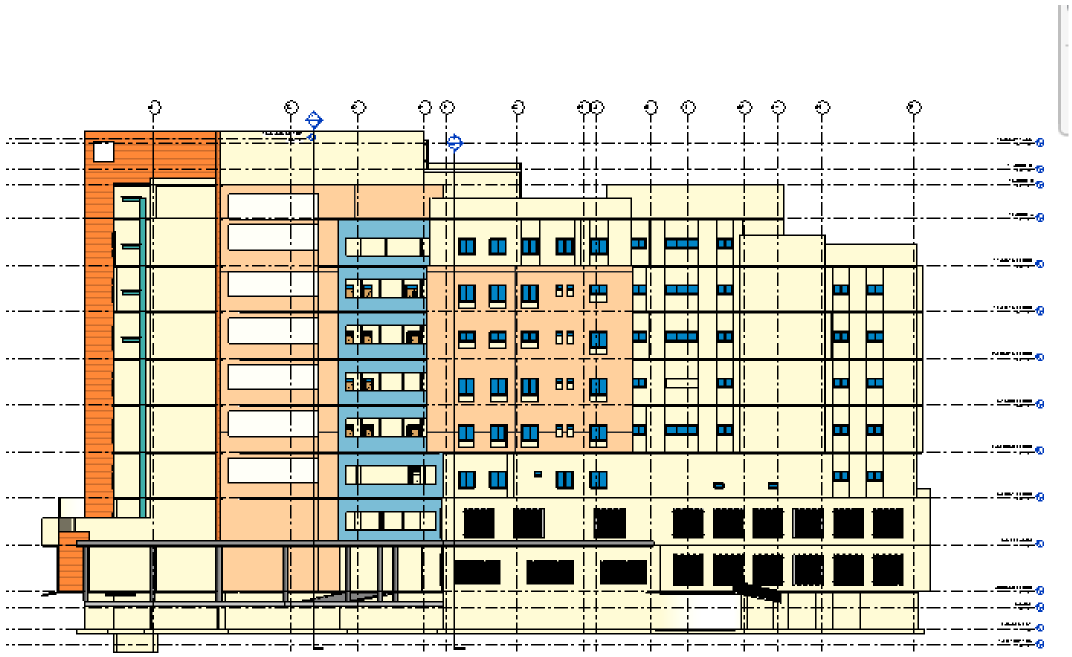

Figure 4.1: South Elevation (Surgical Ward Entrance)

The other entrance at the South side was the Out-Patient Department (OPD) entrance. This entrance granted access of patients to the Ground and Mezzanine floors as shown in Figure 4.2

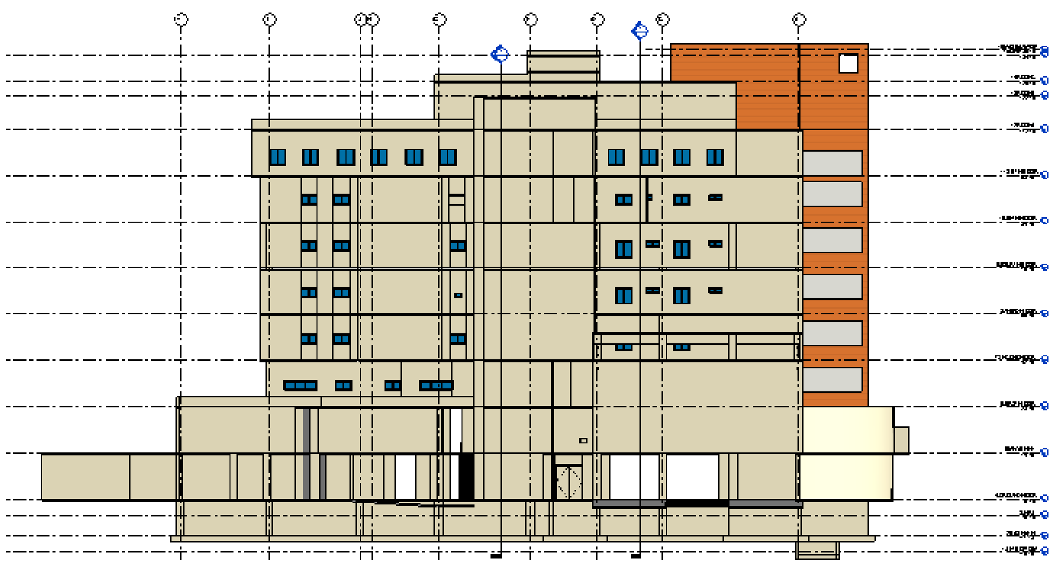

Figure 4.2 North Elevation (OPD Entrance)

The other two figures below show the East and West Elevation.

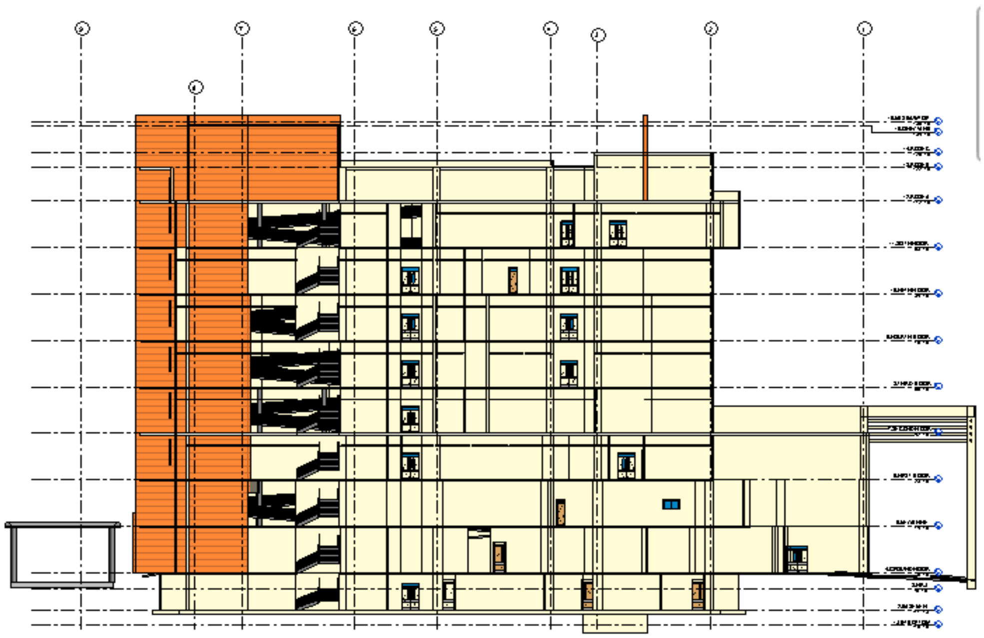

Figure 4.3: East Elevation

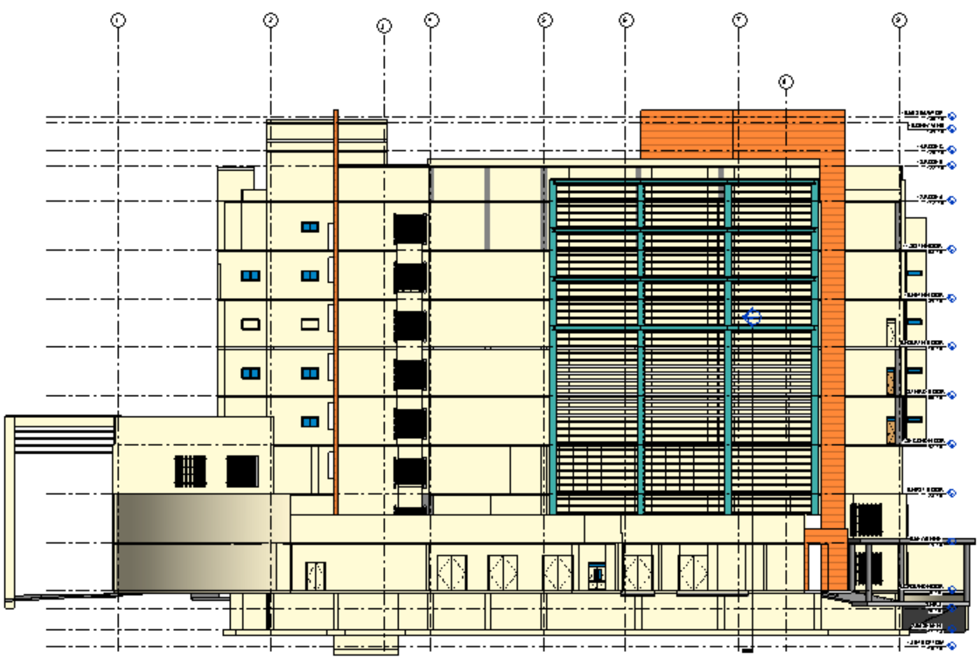

Figure 4.4: West Elevation

The following are some of the cross-sections of the model.

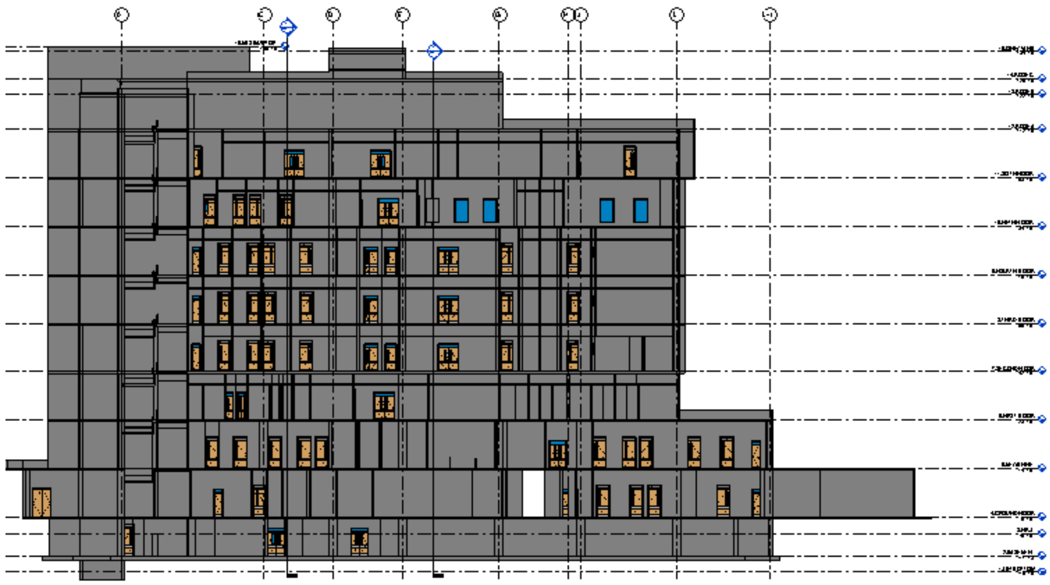

Figure 4.5: Cross-Section 1

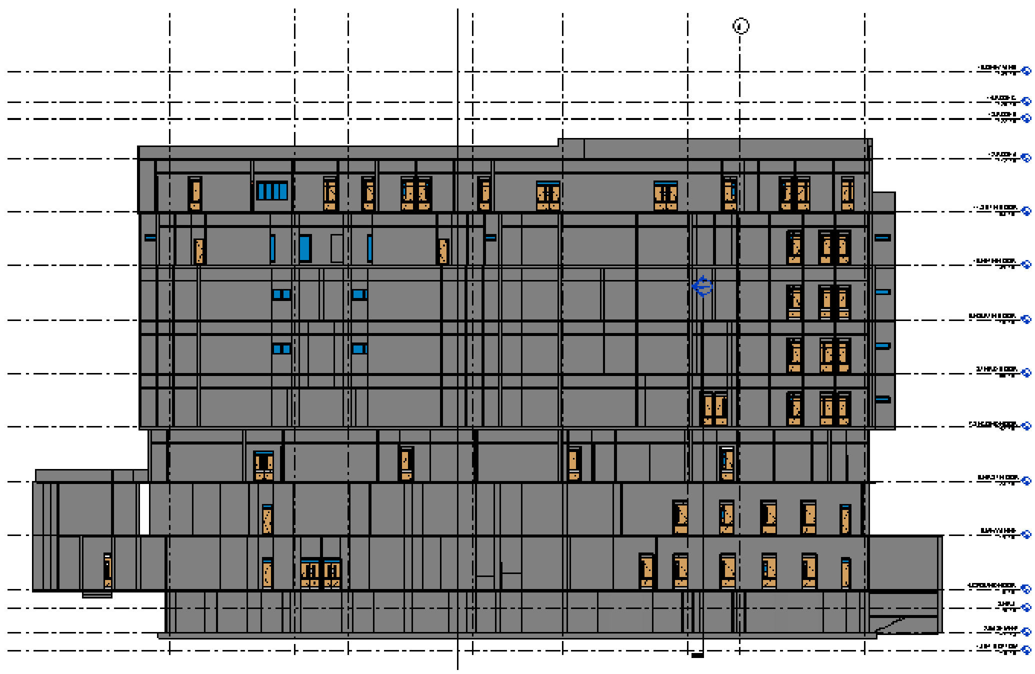

Figure 4.6 Cross-Section 2

4.2.1 Problems in Architectural Model

Misalignment of several architectural features led to many problems. First of all, misalignment caused further inaccuracies of wall placement and also doors and windows placement. The only cause of misalignment was the provision of different sets of drawings. The drawings received for ground and mezzanine floors were as-built, however the drawings received for the rest of the building floors were tender. There had been several changes both eliminations and additions to the drawings which caused such errors in the model. One of the errors is shown in figure 4.7 where it is vivid that the mezzanine columns do not coincide within the axis of the first-floor columns. This would further lead to inaccuracies in modeling of the ramp which is supported next to these columns.

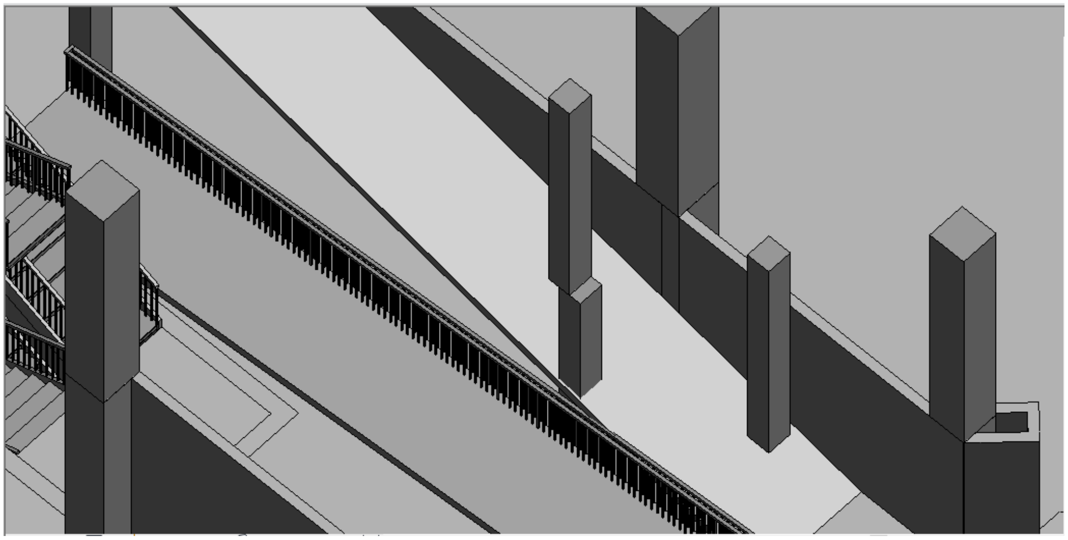

Figure 4.7: Misalignment of Columns

The solution to this was to extend the columns erecting from the ground and mezzanine floor which were modelled according to as-built drawings up to the floors above. Hence, this would eliminate any chances of awkward hanging columns and further eradicate inaccuracies of other modelled features. Figure 4.8 shows the solution to this problem.

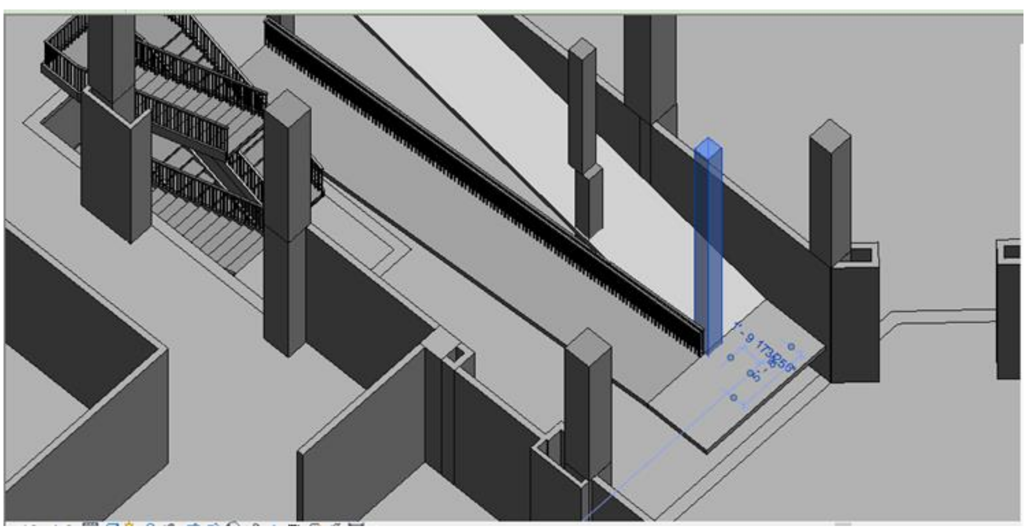

Figure 4.8: After Adjustment of Columns

Some of the components represented in the drawings were not consistent with other information provided to us. For example, some doors like Door D5a, D6a and D6b were illustrated on the drawings however these doors were not present in the schedule of openings provided. For such problems, we adjusted the doors to their general category and most of the doubts were cleared by site visits.

Furthermore, drawings when provided with at most details yields best results. In order to develop a detailed and well-established 3D model, specifics in drawings should be available. This was not the case. In AutoCAD drawings, usually, some sections have sperate call-outs. These callouts are a separate sub-set drawing that describe that particular section in further details. In figure 4.9, it can be seen that a symbol for the callout section of stairs is shown. However, this call-out drawing was not provided to us. We had to use our basic understanding and knowledge to introduce the detailing for such sections.

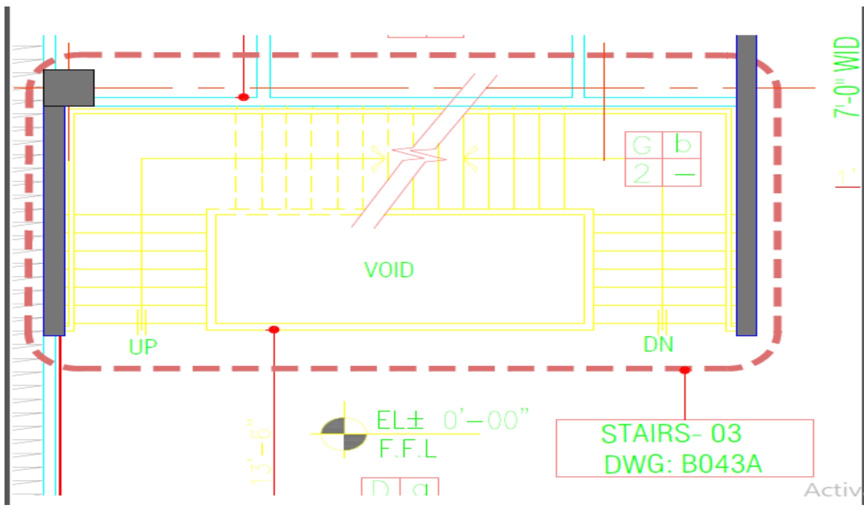

Figure 4.9: Callout for Stairs

Revit software includes of several in-built families of various architectural components. However, these components are in a generic form. To be specific and exact with the details of components provided to us, we had to download several families from the internet and modify. This was especially a huge task to accomplish as every single component had to be modified in one way or another in order to meet the model requirements.

4.3 HVAC MODEL

Jinnah Post-graduate Medical Center consisted of a composite HVAC system. This is due to the fact that the nature and purpose of this building yielded complex ducts and heavily powered Air Handling Units. The major portion of the duct system was laid out on the first, fifth and sixth floor. The main reason supporting this is that the critical Surgical Wards and Rooms were designed to be on these floors. The Air Conditioning system was placed in those areas that bared the professor rooms and offices. Below are some views of the HVAC model:

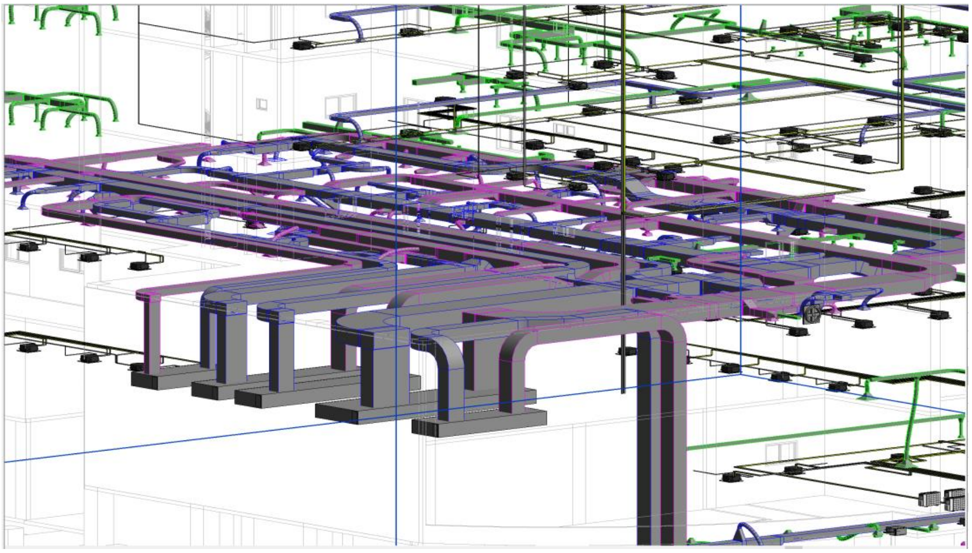

Figure 4.10: First Floor Duct System

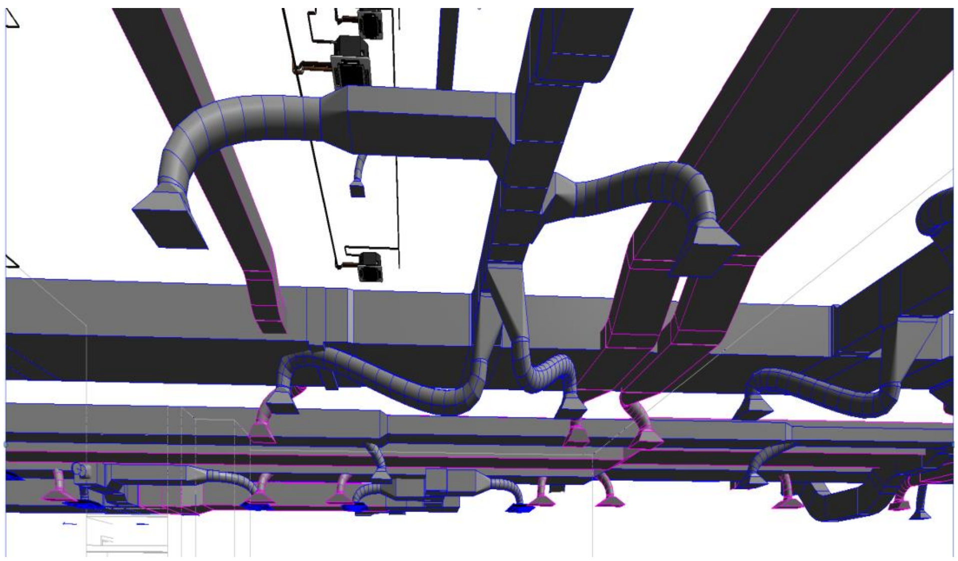

Figure 4.11: First Floor flex Ducts

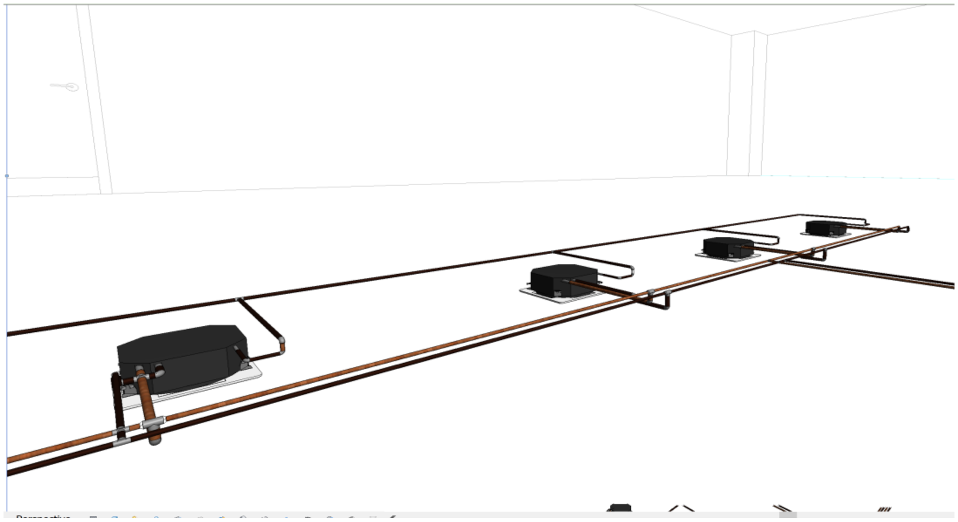

Figure 4.12: First Floor AC system

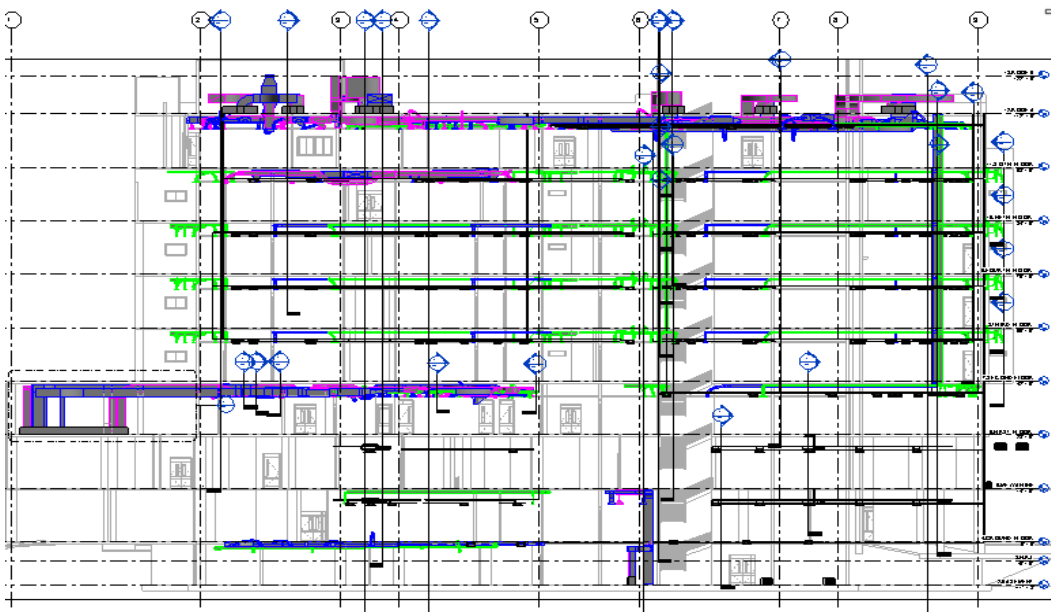

Figure 4.13: Cross-Sectional View of HVAC Model

4.3.1 Problems faced in HVAC Model

The first and foremost problem that we faced was the understanding of drawings. Since HVAC trade lies in the jurisdiction of a mechanical engineer. It was difficult for us to interpret the labelling and the system as a whole. Help was taken from specialist engineers for better understanding and clarification. This problem can be considered important due to the fact that without understanding of drawings, a well-defined methodology for development of this model would not be possible.

The other issue that we faced during our modelling process of HVAC was the visualization of the ducts. This scale of this facility made it prone to a heavy duct system. This meant that the magnitude in terms of size of every designed component of the HVAC system increased.

The drawings that were received represented large ducts with only a single line. As shown in Figure 4.14, ducts the size of 34" by 18", 30" by 18", 30" by 20" and other larger ducts are denoted with thin lines that give no justification to their actual size. The problem arisen here was how to adjust them in Revit where their actual dimensions have to be used for modelling. As shown in figure 4.15, these large ducts when incorporated in Revit often caused clashes amongst one another.

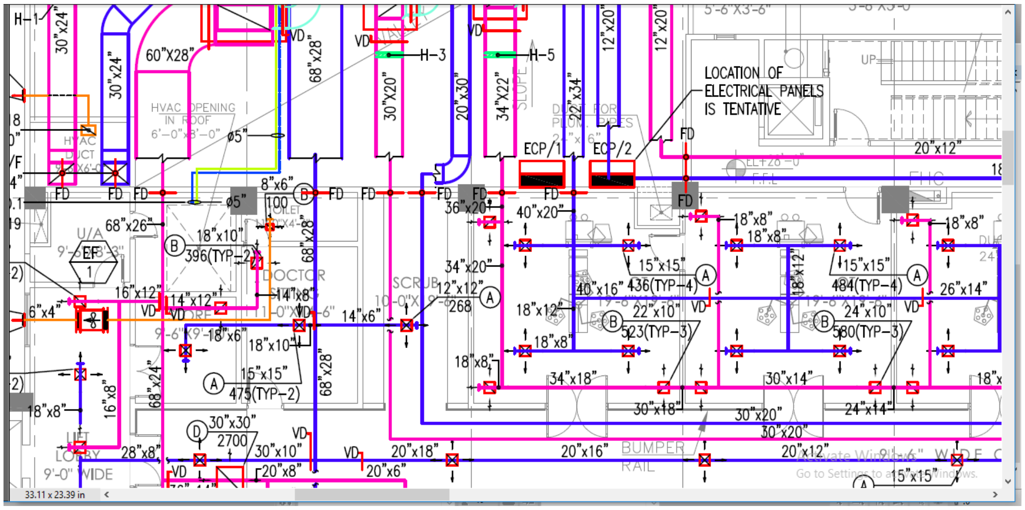

Figure 4.14: HVAC Drawings

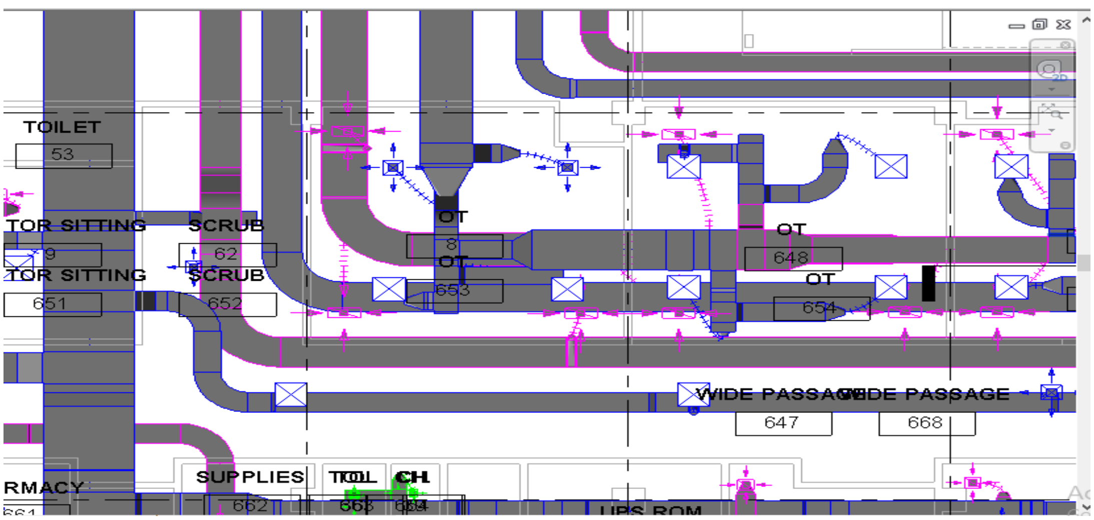

Figure 4.15: Revit Model for HVAC ducts

On site implementation of this system would also be practically impossible as the structure of the building would not allow easy of adjusting of these ducts. During the site visit, this very issue was clearly vivid. Engineers would not be able to effectively adjust or bend ducts as smoothly and effortlessly as it may have been with the case of modelling. Manufactured ducts have pre-defined bends which is a limitation for the execution of this HVAC system

Furthermore, the ceiling height of this building was 4 feet which meant that all parallel building systems had to be squeezed through this space. This space was to cater for HVAC, Electrical, Fire systems, CCTV and Medical Gas supply systems. As mentioned earlier that the scale of ducts was large and hence if any corresponding duct had to be bent beneath another to avoid any clash, it would be exceeding the 4 feet ceiling height hence penetrating below the ceiling. Below in Figure 4.16 is a depiction of this.

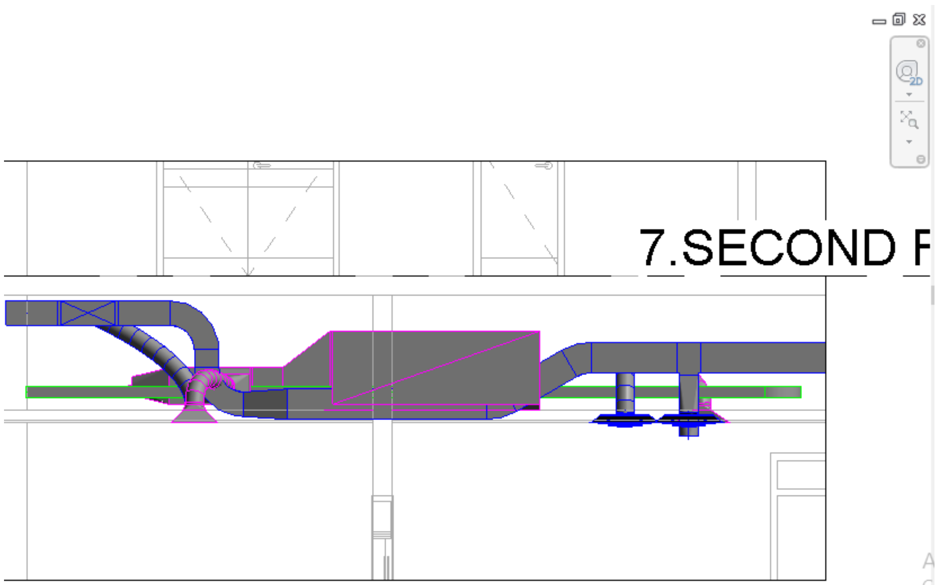

Figure 4.16: Bending Ducts

A simple methodology was devised to counter the above-mentioned problems. For the magnitude of the ducts, the ducts were adjusted by both space and elevation. By varying the elevation of which these ducts exist on, we were able to eliminate possible chances of clashes.

In addition to that, the drawings provided some empty space which could be utilized for adjustments of these ducts. Space area and distances were calculated and these ducts were dragged to their new positions.

For bending ducts beneath one another, the only solution was to modify the elevation of the immediate above placed duct to its maximum ceiling height which would allow the direction of the duct to be bend easily.

4.4 PLUMBING MODEL

Bearing in mind the purpose of this building, the plumbing was design in such a way that every floor consisted of approximately two main public washroom area, one washroom area for the staff and other individual washrooms. In figure 4.17, a public washroom area can be seen. In figure 4.18, a treatment water system is vivid which is found in the surgical wards areas for the hygiene of patients. Figure 4.19, shows the manholes where the sewage system ends.

Figure 4.17: Public Washroom

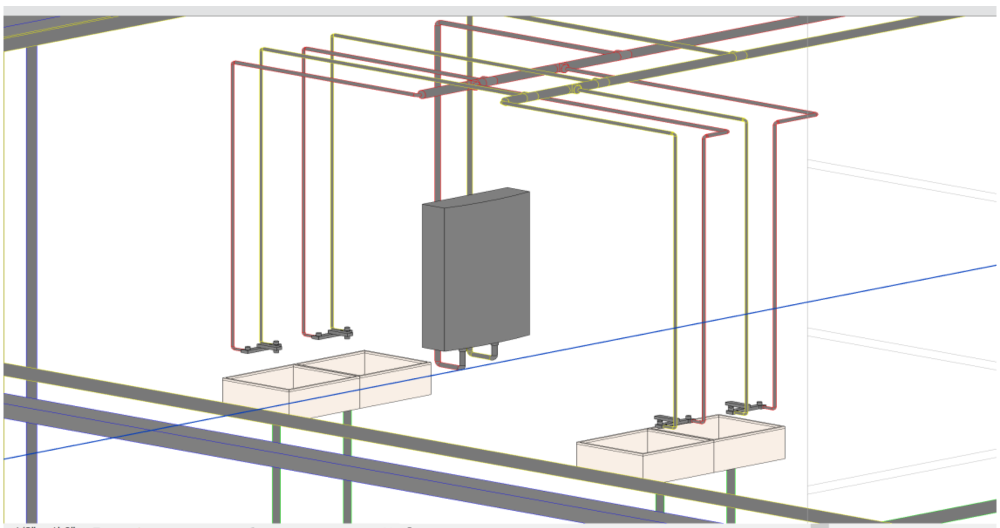

Figure 4.18a: Treatment Water System

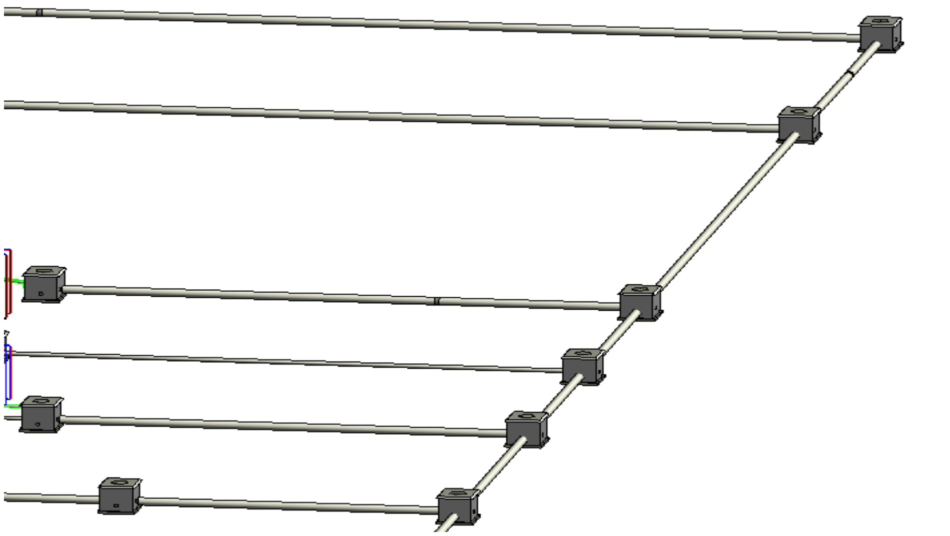

Figure 4.18b: Manhole System

4.4.1 Problems faced in the Plumbing model

To begin with, on-site implementation of plumbing system in the construction industry is often not in total accordance with the drawings. This is because, plumbing systems can easily be altered within space at sites. The issue here was that this was not possible to do in Revit. Due to lack of knowledge of how to alter or adjust pipe inlets and outlets and their directions, it was difficult for us to model it. As you can see in figure 4.19, there is a continuity line showing that the pipes are further joined to main pipes according to site restrictions or allowances.

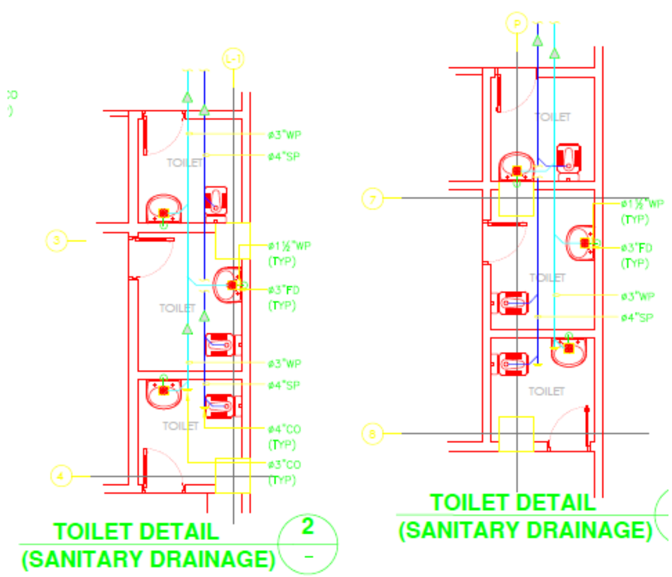

Figure 4.19: Toilet Details showing Continuity lines

Furthermore, the plumbing system is a complex design whereby the slope of each pipe has to be carefully designed in order to allow easy movement of water or sewage under the force of gravity without any external techniques. Every pipe is provided with a minor particular slope to avoid blockage. Also, these slopes then determine the lengths of each pipe to be stretched in a particular room or space for after which a bend is provided. Understanding this concept was indeed a big challenge as this is done by specialist engineers under this domain. This is can be seen from figure 4.20.

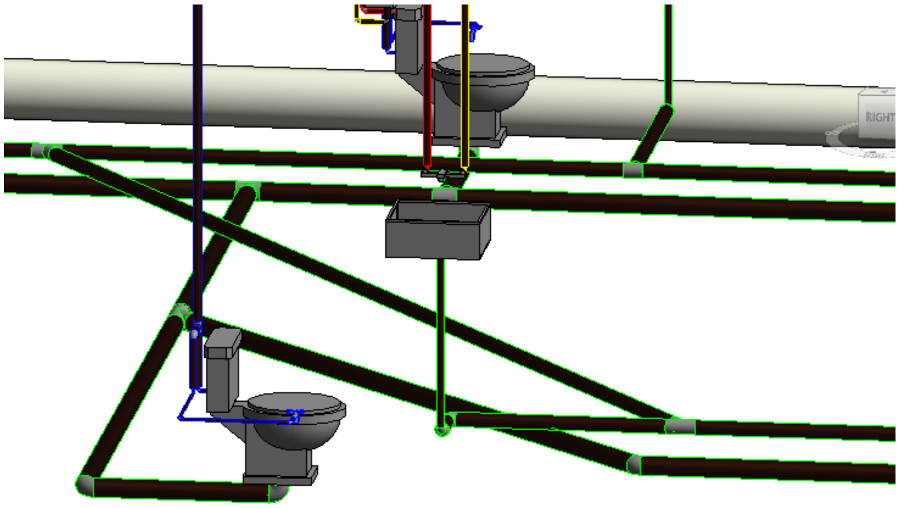

Figure 4.20: Sloping Pipes

Another problem was the elevation of the soil pipes beneath the floor. As this information was not provided in the drawings, it was practically impossible for us to vertically place soil pipes beneath the water closets at our own desired elevation after which it is diverted by a trap.

Real life plumbing implementation are pretty much similar to the ones mentioned above. For the scope of this project, the solution to most of the problems had to be done by assumptions generated by site visits and meetings with engineers.

4.5 ELECTRICAL MODEL

The electrical model consisted of several components linked in a complicated manner. Due to the increased area of this building, there were increased number of components in the electrical trade. In figure 4.21, an electrical room can be seen which serves as the source of power for all the components. This room consists of the distribution boards, main boards, UPS system and others. In figure 4.22, lighting fixtures can be seen. In figure 4.23, an inner view of a room can be seen with switches and receptacles.

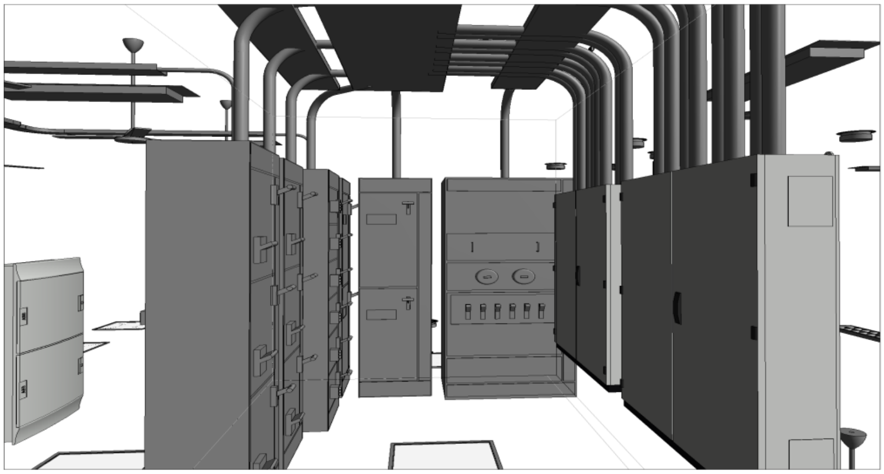

Figure 4.21: Electrical Room

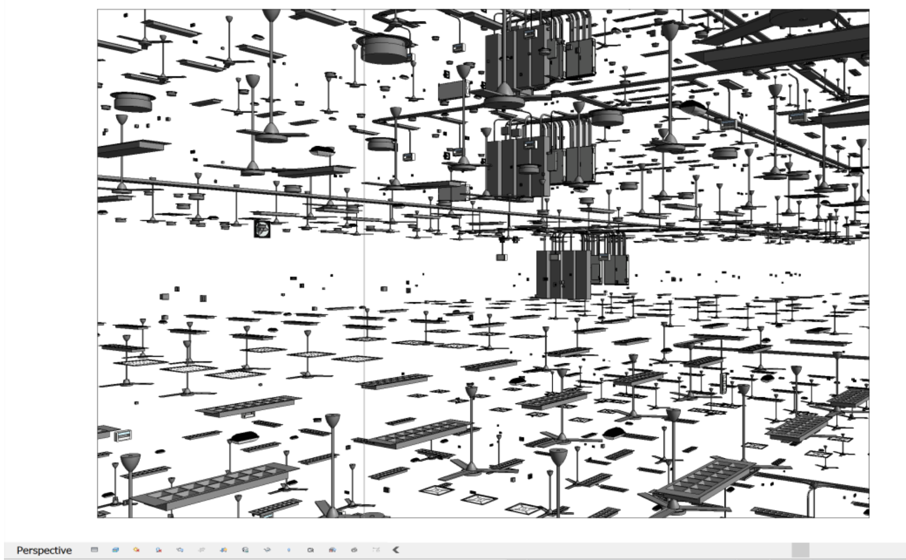

Figure 4.22: Lights and Fixtures

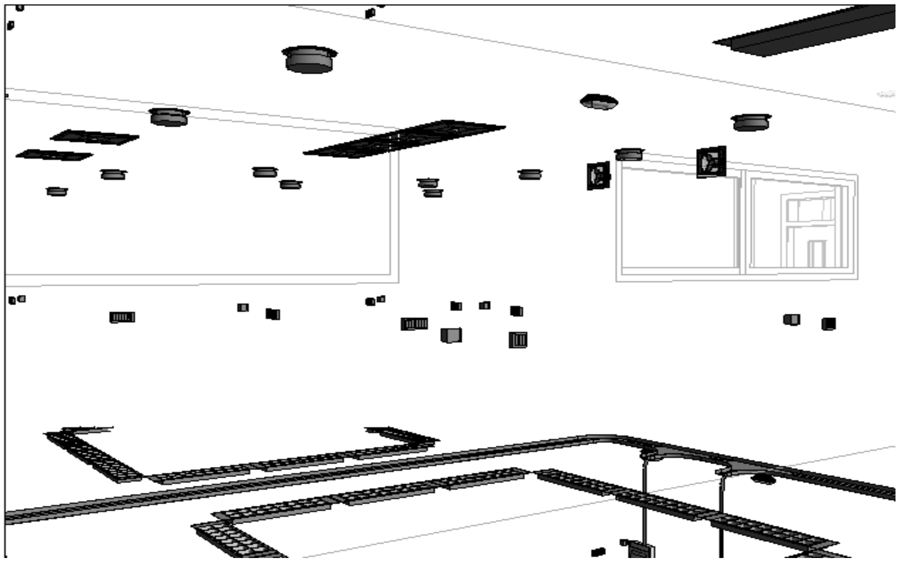

Figure 4.23: Switches and Receptacles

4.5.1 Problems faced in the Electrical model

Interpretation of drawings was a huge and hectic task in this project. Electrical drawings included three sub-drawings for each floor namely; fixtures plan, power plan and single line diagram. Translating single-line diagrams and breaking them into parts for us to understand was in itself impossible to do in the limited time frame. Hence, it was decided not to design these as single line diagrams anyways are not separately designed in Revit. Our basic focus was on the development of the database for facility management and hence this did not serve as a pre-requisite for that. The figure below shows the complexity of single line diagrams.

Furthermore, there were more than 30 different types of components in this model which meant that several families had to be retrieved. This was particularly a vigorous process and yielded a handsome amount of time editing and modifying families with accordance.

4.6 HVAC SCHEDULES

After having developed all the models, the aim of this project was to develop a comprehensive database for facility management. Since, our MEP models were modelled on separate Revit files, it was easier for us to segregate the database of each group. The Mechanical schedules involved the following:

4.6.1 Air Terminal Schedule:

The Air Terminal Schedule involved three types of terminals namely; Supply, return and exhaust terminal. The count of the schedules for Exhaust type component is provided in Table 4.1

Table 4.1: Exhaust Grill Count

Family and Type	Count
Exhaust Grill (Non-Restricted): 06 x 04 Face 03 x 04 Connection 2(Type A)	6

Exhaust Grill (Non-Restricted): 06 x 08 Face 03 x 04 Connection (Type B)	235
Exhaust Grill (Non-Restricted): 10 x 6 Face 12 x 12 Connection (Type C)	23
Exhaust Grill (Non-Restricted): 12 x 6 Face 12 x 12 Connection 2(Type D)	7
Total	271

The count of the schedules for Return type terminals in provided in Table 4.2

Table 4.2: Return Diffuser Count

Family and Type	Count
Return Diffuser1: 09 x 09 Face 4.5 x 4.5 Connection (Type A)	22
Return Diffuser1: 14 x 14 Face 7 x 7 Connection (Type C)	4
Return Diffuser1: 15 x 15 Face 7.5 x 7.5 Connection (Type D)	9
Return Diffuser1: 18 x 18 Face 7.5 x 7.5 Connection 2(Type E)	20
Return Diffuser (non-restricted): 06 x 08 Face 03 x 04 Connection (Type A)	1
Return Diffuser (non-restricted): 12 x 10 Face 06 x 12 Connection 2(Type B)	9
Return Diffuser (non-restricted): 18 x 10 Face 06 x 12 Connection 2(Type E)	21
Return Diffuser (non-restricted): 22 x 10 Face 06 x 12 Connection 2 (Type F)	1
Return Diffuser (non-restricted): 22 x 22 Face 11 x 11 Connection (Type G)	7
Return Diffuser (non-restricted): 24 x 10 Face 06 x 12 Connection (Type H)	17
Return Diffuser (non-restricted): 24 x 12 Face 06 x 12 Connection (Type I)	15
Return Diffuser (non-restricted): 30 x 12 Face 06 x 12 Connection 2 (Type J)	13
Return Diffuser: 24 x 24 Face 12 x 12 Connection (Type K)	7
Total	146

The count of the schedules for Supply type terminals in provided in Table 4.3

Table 4.3: Supply Diffuser Count

Family and Type	Count
Supply Diffuser1: 12 x 12 Face 6 x 6 connection (Type A)	53
Supply Diffuser1: 15 x 15 Face 7.5 x 7.5 connection (Type C)	40
Supply Diffuser1: 22 x 22 Face 11 x 11 connection (Type D)	35
Supply Diffuser1: 24 x 24 Face 12 x 12 Connection (Type E)	16
Supply Diffuser (non-restricted): 06 x 08 Face 03 x 04 Connection (Type F)	2
Supply Diffuser (non-restricted): 18 x 10 Face 06 x 12 connection 2(Type F)	10
Supply Diffuser (non-restricted): 24 x 24 Face 12 x 12 Connection (Type H)	1
Supply_Diffuser-Ceiling-Tuttle_and_Bailey-1300_1300A_LT: Supply Diffuser 18" by 10"	23
Total	180

Furthermore, the HVAC schedules yielded a detailed database that can be useful for a facility manager. The figures below show an exported to excel file Exhaust terminal information database. Figure 4.23 shows the non-geometric properties allied to this exhaust grill as well as its location details. Figure 4.24 shows the geometric properties.

Air Terminal Schedule

Family and Type	Manufacturer	Warrantry Period	Installation Date	Space: Name	Space: Level	Space: Number	Description
Exhaust Grill (Non-Restricted): 06 x 04 Face 03 x 04 Connection 2(Type A)							
Exhaust Grill (Non-Restricted): 06 x 04 Face 03 x 04 Connection	Tuttle & Bailey	3	12/5/2017	SURGEON/ CONSULTANT CHANGIN	11.SIXTH FLOOF	494	Single Deflection type with fixed horizontal bars at 0 deflection and and with control Dampers
Exhaust Grill (Non-Restricted): 06 x 04 Face 03 x 04 Connection	Tuttle & Bailey	3	12/5/2017	RMO P.G. CHANGING (MALE)	11.SIXTH FLOOF	493	Single Deflection type with fixed horizontal bars at 0 deflection and and with control Dampers
Exhaust Grill (Non-Restricted): 06 x 04 Face 03 x 04 Connection	Tuttle & Bailey	3	12/5/2017	RMO P.G. CHANGING (FEMALE)	11.SIXTH FLOOF	490	Single Deflection type with fixed horizontal bars at 0 deflection and and with control Dampers
Exhaust Grill (Non-Restricted): 06 x 04 Face 03 x 04 Connection	Tuttle & Bailey	3	12/5/2017	ANASTHETIST CHANGING (F)	11.SIXTH FLOOF	491	Single Deflection type with fixed horizontal bars at 0 deflection and and with control Dampers
Exhaust Grill (Non-Restricted): 06 x 04 Face 03 x 04 Connection	Tuttle & Bailey	3	12/5/2017	ANASTHETIST CHANGING (M)	11.SIXTH FLOOF	492	Single Deflection type with fixed horizontal bars at 0 deflection and and with control Dampers
Exhaust Grill (Non-Restricted): 06 x 04 Face 03 x 04 Connection	Tuttle & Bailey	3	12/5/2017	SURGEON/ CONSULTANT CHANGIN	11.SIXTH FLOOF	485	Single Deflection type with fixed horizontal bars at 0 deflection and and with control Dampers
Exhaust Grill (Non-Restricted): 06 x 04 Face 03 x 04 Connection 2(Type A): 6							

Figure 4.24a: Non-geometric Properties of Exhaust Grill

Description	Duct Width	Duct Height	Diffuser Width	Diffuser Height	Max Flow	Min Flow	Assembly Code
Single Deflection type with fixed horizontal bars at 0 deflection and and with control Dampers	3"	4"	0' 6"	0' 8"	150 CFM	50 CFM	D3040200
Single Deflection type with fixed horizontal bars at 0 deflection and and with control Dampers	3"	4"	0' 6"	0' 8"	150 CFM	50 CFM	D3040200
Single Deflection type with fixed horizontal bars at 0 deflection and and with control Dampers	3"	4"	0' 6"	0' 8"	150 CFM	50 CFM	D3040200
Single Deflection type with fixed horizontal bars at 0 deflection and and with control Dampers	3"	4"	0' 6"	0' 8"	150 CFM	50 CFM	D3040200
Single Deflection type with fixed horizontal bars at 0 deflection and and with control Dampers	3"	4"	0' 6"	0' 8"	150 CFM	50 CFM	D3040200
Single Deflection type with fixed horizontal bars at 0 deflection and and with control Dampers	3"	4"	0' 6"	0' 8"	150 CFM	50 CFM	D3040200

Figure 4.24b: Geometric Properties of Exhaust Grill

4.6.2 Mechanical Equipment Schedule

The Mechanical Equipment schedule involved of Air Conditioners, Heat Pumps, Fan Coil Units and Air Handling Units.

The count of the schedules for Air Conditioners is given in Table 4.4

Table 4.4: Air Conditioners Count

Family and Type	Count
S4R_Mitsubishi_PLFY_VCM: PLFY-P40 VCM-E(AC4)	57
S4R_Mitsubishi_PLFY_VCM: PLFY-P32 VCM-E(AC3)	21
S4R_Mitsubishi_PLFY_VCM: PLFY-P25 VCM-E(AC2)	24
S4R_Mitsubishi_PLFY_VCM: PLFY-P20 VCM-E(AC1)	89
Total	191

The count of the schedules for Heat Pumps is given in Table 4.5

Table 4.5: Heat Pump Count

Family and Type	Count
HC_HeatPump_MEPcontent_Mitsubishi Electric Corporation_MXZ-2F_INT-EN: MXZ-2F42VF (Type B)	3
HC_HeatPump_MEPcontent_Mitsubishi Electric Corporation_MXZ-2F_INT-EN: MXZ-2F33VF (Type A)	25
Total	28

The count of the schedules for Fan Coil Units is given in Table 4.6

Table 4.6: Fan Coil Unit Count

Family and Type	Count
Fan Coil Unit with Plenum - Horizontal Basic Concealed: 200 CFM (Type A)	5
Total	5

The count of the schedules for Air Handling Units is given in Table 4.7

Table 4.7: Air Handling Unit Count

Family and Type	Count
Air Handling Unit - Split System - Horizontal: 60000 Btu (AHU 10)	1
Air Handling Unit - Split System - Horizontal: 30000 Btu (AHU2)	2
Air Handling Unit - Split System - Horizontal: 30000 Btu 8 x 30(AHU 9)	2
Air Handling Unit - Split System - Horizontal: 30000 Btu 8 x 28(AHU3)	2
Air Handling Unit - Split System - Horizontal: 30000 Btu 5 x 25 (AHU4)	3
Air Handling Unit - Split System - Horizontal: 30000 Btu 5 x 24 (AHU 5)	1
Air Handling Unit - Split System - Horizontal: 30000 Btu 5 x 18(AHU 7)	2
Air Handling Unit - Split System - Horizontal: 30000 Btu 5 x 12(AHU6)	1
Total	14

Furthermore, the database for the Mechanical Schedules are shown in the figures below. This particular shows a crisp view of the Air Conditioners. Figure 4.25 shows the non-geometric properties and location and Figure 4.26 shows the geometric properties.

Mechanical Equipment Schedule

S4R_Mitsubishi_PLFY_VCM
Cassette unit airconditioning
S4R_Mitsubishi_PLFY_VCM: PLFY-P40 VCM-E(AC4)

Family	Description	Model	Manufacturer	Level
S4R_Mitsubishi_PLFY_VCM	Cassette unit airconditioning	PLFY-P40 VCM-E	Mitsubishi Electric	7.SECOND FLOOR
S4R_Mitsubishi_PLFY_VCM	Cassette unit airconditioning	PLFY-P40 VCM-E	Mitsubishi Electric	7.SECOND FLOOR
S4R_Mitsubishi_PLFY_VCM	Cassette unit airconditioning	PLFY-P40 VCM-E	Mitsubishi Electric	7.SECOND FLOOR
S4R_Mitsubishi_PLFY_VCM	Cassette unit airconditioning	PLFY-P40 VCM-E	Mitsubishi Electric	7.SECOND FLOOR
S4R_Mitsubishi_PLFY_VCM	Cassette unit airconditioning	PLFY-P40 VCM-E	Mitsubishi Electric	7.SECOND FLOOR
S4R_Mitsubishi_PLFY_VCM	Cassette unit airconditioning	PLFY-P40 VCM-E	Mitsubishi Electric	7.SECOND FLOOR
S4R_Mitsubishi_PLFY_VCM	Cassette unit airconditioning	PLFY-P40 VCM-E	Mitsubishi Electric	7.SECOND FLOOR

Figure 4.25: Non-geometric Properties of Air Conditioners

Mechanical Equipment Schedule

Manufacturer	Level	Width	Height	Voltage	Airflow Rate (ft3/min)	Heating Current (A)	Unit Weight (kg)
Mitsubishi Electric	7.SECOND FLOOR	2' 1 151/256"	0' 9 65/256"	230.00 V	725.00 CFM	0.28	17
Mitsubishi Electric	7.SECOND FLOOR	2' 1 151/256"	0' 9 65/256"	230.00 V	725.00 CFM	0.28	17
Mitsubishi Electric	7.SECOND FLOOR	2' 1 151/256"	0' 9 65/256"	230.00 V	725.00 CFM	0.28	17
Mitsubishi Electric	7.SECOND FLOOR	2' 1 151/256"	0' 9 65/256"	230.00 V	725.00 CFM	0.28	17
Mitsubishi Electric	7.SECOND FLOOR	2' 1 151/256"	0' 9 65/256"	230.00 V	725.00 CFM	0.28	17
Mitsubishi Electric	7.SECOND FLOOR	2' 1 151/256"	0' 9 65/256"	230.00 V	725.00 CFM	0.28	17
Mitsubishi Electric	7.SECOND FLOOR	2' 1 151/256"	0' 9 65/256"	230.00 V	725.00 CFM	0.28	17

Figure 4.26: Geometric Properties of Air Conditioners

4.7: PLUMBING SCHEDULES

The schedule that was developed for plumbing model had all its components in one single database.

The table below represents the count for the schedules of shower taps.

Table 4.8: Shower Tap Count

Family and Type	Count
Double Closet Shower Taps: Double Closet Shower Taps	8
Total	8

The table below represents the count for the schedules of Water closets.

Table 4.9: Water Closet Count

Family and Type	Count
Fixture-Water_Closet-Zurn-Eastern-Z1290: WATER CLOSET 4" Outlet (TYPE A)	26
Water Closet - Flush Tank: Private - Flushing (Type B)	78
Water Closet - Flush Tank: Private - Flushing (Type A)	28
Water Closet - Flush Tank: Public - Flushing (Type A)	8
Water Closet - Flush Tank: Public - Flushing (Type B)	36
Water Closet - Quiet Flush Tank: Private - Flushing (TYPE A)	22
Water Closet - Quiet Flush Tank: Private - Flushing (Type B)	8
Water Closet - Quiet Flush Tank: Public - Flushing (Type A)	8
Total	214

The table below represents the count for schedules of Geysers

Table 4.10: Geysers Count

Family and Type	Count
Instant Gyser.0002: 3 Gallon Geyser	66
Total	66

The Table below represents the count for schedules of Sinks

Table 4.11: Sinks Count

Family and Type	Count
Sink - Work: Sink-Public	161
Sink - Work: Sink-Staff	119
Total	280

The table below represents the count for schedules of Manholes

Table 4.12: Manholes Count

Family and Type	Count
Standard Main Hole.0001: Standard Main Hole.0001	22
Total	22

The table below represents the count for schedules of Water taps

Table 4.13: Water Taps Count

Family and Type	Count
Water tap with toilet shower: water tap with toilet shower	214
Total	214

The information provided for plumbing database for each component had to sufficient for a facility manager to perform his tasks effectively. The Figures below show a sample of the information for a water closet in the plumbing schedule. Figure 4.27 shows the non-geometric properties and Figure 4.28 shows the geometric properties.

Plumbing Fixture Schedule

Standard Main Hole.0001: Standard Main Hole.0001: 22

Water Closet - Flush Tank: Private - Flushing (Type B)

Family and Type	Manufacturer	Model	Description	Assembly Code	Material	Level
Water Closet - Flush Tank: Private - Flushing (Type B)	PORTA	HD41	Squatting pan	D2010110	Fixtures - Porcelain - Linen	6.FIRST FLOOR
Water Closet - Flush Tank: Private - Flushing (Type B)	PORTA	HD41	Squatting pan	D2010110	Fixtures - Porcelain - Linen	6.FIRST FLOOR
Water Closet - Flush Tank: Private - Flushing (Type B)	PORTA	HD41	Squatting pan	D2010110	Fixtures - Porcelain - Linen	6.FIRST FLOOR
Water Closet - Flush Tank: Private - Flushing (Type B)	PORTA	HD41	Squatting pan	D2010110	Fixtures - Porcelain - Linen	6.FIRST FLOOR
Water Closet - Flush Tank: Private - Flushing (Type B)	PORTA	HD41	Squatting pan	D2010110	Fixtures - Porcelain - Linen	6.FIRST FLOOR
Water Closet - Flush Tank: Private - Flushing (Type B)	PORTA	HD41	Squatting pan	D2010110	Fixtures - Porcelain - Linen	6.FIRST FLOOR
Water Closet - Flush Tank: Private - Flushing (Type B)	PORTA	HD41	Squatting pan	D2010110	Fixtures - Porcelain - Linen	6.FIRST FLOOR
Water Closet - Flush Tank: Private - Flushing (Type B)	PORTA	HD41	Squatting pan	D2010110	Fixtures - Porcelain - Linen	6.FIRST FLOOR
Water Closet - Flush Tank: Private - Flushing (Type B)	PORTA	HD41	Squatting pan	D2010110	Fixtures - Porcelain - Linen	6.FIRST FLOOR
Water Closet - Flush Tank: Private - Flushing (Type B)	PORTA	HD41	Squatting pan	D2010110	Fixtures - Porcelain - Linen	6.FIRST FLOOR
Water Closet - Flush Tank: Private - Flushing (Type B)	PORTA	HD41	Squatting pan	D2010110	Fixtures - Porcelain - Linen	6.FIRST FLOOR
Water Closet - Flush Tank: Private - Flushing (Type B)	PORTA	HD41	Squatting pan	D2010110	Fixtures - Porcelain - Linen	6.FIRST FLOOR
Water Closet - Flush Tank: Private - Flushing (Type B)	PORTA	HD41	Squatting pan	D2010110	Fixtures - Porcelain - Linen	6.FIRST FLOOR
Water Closet - Flush Tank: Private - Flushing (Type B)	PORTA	HD41	Squatting pan	D2010110	Fixtures - Porcelain - Linen	6.FIRST FLOOR

Figure 4.27: Non-geometric Properties of Water Closets

Level	Sanitary Radius	Sanitary Dia	Cold Water Radius	Hot water Dia	Cold Water Dia	WFU	HWFU	CWFU
6.FIRST FLOOR	2"	4"	1/4"		1/2"	4	0	2.2
6.FIRST FLOOR	2"	4"	1/4"		1/2"	4	0	2.2
6.FIRST FLOOR	2"	4"	1/4"		1/2"	4	0	2.2
6.FIRST FLOOR	2"	4"	1/4"		1/2"	4	0	2.2
6.FIRST FLOOR	2"	4"	1/4"		1/2"	4	0	2.2
6.FIRST FLOOR	2"	4"	1/4"		1/2"	4	0	2.2
6.FIRST FLOOR	2"	4"	1/4"		1/2"	4	0	2.2
6.FIRST FLOOR	2"	4"	1/4"		1/2"	4	0	2.2
6.FIRST FLOOR	2"	4"	1/4"		1/2"	4	0	2.2
6.FIRST FLOOR	2"	4"	1/4"		1/2"	4	0	2.2
6.FIRST FLOOR	2"	4"	1/4"		1/2"	4	0	2.2
6.FIRST FLOOR	2"	4"	1/4"		1/2"	4	0	2.2

Figure 4.28: Geometric Properties of Water Closets

4.8 ELECTRICAL SCHEDULES

The electrical schedules were divided into four categories. These are as follows

4.8.1 Lighting Device Schedule

The Table below represents the count for schedule of Lighting Switches

Table 4.14: Lighting Switches Count

Family and Type	Count
Lighting Switches: Door	10
Multigang Lighting Switches + 2pin Socket [Linked] (with ELE Connectors): 2 Gang Switch + 2-pin Socket	20
Multigang Lighting Switches + 2pin Socket [Linked] (with ELE Connectors): 3 Gang Switch + 2-pin Socket	15
Multigang Lighting Switches + 2pin Socket [Linked] (with ELE Connectors): 5 Gang Switch + 2-pin Socket	5
Multigang Lighting Switches [Linked] (with ELE Connectors): Gang Switch (type 2)	218

Multigang Lighting Switches [Linked] (with ELE Connectors): Gang Switch (type 3)	230
Multigang Lighting Switches [Linked] (with ELE Connectors): Gang Switch (type 4)	126
Multigang Lighting Switches [Linked] (with ELE Connectors): Gang Switch (type 5)	318
Multigang Lighting Switches [Linked] (with ELE Connectors): Gang Switch (type 7)	36
Multigang Lighting Switches [Linked] (with ELE Connectors): Gang Switch (type 8)	119
Multigang Lighting Switches [Linked] (with ELE Connectors): Gang Switch (type 9)	144
Total	1241

The information provided for this schedule is shown in the Figures below.

Lighting Device Schedule				
Family and Type	Model	Manufacturer	Description	URL
Multigang Lighting Switches [Linked] (with ELE Connectors): Gang Switch (type 2)				
Multigang Lighting Switches [Linked] (with ELE Connectors): Gang Switch (type 2)	SS1362	MK Electric	Multiple Switching	https://www.mkelectric.com/Documents/English/EN%25MK
Multigang Lighting Switches [Linked] (with ELE Connectors): Gang Switch (type 2)	SS1362	MK Electric	Multiple Switching	https://www.mkelectric.com/Documents/English/EN%25MK
Multigang Lighting Switches [Linked] (with ELE Connectors): Gang Switch (type 2)	SS1362	MK Electric	Multiple Switching	https://www.mkelectric.com/Documents/English/EN%25MK
Multigang Lighting Switches [Linked] (with ELE Connectors): Gang Switch (type 2)	SS1362	MK Electric	Multiple Switching	https://www.mkelectric.com/Documents/English/EN%25MK
Multigang Lighting Switches [Linked] (with ELE Connectors): Gang Switch (type 2)	SS1362	MK Electric	Multiple Switching	https://www.mkelectric.com/Documents/English/EN%25MK
Multigang Lighting Switches [Linked] (with ELE Connectors): Gang Switch (type 2)	SS1362	MK Electric	Multiple Switching	https://www.mkelectric.com/Documents/English/EN%25MK
Multigang Lighting Switches [Linked] (with ELE Connectors): Gang Switch (type 2)	SS1362	MK Electric	Multiple Switching	https://www.mkelectric.com/Documents/English/EN%25MK
Multigang Lighting Switches [Linked] (with ELE Connectors): Gang Switch (type 2)	SS1362	MK Electric	Multiple Switching	https://www.mkelectric.com/Documents/English/EN%25MK
Multigang Lighting Switches [Linked] (with ELE Connectors): Gang Switch (type 2)	SS1362	MK Electric	Multiple Switching	https://www.mkelectric.com/Documents/English/EN%25MK
Multigang Lighting Switches [Linked] (with ELE Connectors): Gang Switch (type 2)	SS1362	MK Electric	Multiple Switching	https://www.mkelectric.com/Documents/English/EN%25MK
Multigang Lighting Switches [Linked] (with ELE Connectors): Gang Switch (type 2)	SS1362	MK Electric	Multiple Switching	https://www.mkelectric.com/Documents/English/EN%25MK

Figure 4.29: Non-geometric Properties of Switches

4.8.2 Lighting Fixture schedule

The table below shows the count for the lights schedule

Table 4.15: Lights Count

Family and Type	Count
63_PHILIPS_CoreLine Panel RC125B RC126B: RECESSED TYPE SQUARE PANNEL	481
63_PHILIPS_dayzone-round_f.0002: RECESSED TYPE DOWNLIGHT (TYPE 1)	570
63_PHILIPS_dayzone-round_f.0002: RECESSED TYPE DOWNLIGHT (TYPE 2)	324
63_PHILIPS_dayzone-round_f.0002: RECESSED TYPE DOWNLIGHT (TYPE 3)	268
63_PHILIPS_dayzone-round_f.0002: RECESSED TYPE DOWNLIGHT (TYPE 4)	6
63_PHILIPS_dayzone-round_f.0002: RECESSED TYPE DOWNLIGHT (TYPE 5)	421

63_PHILIPS_dayzone-round_f.0002: RECESSED TYPE DOWNLIGHT (TYPE 6)	12
63_PHILIPS_dayzone-round_f.0002: RECESSED TYPE DOWNLIGHT (TYPE 8)	128
63_PHILIPS_PowerBalance PoE_RC463B POE W31L125: RECESSED TYPE RECTANGULAR PANNEL (TYPE 3)	281
63_PHILIPS_PowerBalance PoE_RC463B POE W31L125: RECESSED TYPE RECTANGULAR PANNEL (TYPE 4)	575
63_PHILIPS_PowerBalance PoE_RC463B POE W31L125: RECESSED TYPE RECTANGULAR PANNEL (TYPE 7)	244
63_PHILIPS_PowerBalance PoE_RC463B POE W31L125: RECESSED TYPE RECTANGULAR PANNEL (TYPE 8)	636
63_PHILIPS_PowerBalance PoE_RC463B POE W31L125: RECESSED TYPE RECTANGULAR PANNEL (TYPE 9)	26
63_PHILIPS_PowerBalance PoE_RC463B POE W31L125: RECESSED TYPE RECTANGULAR PANNEL (TYPE 10)	100
63_PHILIPS_PowerBalance PoE_RC463B POE W31L125: RECESSED TYPE RECTANGULAR PANNEL (TYPE B2)	32
63_PHILIPS_PowerBalance PoE_RC463B POE W31L125: RECESSED TYPE RECTANGULAR PANNEL (TYPE G3)	12
E_LightingFixture_F_MEPcontent_Philips_FCC 110: BULK HEAD FIXTURE	576
Total	4692

The information for this database is shown in the figures below.

Lighting Fixture Schedule 5						
Family and Type	**Manufacturer**	**Model**	**Description**	**Level**	**Apparent Load**	**Lamp type**
63_PHILIPS_CoreLine Panel RC125B RC126B : RECESSED TYPE SQUARE PANNEL						
63_PHILIPS_CoreLine Panel RC125B RC126B : RECESSED TYPE SQUARE PAN	Philips	RC126B RC125B RC125B	CoreLine Panel	6.FIRST FLOOR	41 VA	LED34S/840/-
63_PHILIPS_CoreLine Panel RC125B RC126B : RECESSED TYPE SQUARE PAN	Philips	RC126B RC125B RC125B	CoreLine Panel	6.FIRST FLOOR	41 VA	LED34S/840/-
63_PHILIPS_CoreLine Panel RC125B RC126B : RECESSED TYPE SQUARE PAN	Philips	RC126B RC125B RC125B	CoreLine Panel	6.FIRST FLOOR	41 VA	LED34S/840/-
63_PHILIPS_CoreLine Panel RC125B RC126B : RECESSED TYPE SQUARE PAN	Philips	RC126B RC125B RC125B	CoreLine Panel	6.FIRST FLOOR	41 VA	LED34S/840/-
63_PHILIPS_CoreLine Panel RC125B RC126B : RECESSED TYPE SQUARE PAN	Philips	RC126B RC125B RC125B	CoreLine Panel	6.FIRST FLOOR	41 VA	LED34S/840/-
63_PHILIPS_CoreLine Panel RC125B RC126B : RECESSED TYPE SQUARE PAN	Philips	RC126B RC125B RC125B	CoreLine Panel	6.FIRST FLOOR	41 VA	LED34S/840/-
63_PHILIPS_CoreLine Panel RC125B RC126B : RECESSED TYPE SQUARE PAN	Philips	RC126B RC125B RC125B	CoreLine Panel	6.FIRST FLOOR	41 VA	LED34S/840/-
63_PHILIPS_CoreLine Panel RC125B RC126B : RECESSED TYPE SQUARE PAN	Philips	RC126B RC125B RC125B	CoreLine Panel	6.FIRST FLOOR	41 VA	LED34S/840/-
63_PHILIPS_CoreLine Panel RC125B RC126B : RECESSED TYPE SQUARE PAN	Philips	RC126B RC125B RC125B	CoreLine Panel	6.FIRST FLOOR	41 VA	LED34S/840/-
63_PHILIPS_CoreLine Panel RC125B RC126B : RECESSED TYPE SQUARE PAN	Philips	RC126B RC125B RC125B	CoreLine Panel	6.FIRST FLOOR	41 VA	LED34S/840/-

Figure 4.30: Non-geometric Properties of Lights

Level	Apparent Load	Lamp type	Type Comme	Width	Total Light Loss Fact	INITIAL IN	INITIAL COL	REFLECTOR	HOUSING	GLAS
6.FIRST FLOOR	41 VA	LED34S/840/-	Recessed	2' 0"	1	3400 lm	3000	Steel, Chrome Plat	Paint white	Glass
6.FIRST FLOOR	41 VA	LED34S/840/-	Recessed	2' 0"	1	3400 lm	3000	Steel, Chrome Plat	Paint white	Glass
6.FIRST FLOOR	41 VA	LED34S/840/-	Recessed	2' 0"	1	3400 lm	3000	Steel, Chrome Plat	Paint white	Glass
6.FIRST FLOOR	41 VA	LED34S/840/-	Recessed	2' 0"	1	3400 lm	3000	Steel, Chrome Plat	Paint white	Glass
6.FIRST FLOOR	41 VA	LED34S/840/-	Recessed	2' 0"	1	3400 lm	3000	Steel, Chrome Plat	Paint white	Glass
6.FIRST FLOOR	41 VA	LED34S/840/-	Recessed	2' 0"	1	3400 lm	3000	Steel, Chrome Plat	Paint white	Glass
6.FIRST FLOOR	41 VA	LED34S/840/-	Recessed	2' 0"	1	3400 lm	3000	Steel, Chrome Plat	Paint white	Glass
6.FIRST FLOOR	41 VA	LED34S/840/-	Recessed	2' 0"	1	3400 lm	3000	Steel, Chrome Plat	Paint white	Glass
6.FIRST FLOOR	41 VA	LED34S/840/-	Recessed	2' 0"	1	3400 lm	3000	Steel, Chrome Plat	Paint white	Glass
6.FIRST FLOOR	41 VA	LED34S/840/-	Recessed	2' 0"	1	3400 lm	3000	Steel, Chrome Plat	Paint white	Glass
6.FIRST FLOOR	41 VA	LED34S/840/-	Recessed	2' 0"	1	3400 lm	3000	Steel, Chrome Plat	Paint white	Glass

Figure 4.31: Geometric Properties of Lights

4.8.3 Electrical Fixture Schedule

The table below represents the count for the receptacles schedule

4.16: Receptacles Count

Family and Type	Count
Duplex Receptacle: Standard Receptacle (TYPE A)	75
M_Duplex Receptacle: Standard Receptacle (TYPE B)	73
Total	148

The table below represents the count for the sockets schedule

Table 4.17: Sockets Count

Family and Type	Count
Single Pole Switched Socket Outlet [Linked] (5,15,20 A): 3-pin Socket (TYPE A)	550
Single Pole Switched Socket Outlet [Linked] (5,15,20 A): 3-pin Socket (TYPE B)	227
Total	777

The table below represents the count for the Electrical Distribution panel schedules

Table 4.18: Distribution Panels Count

Family and Type	Count
Electrical Distribution Panel MEPcontent XL3 Single-Line Wall Mounting (125): BUILDING HEALTH UNIT	76
Total	76

The figures below represent the kind of information provided in this schedule.

Electrical Fixture Schedule 2				
Family and Type	Description	Level	Manufacturer	Model
Electrical Distribution Panel MEPcontent XL3 Single-Line Wall Mounting (125): BUILDING HEALTH UNIT				
Electrical Distribution Panel MEPcontent XL3 Single-Line Wall Mounting (125): BUILDING HEALTH UNIT	Automated Unit Control	6.FIRST FLOOR	Legrand	BS1363
Electrical Distribution Panel MEPcontent XL3 Single-Line Wall Mounting (125): BUILDING HEALTH UNIT	Automated Unit Control	6.FIRST FLOOR	Legrand	BS1363
Electrical Distribution Panel MEPcontent XL3 Single-Line Wall Mounting (125): BUILDING HEALTH UNIT	Automated Unit Control	6.FIRST FLOOR	Legrand	BS1363
Electrical Distribution Panel MEPcontent XL3 Single-Line Wall Mounting (125): BUILDING HEALTH UNIT	Automated Unit Control	6.FIRST FLOOR	Legrand	BS1363
Electrical Distribution Panel MEPcontent XL3 Single-Line Wall Mounting (125): BUILDING HEALTH UNIT	Automated Unit Control	6.FIRST FLOOR	Legrand	BS1363
Electrical Distribution Panel MEPcontent XL3 Single-Line Wall Mounting (125): BUILDING HEALTH UNIT	Automated Unit Control	6.FIRST FLOOR	Legrand	BS1363
Electrical Distribution Panel MEPcontent XL3 Single-Line Wall Mounting (125): BUILDING HEALTH UNIT	Automated Unit Control	6.FIRST FLOOR	Legrand	BS1363
Electrical Distribution Panel MEPcontent XL3 Single-Line Wall Mounting (125): BUILDING HEALTH UNIT	Automated Unit Control	6.FIRST FLOOR	Legrand	BS1363

Figure 4.32: Non-geometric Properties of Electrical Distribution Panel

e Schedule 2							
Description	Level	Manufacturer	Model	Depth	Height	Width	GTIN
UILDING HEALTH UNIT							
Automated Unit Control	6.FIRST FLOOR	Legrand	BS1363	0' - 5 29/32"	0' - 11 13/16"	1' - 5 23/32"	3.25E+12
Automated Unit Control	6.FIRST FLOOR	Legrand	BS1363	0' - 5 29/32"	0' - 11 13/16"	1' - 5 23/32"	3.25E+12
Automated Unit Control	6.FIRST FLOOR	Legrand	BS1363	0' - 5 29/32"	0' - 11 13/16"	1' - 5 23/32"	3.25E+12
Automated Unit Control	6.FIRST FLOOR	Legrand	BS1363	0' - 5 29/32"	0' - 11 13/16"	1' - 5 23/32"	3.25E+12
Automated Unit Control	6.FIRST FLOOR	Legrand	BS1363	0' - 5 29/32"	0' - 11 13/16"	1' - 5 23/32"	3.25E+12
Automated Unit Control	6.FIRST FLOOR	Legrand	BS1363	0' - 5 29/32"	0' - 11 13/16"	1' - 5 23/32"	3.25E+12
Automated Unit Control	6.FIRST FLOOR	Legrand	BS1363	0' - 5 29/32"	0' - 11 13/16"	1' - 5 23/32"	3.25E+12
Automated Unit Control	6.FIRST FLOOR	Legrand	BS1363	0' - 5 29/32"	0' - 11 13/16"	1' - 5 23/32"	3.25E+12
Automated Unit Control	6.FIRST FLOOR	Legrand	BS1363	0' - 5 29/32"	0' - 11 13/16"	1' - 5 23/32"	3.25E+12

Figure 4.33: Geometric Properties of Electrical Distribution Panel

4.8.4 Electrical Equipment Schedule

The table below shows the count for the schedules of Ceiling fans

Table 4.19: Ceiling Fans Count

Family and Type	Count
Ceiling Fan [Hosted] (with ELE Connectors): CEILING FAN (TYPE A)	746
Ceiling Fan [Hosted] (with ELE Connectors): CEILING FAN (TYPE B)	201
Total	947

The table below shows the count for the schedules of Electrical Room Equipment.

Table 4.20: Electrical Room Equipment Count

Family and Type	Count
Distribution Board Mistral, L41F Wall-Mounted 48M-72M (Double): Typical Distribution Board	67
Electrical Distribution Board MEP Content Mounting Cabinet TwinLine L-Floor Double	13

Insulated (600): Floor Main Control Board (TYPE B)	
Electrical Distribution Board MEP Content Mounting Cabinet TwinLine L-Floor Double Insulated (600): Floor Main Control Board (TYPE A)	16
Electrical Distribution Board MEP Content Mounting Cabinet TwinLine L-Floor Double Wall Mounting Cabinet Earthed: THIS IS A TYPE CATALOG FAMILY	5
M_Modular Motor Control Centers - Circuit Breaker Section: Floor Switching Control Unit (TYPE A)	15
M_Modular Motor Control Centers - Circuit Breaker Section: Floor Switching Control Unit (TYPE B)	18
M_Modular Motor Control Centers - Power Monitoring Section: 508mmx381mm	1
M_Modular Motor Control Centers - Power Monitoring Section: Floor Power System (TYPE A)	17
M_Modular Motor Control Centers - Power Monitoring Section: Floor Power System (type B)	26
M_Modular Motor Control Centers - Power Monitoring Section: ups system	23
M_Utility Switchboard: 914mmx413mm	1
M_Utility Switchboard: Utility Switchboard	5

The figure below shows a depiction of the kind of information in this database.

Electrical Equipment Schedule

Family and Type	Manufacturer	Model	URL	Description
Ceiling Fan [Hosted] (with ELE Conectors): CEILING FAN (TYPE A)				
Ceiling Fan [Hosted] (with ELE Conectors): CEILING FAN (TYPE A)	ROYAL FANS	RL-080 Ceiling Fan	https://www.royalfans.com/product/	CEILING CAPACITOR BASED CEILING FAN
Ceiling Fan [Hosted] (with ELE Conectors): CEILING FAN (TYPE A)	ROYAL FANS	RL-080 Ceiling Fan	https://www.royalfans.com/product/	CEILING CAPACITOR BASED CEILING FAN
Ceiling Fan [Hosted] (with ELE Conectors): CEILING FAN (TYPE A)	ROYAL FANS	RL-080 Ceiling Fan	https://www.royalfans.com/product/	CEILING CAPACITOR BASED CEILING FAN
Ceiling Fan [Hosted] (with ELE Conectors): CEILING FAN (TYPE A)	ROYAL FANS	RL-080 Ceiling Fan	https://www.royalfans.com/product/	CEILING CAPACITOR BASED CEILING FAN
Ceiling Fan [Hosted] (with ELE Conectors): CEILING FAN (TYPE A)	ROYAL FANS	RL-080 Ceiling Fan	https://www.royalfans.com/product/	CEILING CAPACITOR BASED CEILING FAN
Ceiling Fan [Hosted] (with ELE Conectors): CEILING FAN (TYPE A)	ROYAL FANS	RL-080 Ceiling Fan	https://www.royalfans.com/product/	CEILING CAPACITOR BASED CEILING FAN
Ceiling Fan [Hosted] (with ELE Conectors): CEILING FAN (TYPE A)	ROYAL FANS	RL-080 Ceiling Fan	https://www.royalfans.com/product/	CEILING CAPACITOR BASED CEILING FAN
Ceiling Fan [Hosted] (with ELE Conectors): CEILING FAN (TYPE A)	ROYAL FANS	RL-080 Ceiling Fan	https://www.royalfans.com/product/	CEILING CAPACITOR BASED CEILING FAN
Ceiling Fan [Hosted] (with ELE Conectors): CEILING FAN (TYPE A)	ROYAL FANS	RL-080 Ceiling Fan	https://www.royalfans.com/product/	CEILING CAPACITOR BASED CEILING FAN
Ceiling Fan [Hosted] (with ELE Conectors): CEILING FAN (TYPE A)	ROYAL FANS	RL-080 Ceiling Fan	https://www.royalfans.com/product/	CEILING CAPACITOR BASED CEILING FAN

Figure 4.34: Non-geometric Properties of Ceiling Fans

Load Classification	Connector Voltage	Number of Poles	Voltage	Wattage	Depth	Size	Radius	Dia
Fan	220.00 V	2		80W	4' 0"	2' 0"	0' 0 1/2"	0' 1"
Fan	220.00 V	2		80W	4' 0"	2' 0"	0' 0 1/2"	0' 1"
Fan	220.00 V	2		80W	4' 0"	2' 0"	0' 0 1/2"	0' 1"
Fan	220.00 V	2		80W	4' 0"	2' 0"	0' 0 1/2"	0' 1"
Fan	220.00 V	2		80W	4' 0"	2' 0"	0' 0 1/2"	0' 1"
Fan	220.00 V	2		80W	4' 0"	2' 0"	0' 0 1/2"	0' 1"
Fan	220.00 V	2		80W	4' 0"	2' 0"	0' 0 1/2"	0' 1"
Fan	220.00 V	2		80W	4' 0"	2' 0"	0' 0 1/2"	0' 1"
Fan	220.00 V	2		80W	4' 0"	2' 0"	0' 0 1/2"	0' 1"

Figure 4.35: Geometric Properties of Ceiling Fans

4.9 ANALYSIS OF RESULTS

The above shown databases were the actual output of this project. Our target was to make a comprehensive database for facility management. In order to analyze our solution, we conducted survey amongst reputable hospitals around the region of Islamabad. The hospitals include:

- Shifa International Hospital
- Quaid-e-Azam International Hospital
- Pakistan Institute of Medical Sciences (PIMS) Hospital
- Khan Research Laboratories (KRL)

The hospitals were approached and a questionnaire attached in Appendix A was presented to them. Furthermore, detailed interviews with the facility management department regarding how facility management is being done at their Health facility was carried out.

The questionnaire was designed in two sections. This first section involved of questions addressing what kind of facility management system is currently being implemented at their place and in case they are need of any updated system.

The second part of the survey was designed in such a way that would enable us to analyze the impact of our project in the field. Four governing parameters through research were selected under which we believed our project could best be analyzed. The parameters include:

- Integration
- Quality
- Time
- Cost

The graph below shows the industry practices currently being carried out for facility management.

Question 1: How facilities are being managed at your workplace?

Figure 4.36: Facility Management at Workplaces

From this graph, it can be seen that facility management is a field which is yet untouched. The majority of the people have voted a conventional method. This conventional method involved book keeping records and other manual procedures for facility management. Shifa International hospital has Computerized Maintenance Management System (CMMS) which is at its initial stages and has not yet been used effectively. CMMS provides only a message delivery task for facility management. There is no visualization involved in this process.

Question 2: If Using software, which of the following is being used?

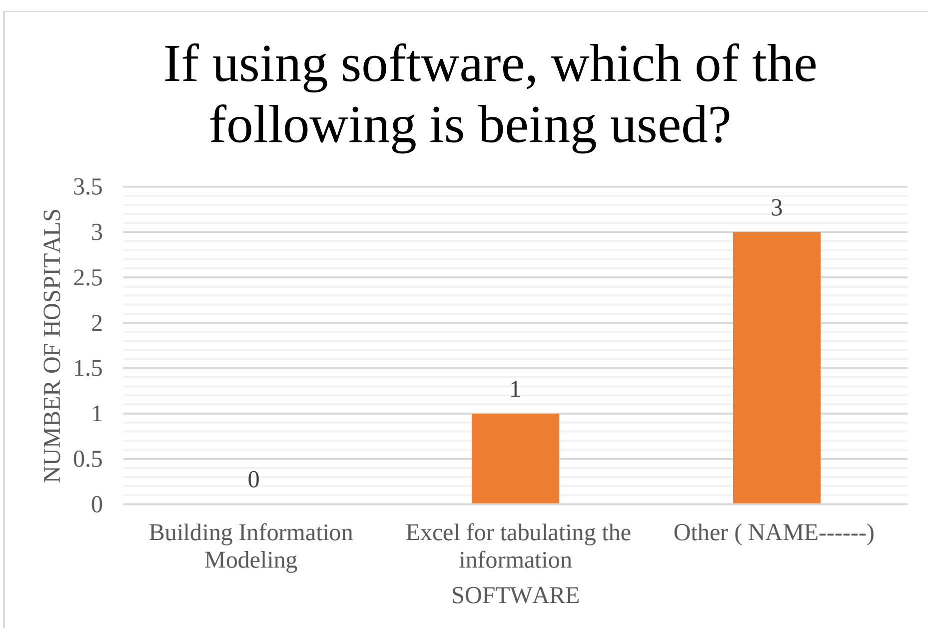

Figure 4.37: Software being used for Facility Management in the Industry

As we had discovered that facility management has not yet been fully exposed using BIM, we have come to a conclusion that this statement as per our graphs justifies it. No hospital had been using Building Information Modeling for facility management. This is due to the fact that BIM is not a really welcoming software in Pakistan's construction industry due to various factors. And hence, its slight chance of it being used for facility management is unexpected.

Our solution was proposed to these hospitals and we asked them to analyze it according to facility management needs.

Question 3: Integration- Would you be satisfied with all your facilities linked to a single database with a 3D model?

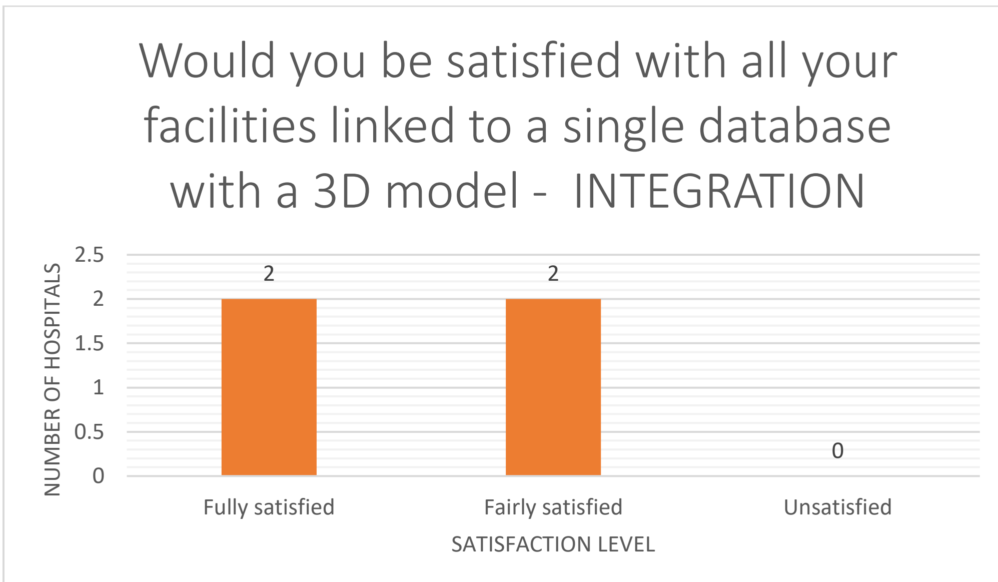

Figure 4.38: Analysis of Integration

From this graph, it can be seen that most of the hospitals were relatively satisfied with a well-developed 3D model linked to a database for facility management. The process of facility management involves mainly complaints' management and communication. However, this solution has proved that not only can you perform the basic tasks, you are also able to a proper linkage between the data and information to something physical which in this case is the 3D model.

Furthermore, this integration does not only link data, it also facilitates the task by adding an extra advantage of visualization. It is evident that in case of any failures in a building, it is practically impossible to visualize what's hidden behind. The 3D model successfully tackles this barrier to efficient facility management. One can use this model effectively to view any possible causes to a damage, view the situation as a whole around the damaged component and also perform necessary analysis if required.

Question 4: Do you believe that the database successfully includes all relevant information needed for effective facility management?

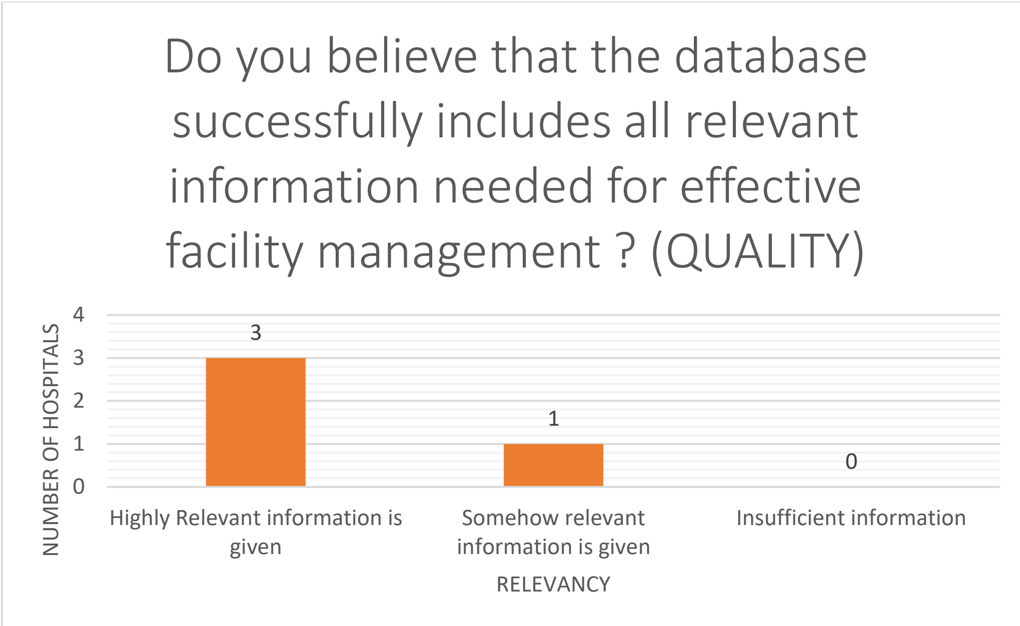

Figure 4.39: Analysis of Quality

From the graph above, majority of the hospitals selected high relevant information being provided in this database. In order to have an effective on-going process of facility management, one requires all necessary information. The schedules of each model have been presented above and it can be seen that sufficient information has been provided. The first and foremost information required for a facility manager are usually the Model, Make, Warranty, Installation date and then further moving on to geometric parameters of a component. All this is collectively provided.

Question 5: Do you believe that implementation of this system would help you in effective time management and saving for execution of work orders?

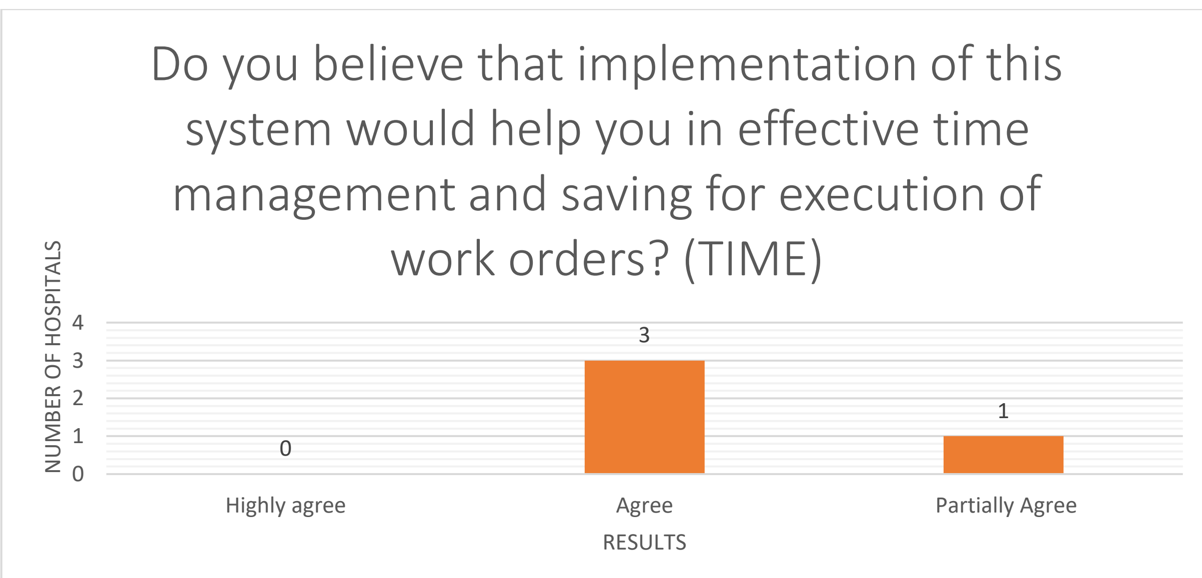

Figure 4.40: Analysis of Time

It can be clearly depicted that majority of the hospitals agree that time would be saved via this solution. On further interviewing the hospitals regarding time saving, we discovered that the manual process involves various time lags that delay the process of facility management.

First and foremost, during the manual process time is delayed by physically going on to site and analyzing the situation at hand. With a computerized system and a 3D model, this issue is eliminated as one operating a facility simply can open the 3D model and navigate to his/her required component to view the situation at hand with a better understanding and also without halting on-going activities at site.

Moving on, time is also consumed in manual communication processes via telephone. With our solution, one can upload the model on a cloud server which is accessible to all personnel and automatically generate work-orders online which a quicker process.

Question 6: Do you believe that replacement of existing system with the proposed system will help in saving any costs incurred in facility management?

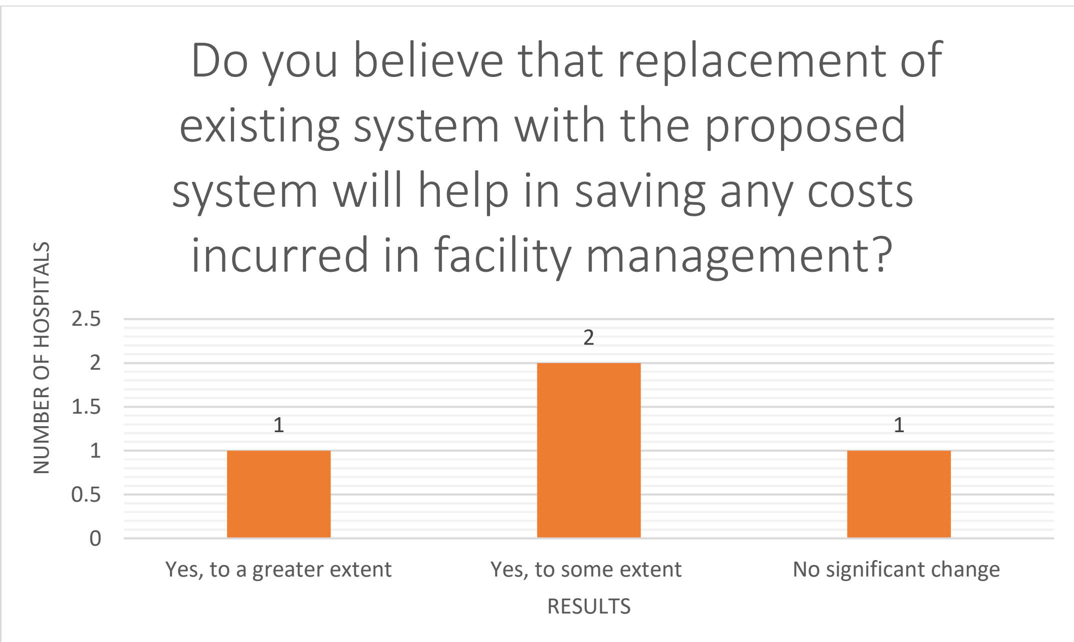

Figure 4.41: Analysis of Cost

It can be noted that majority of the hospitals believe that cost will be saved with this solution. On further investigation with them, it was understood that time and cost work hand in hand. If time is saved, simultaneously, cost is saved too. Time and cost are interdependent on each other.

However, we discovered that these hospitals believed that if this solution was to be implemented in the design phase, it would yield more advantages as compared to being implemented on an already built facility. And for this case, the hospitals approached were all built-up facilities.

The reason to this was difficulty of change in system which would not yield perfect results. Also, adaptability of the system for the health facility as a whole would not be easy as well. Furthermore, this means that the costs incurred in the implementation of an updated system would not be recovered well. The execution of this solution in the design phase would actually make it easier for operation of the facility as all systems would be integrated right from the start.

Chapter 5

CONCLUSION

5.1 REVIEW OF THE RESEARCH OBJECTIVES

The objectives of this project were the following:

- To determine the levels of facility management and their implementation.
- To develop a comprehensive 3D model (Architectural, MEP and other parallel systems) of a large complex health facility
- To develop a comprehensive database for Facility Management

5.2 CONCLUSIONS

After a thorough study in facility management, it can be concluded that this process should be adopted by large and complex buildings in the AEC industry because of the benefits it offers. The following deductions are made through this study:

- Facility Management had been an unexposed arena in BIM. Via this study, it can be clearly understood of the effectiveness of BIM for Facility Management.
- Visualization, an issue that always hinders the efficiency of FM process, can now easily be catered for. The 3D BIM model attends to this issue so successfully that eventually improves the process of facility management
- BIM is not just about modeling; it includes *Building Information* too. This project has enabled us to tap this arena which serves as a prerequisite for a linked database.
- Integration of information on a single platform has always been a big challenge in the AEC industry. BIM allows large amount information to be stored and accessed as your ease. In the case of FM, this increases its advantages as linkage between a physical model, which is an exact representation of an existing facility, and its information is possible in real-time and with a click away
- Quality of information stored for every single component on the BIM model assures a facility manager perform his tasks with ease. The information provided is sufficient and relevant.
- Time is saved with the implementation of this process. This implies that FM process can be carried out competently.
- It has also been discovered that with saving of time, cost has also been saved.
- Implementation of BIM for Facility Management would yield far much better results if it conducted in the design as compared to being conducted on an already built facility.
- BIM for Facility Management would require simple training on implementation.

5.3 RECOMMENDATIONS

Due to the benefits provided by BIM for FM as mentioned in the above section, it is recommended that an initiative should be taken by firms to fully implement such a system for large and complex buildings.

The process is quite simple, a 3D BIM model is to be developed and information is to be added. This very information is to be extracted for ease of use for a facility manager and some training provided to staff personnel who will be operating this process. Furthermore, not only does BIM offer its services in the FM process, BIM can be used for many other analyses which can allow smooth running of parallel activities in a building. BIM eliminates many problems and issues faced during the operation of any building.

5.4 RECOMMENDATIONS FOR FUTURE STUDY

Further research should be carried out in the following areas:

- Making this process a Smart process.
- Exploration of FM by other software and a comparison made
- Real-time visualization using hand-held devices to be discovered
- Virtual Augmented Reality for Facility Management
- Maintenance Work Order using BIM

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APPENDIX A: MARKET SURVEY FORM

MARKET SURVEY

FACILITIES MANAGEMENT AT YOUR WORKPLACE (SECTION A)

Date- ___________________ Organization- ___________________

Personnel - ___________________ Designation- _______________

Please answer the following to the best of your knowledge and technical expertise related to the particular information required.

1. How facilities are being managed at your workplace.
   a. Conventional Method ☐
   b. Software Integrated ☐
   c. Other ☐
2. If using software, which of the following is being used
   a. Building Information Modeling (BIM) ☐
   b. Excel for tabulating the information ☐
   c. Other (NAME------) ☐
3. Satisfaction level with software being used
   a. Very Satisfied ☐
   b. Satisfied ☐
   c. Unsatisfied ☐
4. Weakness of the incumbent method (can tick more than one)
   a. Time taking ☐
   b. Costly ☐
   c. Inefficient ☐
   d. Unintegrated ☐
5. Do you feel the need of a better software for facility management?
   a. Absolutely Yes ☐
   b. Fairly Yes ☐
   c. Absolutely No ☐

FACILITY MANAGEMENT USING BUILDING INFORMATION MODELING (SECTION B):

Our proposed approach.

Please answer the following to the best of your knowledge and technical expertise related to the particular information required.

Do you wish to use BIM and its allied software for facility management of your organization?

a. Yes ☐
b. No ☐
c. Some other software (____) ☐

How effectively do the following parameters satisfy BIM and Facility Management Database shown to you?

Integration:

Would you be satisfied with all your facilities linked to a single database with a 3D model?

a. Fully satisfied ☐
b. Fairly satisfied ☐
c. Unsatisfied ☐

Quality:

Do you believe that the database successfully includes all relevant information needed for effective facility management?

a. Highly Relevant information is given ☐
b. Somehow relevant information is given ☐
c. Insufficient information ☐

Time:

Do you believe that implementation of this system would help you in effective time management and saving for execution of work orders?

a. Highly agree ☐
b. Agree ☐
c. Partially Agree ☐

Cost:

1. Do you believe that replacement of existing system with the proposed system will help in saving any costs incurred in facility management?
   a. Yes, to a greater extent ☐
   b. Yes, to some extent ☐
   c. No significant change ☐

Your Comments:

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APPENDIX B: ARCHITECTURAL MODEL 3D VIEWS

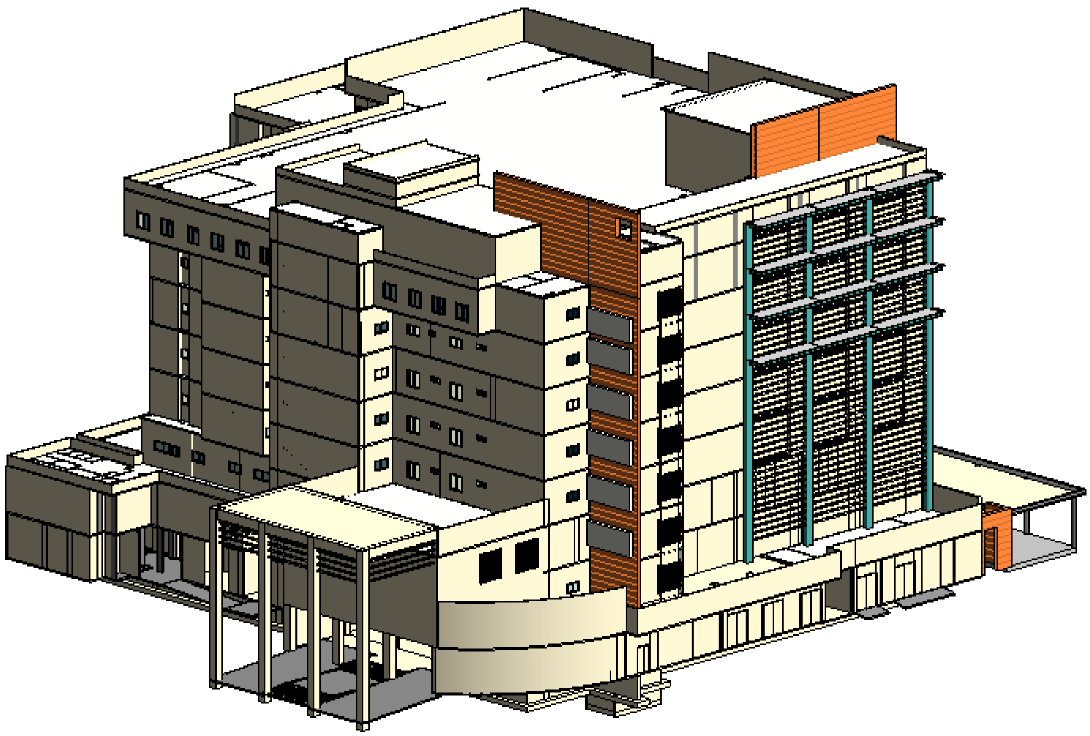

Figure A: OPD Entrance 3D View

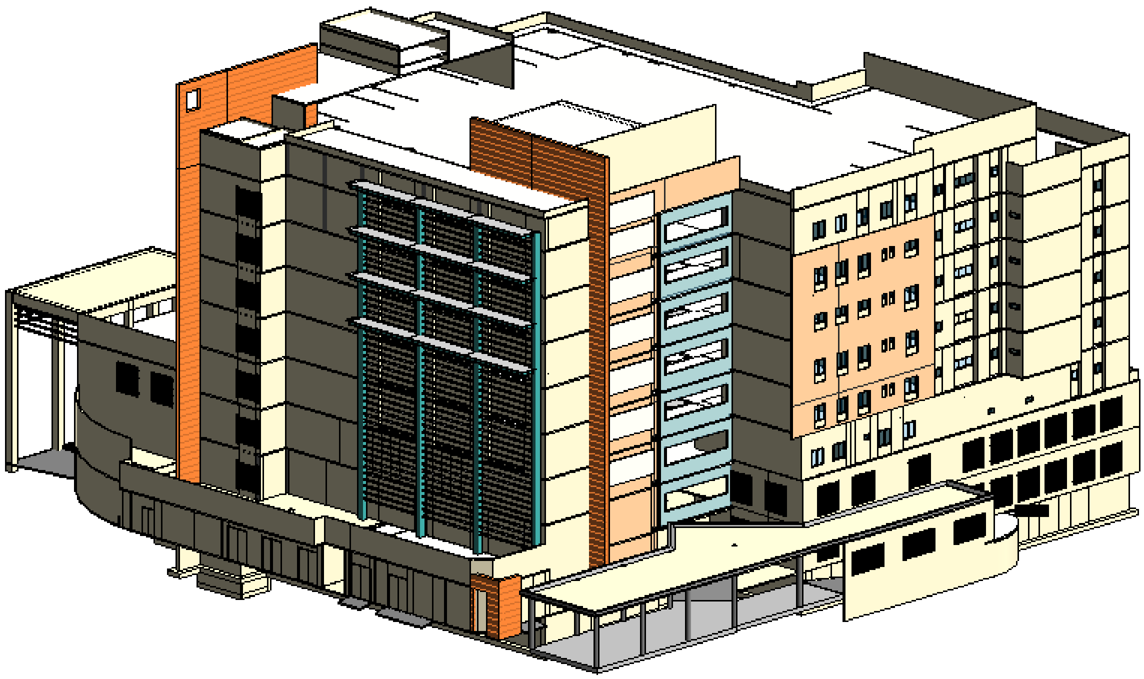

Figure B: Surgical Ward Entrance 3D View

APPENDIX C: HVAC MODEL 3D VIEWS

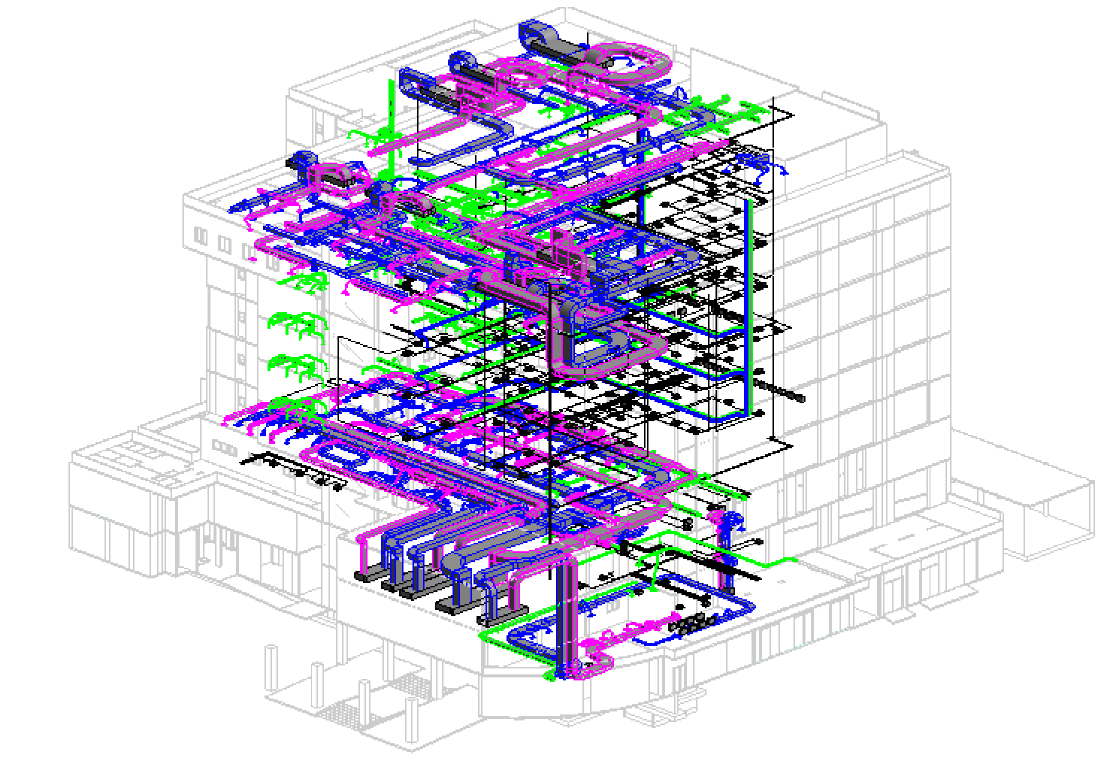

Figure C: HVAC 3D View

APPENDIX D: PLUMBING MODEL 3D VIEWS

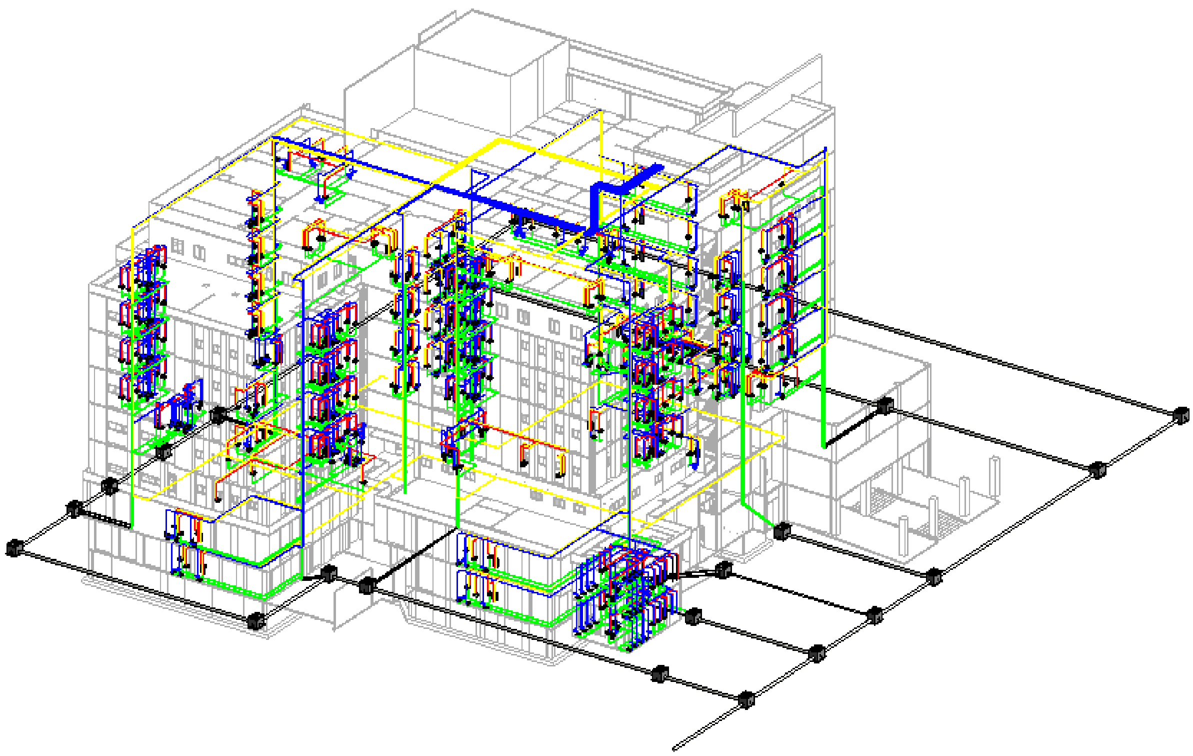

Figure D: Plumbing 3D View

APPENDIX E: ELECTRICAL MODEL 3D VIEWS

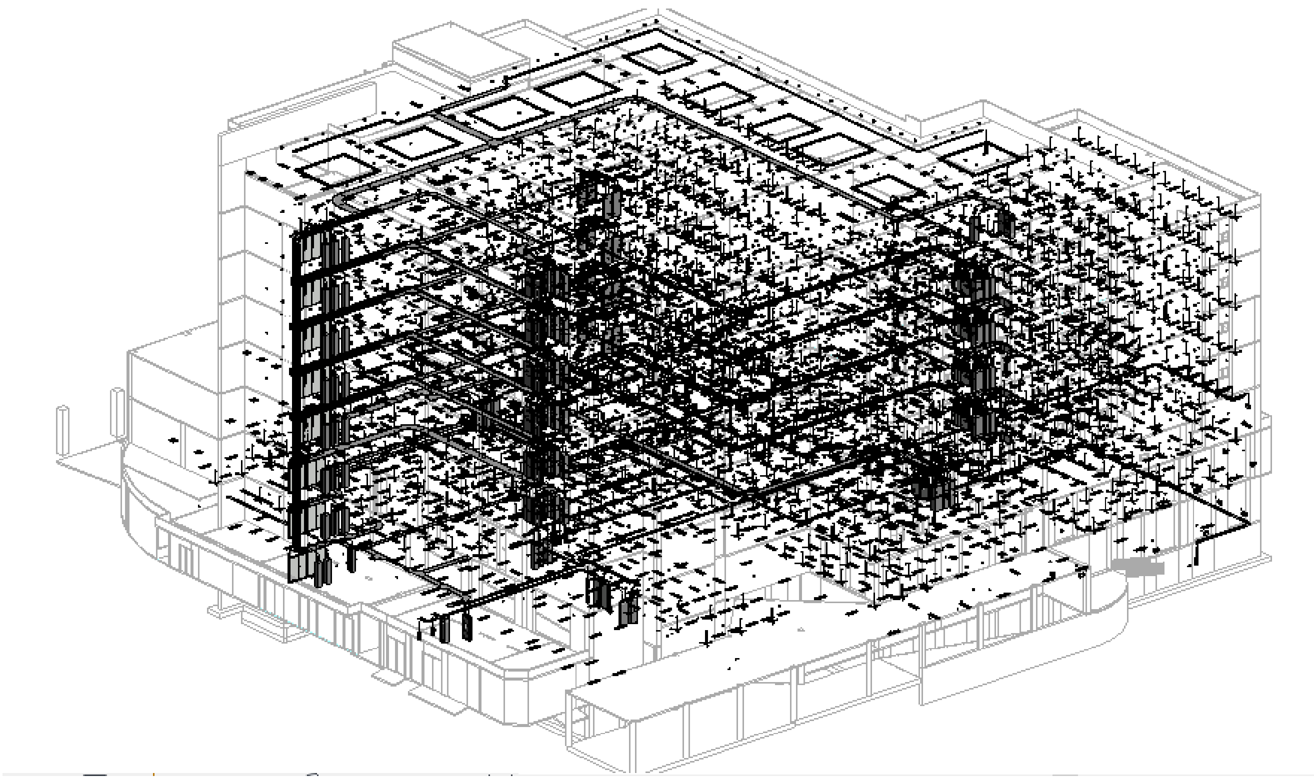

Figure D: Electrical 3D View