Integrating Building Management Systems in High-Rise Structures using Building Information Modeling

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Abstract
Rapid industrialization and population growth in urban areas has resulted in scarce land resources thus changing built form tremendously. Complex construction such as high-rise structures are becoming an essential requirement in urban areas. Efficient Building Management System (BMS) such as fire safety, heating ventilation and air-conditioning, security, and surveillance along with the operation and maintenance is crucial for high-rise construction projects. The construction industry is one of the most labor-intensive industries in the world with a human centric management approach. With the advent of computer technologies, planning and management of building systems in a construction project have become easier. The concept of Building Information Modeling (BIM) to manage building management systems in construction projects is gaining popularity. In this study, an integrated framework is proposed that includes numerous aspects of building management systems in high-rise structures with a dynamic BIM model. This proposed framework was explored with a case illustration of a multi-story building. Preliminary results of the model are presented herewith.
Keywords: Building Management System; Building Information Modeling; High-Rise Structures; Construction Projects.

1. Introduction

Modern buildings' operating capabilities and energy efficiency are greatly improved using building automation systems. These systems use sensors and Internet of Things (IoT) devices to gather data on many elements of a building's environment and activities (Flax, 1991). They are also known as Building Automation and Control Systems (BACS) or Building Management Systems (BMS). After analysis, this data is used to automate tasks including access control, security, lighting, ventilation, and air conditioning (HVAC). The capacity of a building automation system to make wise decisions based on the data it gathers is one of its main advantages. Occupancy sensors, for instance, can be used to identify the parts of a building that are being used. This information enables the system to make energy-saving adjustments to the HVAC and lighting systems. Like this, temperature sensors may identify changes in temperature and modify HVAC settings to minimize energy use and maintain a comfortable environment (Azhar, 2011).

Building automation systems, as shown in Figure 1, improve a building's total operational efficiency in addition to its energy efficiency. Maintenance and administration responsibilities are made easier by these systems, which centralize control of several building systems, including security, HVAC, and lighting. Building managers, for instance, can more effectively schedule maintenance chores, get real-time warnings about problems or abnormalities, and remotely monitor and operate building systems (Wong,1997). One other technological advancement that has completely changed building management and construction is Building Information Modelling (BIM). Building Information Modelling (BIM) entails generating a digital model of a structure that includes comprehensive details on its structural and operational attributes. This data can range from the arrangement of rooms and the placement of structural components to the composition of the building materials and the functionalities of the building systems (Hardin, 2009).

BIM's capacity to centralize and simplify building information management is one of its main benefits. BIM facilitates information access and sharing, teamwork on design and construction projects, and informed decision-making by establishing a single, centralized repository for all building-related data (Skandhakumar et al., 2012). BIM is essential for streamlining the design, construction, and management processes when it comes to integrating building management systems in high-rise buildings. BIM, for instance, can be used to produce intricate 3D models of tall buildings that include details on the placement and characteristics of building systems, such as plumbing, electrical, and HVAC ducts. The installation of building systems may thus be planned and coordinated using this information, guaranteeing an accurate and effective installation (Azhar et al., 2012). An integrated framework proposing numerous aspects of building management systems in high-rise structures with a BIM model is shown in Figure 2.

With this integration, high-rise buildings can gain a great deal from the integration of building management systems and BIM, including increased energy efficiency, better operational efficiency, and streamlined design and construction procedures. Building managers and owners can design more sustainable and efficient structures, as well as ones that are more practical and comfortable for their occupants, by utilizing these technologies (Afara et al., 2024; Amen et al., 2024)

. To improve user comfort and energy efficiency, current research in the subject focuses on combining BIM with lighting automation systems. With daylight analysis enabling energy conservation through the optimization of natural

illumination and the adjustment of artificial lighting settings, parametric design, enabled by BIM, enables automatic changes in lighting layouts by associating lighting characteristics with design elements (Liu & Ning, 2019) Energy performance simulation tools help maximize energy use in lighting systems, while BIM integration with lighting control systems allows for dynamic management depending on occupancy and user preferences, further improving energy efficiency.
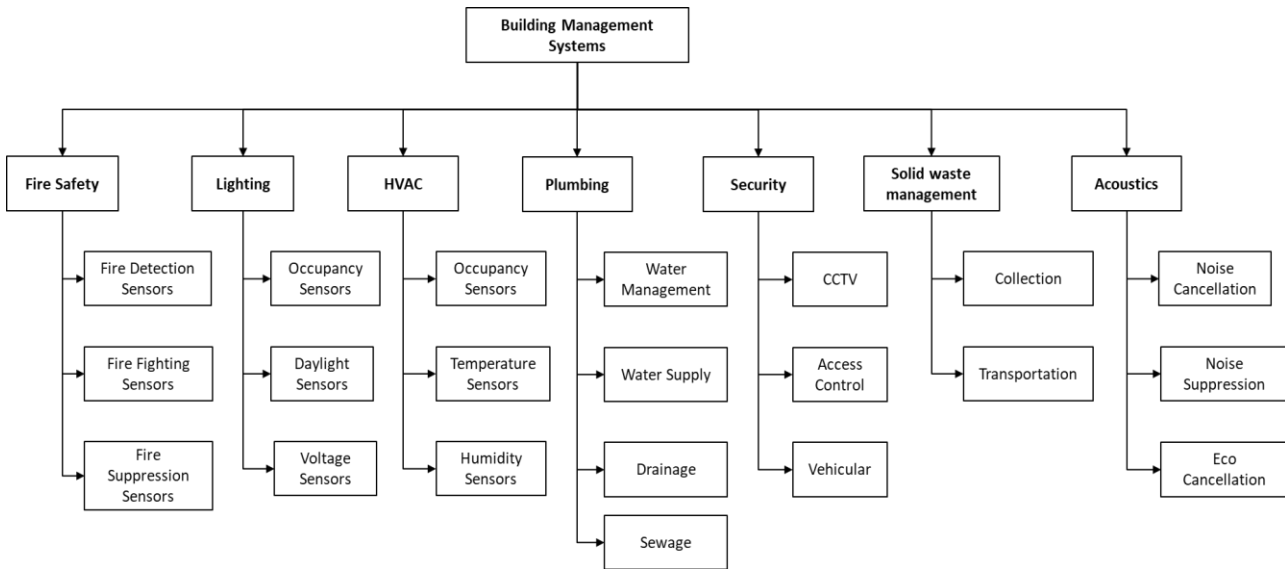
Figure 1. Components of Building Management Systems (Developed by Author).
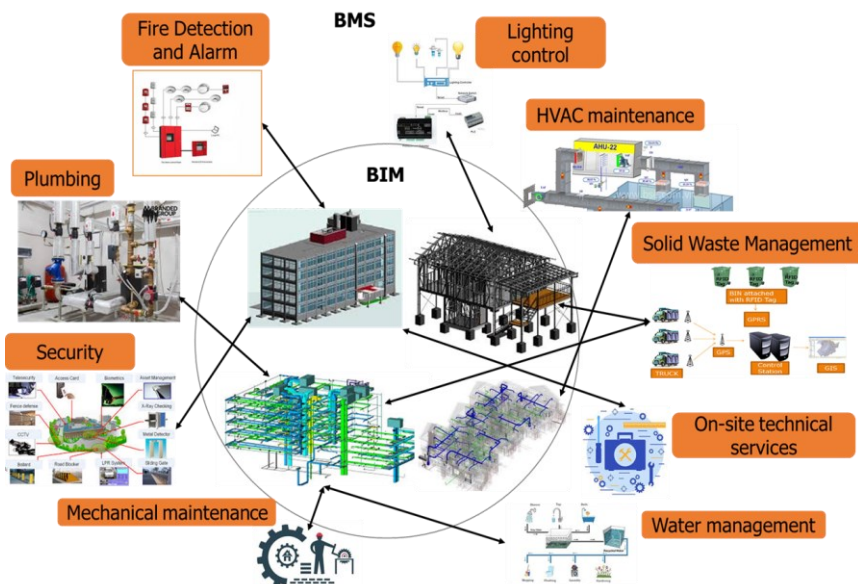
Figure 2. Proposed Integrated BIM-BMS Framework (Developed by Author).

BIM provides a dependable way to automate HVAC systems in buildings, making commissioning easier by generating HVAC control plans automatically based on BIM data (Sporr et al., 2020). While standardized BIM data, like that provided by the Industry Foundation Classes (IFC) standard, eases stakeholder information interchange and aids in the advancement of Building Automation and Control (BAC) systems, which ultimately leads to more efficient control strategy implementation, thermal characteristics can be incorporated into BIM models to enhance simulation accuracy and facilitate the design of efficient HVAC systems. Through simulation settings for validation, BIM enhances system performance and energy efficiency by realistically testing various HVAC configurations prior to installation.

By offering a three-dimensional representation of buildings, Building Information Models (BIM) are transforming the administration of physical access control. This allows administrators to assess spatial relationships and optimize access routes. By allowing users to pick target resources inside the model, BIM makes the process of creating access control policies easier to understand and more effective. Furthermore, by visualizing access logs on the model, BIM may be used to audit and analyze previous access records, improving monitoring and analysis capabilities. Overall, security administration procedures in complex environments are being improved by BIM's visualization, path computation, rule formulation, and audit functions (Skandhakumar et al., 2012).

The use of BIM (Building Information Modelling) technology, which provides risk assessment, data integration, real-time monitoring, visualization, and lifecycle management, greatly enhances the monitoring of safety in underground spaces. BIM helps to better comprehend the layout and possible hazards of subterranean structures by providing a visual representation through full 3D modeling. A full perspective of the structure is made possible by BIM's integration of several data sources, which improves decision-making for safety monitoring. Systems for real-time monitoring built with BIM enable constant surveillance of structural data to quickly identify anomalies. Additionally, by monitoring performance degradation over time and analyzing environmental elements that affect structures, BIM enables risk assessment and improves lifecycle management. In general, BIM improves subterranean safety monitoring by offering instruments for risk assessment, management, visualization, data integration, and monitoring (Zhang, 2020).

2. Methodology and Case Study

The research methodology followed for the study conducted is presented in the Figure 3. A hypothetical case example is chosen for exploring the integration of BMS and BIM. PANOPTICON is a surveillance tower in the GCR road of Gurgaon, Haryana, aiming to maintain peace and surveillance in 2075. It is situated near the Sikanderpur yellow line metro station and has its own monitoring room, surveillance methods, record rooms, and every other thing needed for the surveillance of the GCR. It is inspired by the Natural habitat of SNAIL and will act as the hidden CCTV of the entire GCR, allowing people to file complaints, get information, and act as a mini prison for criminals in the detention and isolation cell. The 3D models of the case study are shown in Figures 4 and 5.
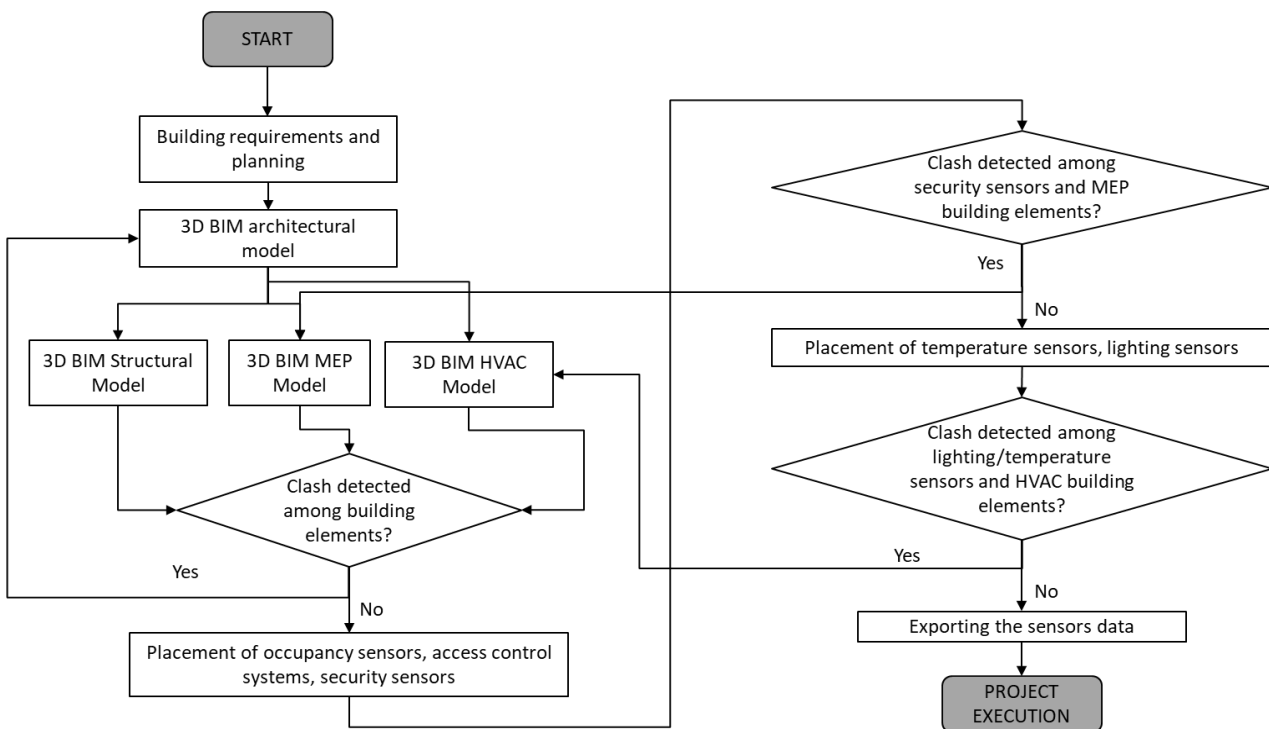
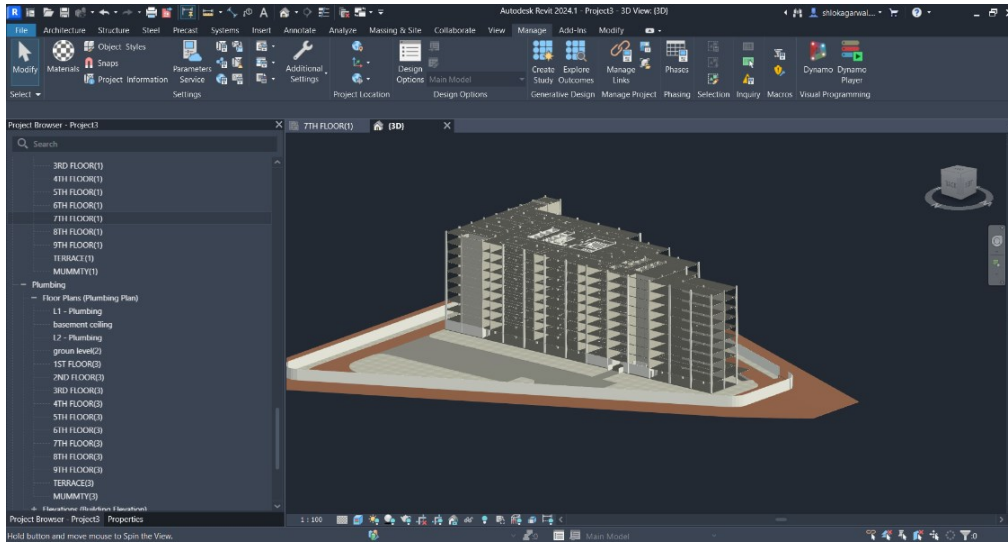**Figure 3.** Proposed Research Methodology.

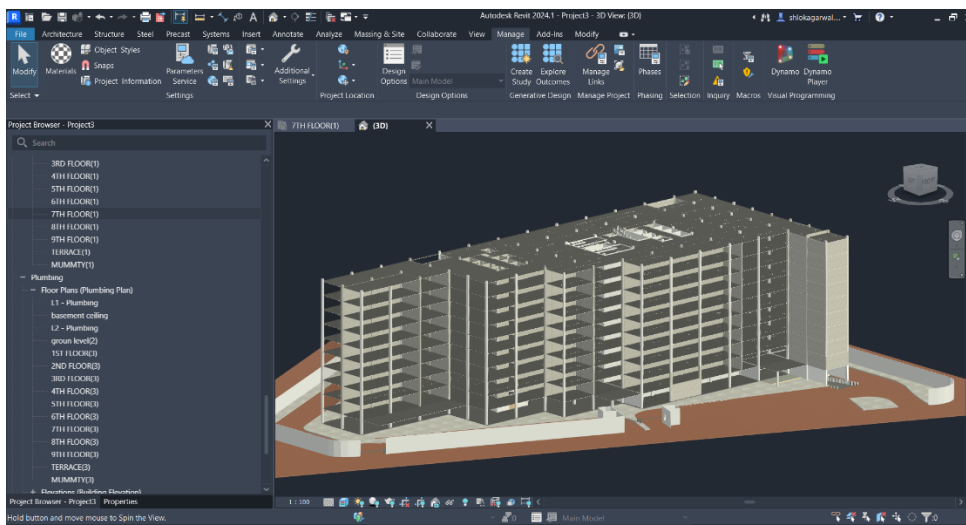**Figure 4.** 3D Model of Panopticon Building (View 1).

Figure 5. 3D Model of Panopticon Building (View 2).

3. Model Development and Results
This section presents the basement, ground floor, first floor and site plan with the Building Management Systems components placed across various levels.
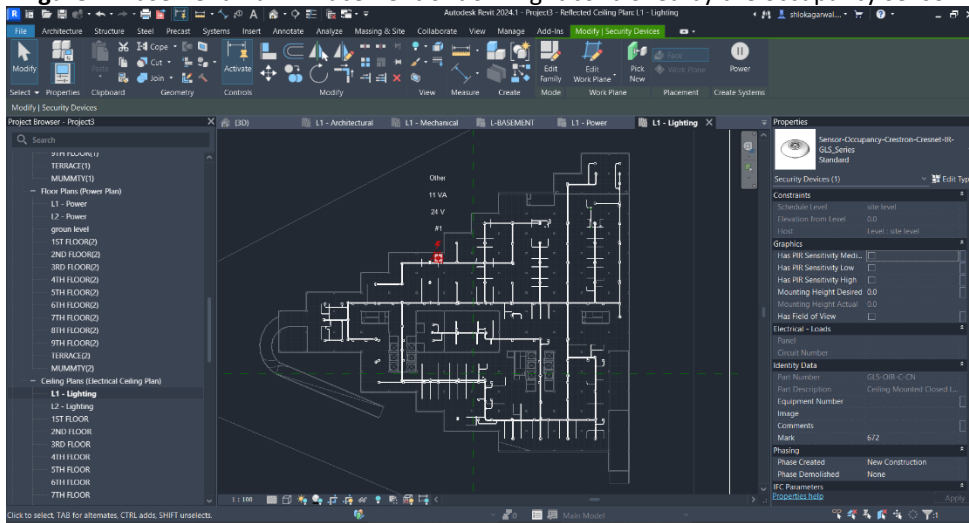
3.1. Basement Plan
The basement of this building with placement of BMS are as shown from Figure 6 to Figure 9. The basement is being used for building visitor parking and is situated on the surface parking. The basement of this building consists of a car park and BMS control room, fire water tank and other building services.
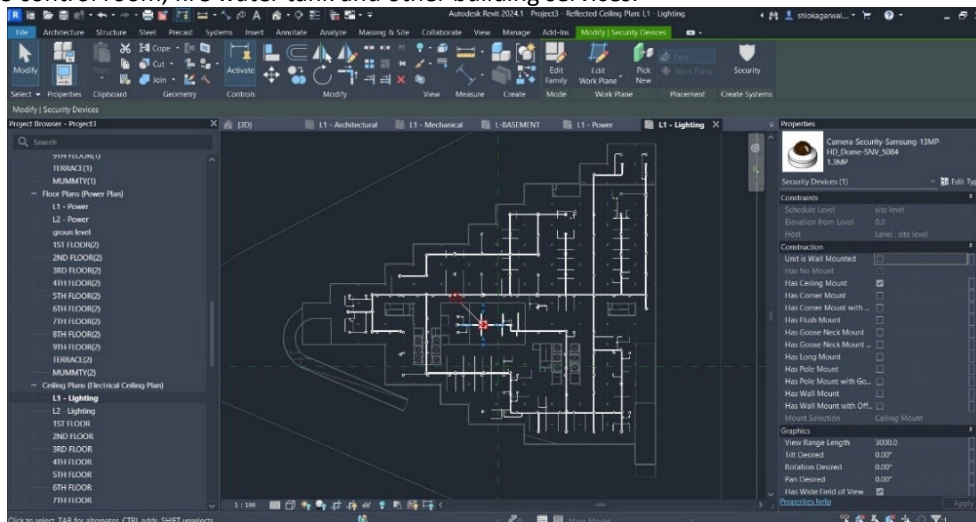
Figure 6. Basement Plan – Placement of camera for surveillance.
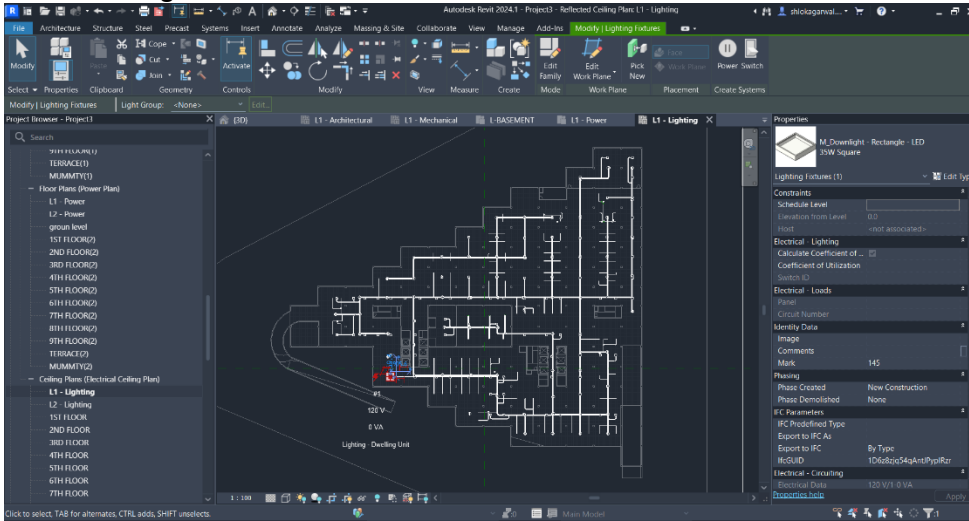
Figure 7. Basement Plan – Placement of downlight controlled by the occupancy sensor.

Figure 8. Basement Plan – Placement of Occupancy Sensor.
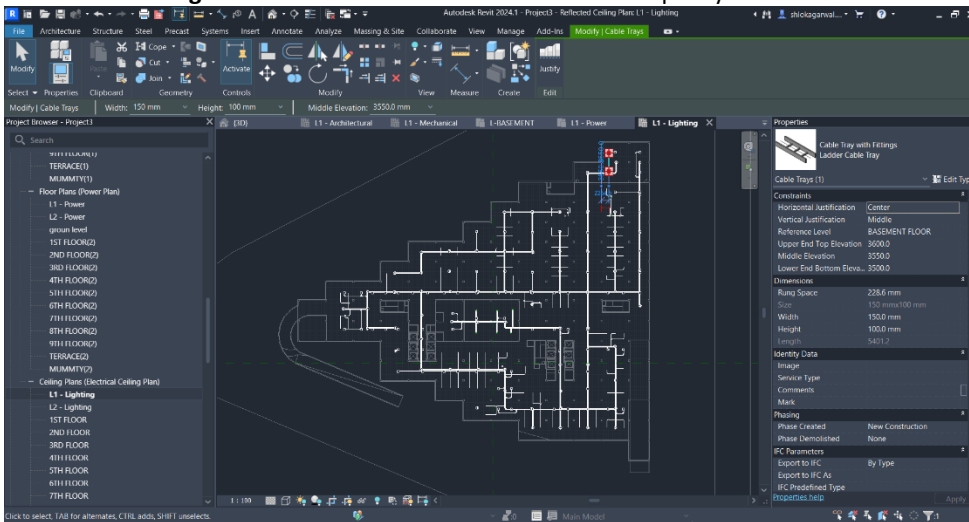
Figure 9. Basement Plan – Placement of cable trays connecting all the components to the BMS via conduits.

3.2. Site Plan

The site plan consists of the boom barrier, surface parking, streetlight, roads, pathways etc. is as shown in Figures 10 and 11.
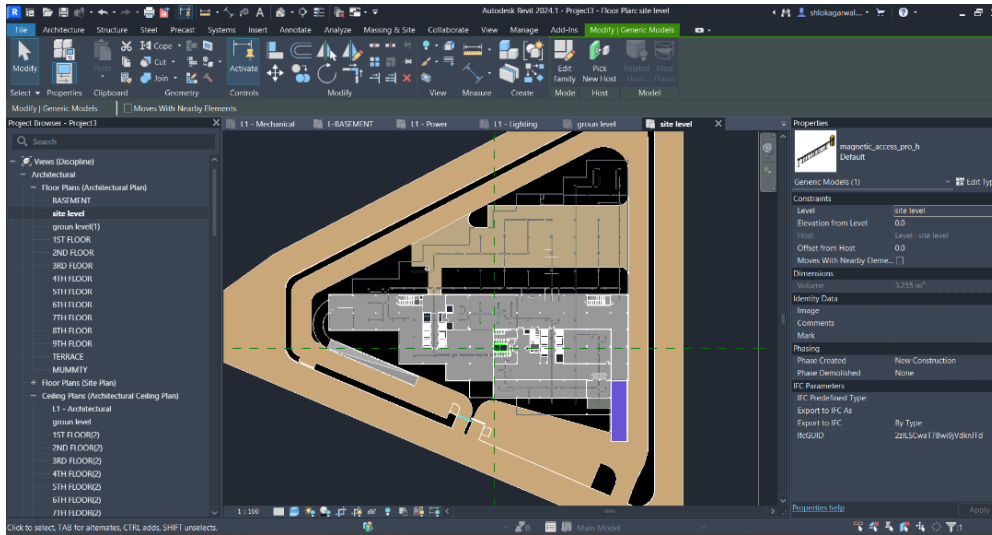
Figure 10. Site Plan – Boom barrier placement for access control on the site.
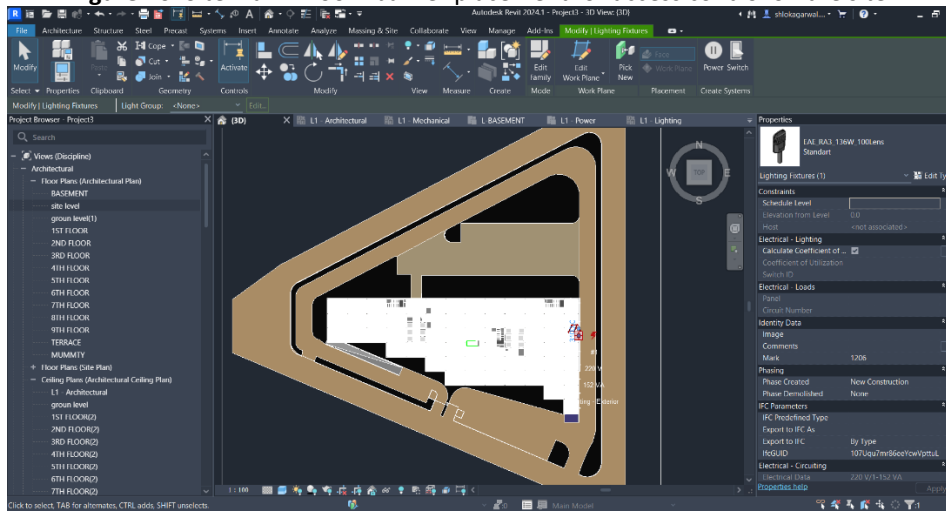

Figure 11. Site Plan – Street light placement for the external lighting.

3.3. Ground Floor

The ground of the building consists of the panel room, visitors' entry, lift lobby, admin office and other area which are secured using access card readers in the turnstile while the area for visitors' entry access is open to all. The placement of Building Management Systems is as shown in Figures 12, 13, 14 and 15.
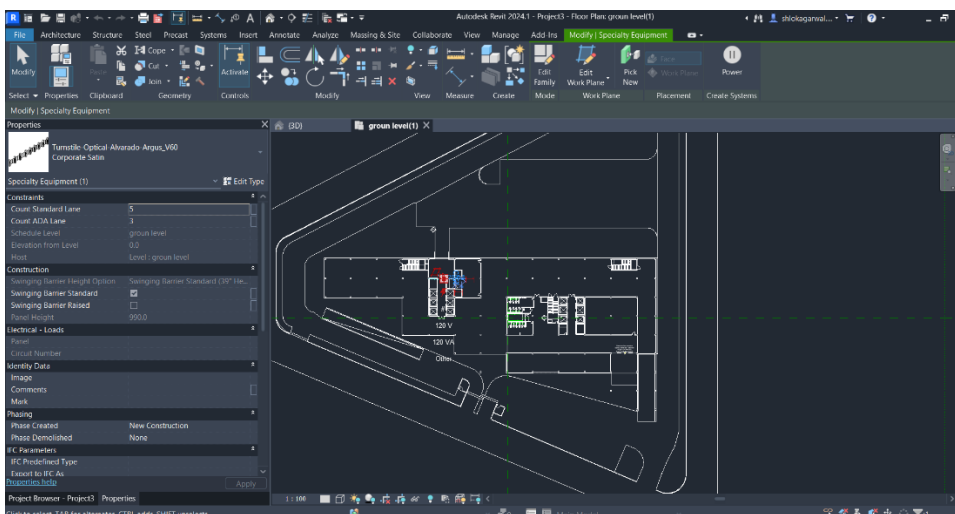

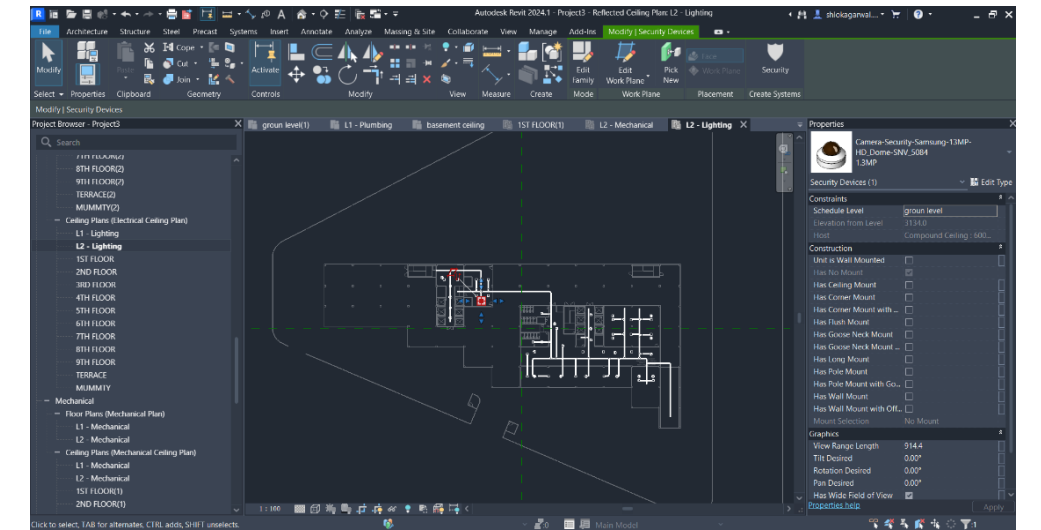**Figure 12.** Ground Floor Plan – Placement of turnstile for access control.

Figure 13. Ground Floor Plan – Placement camera for security.
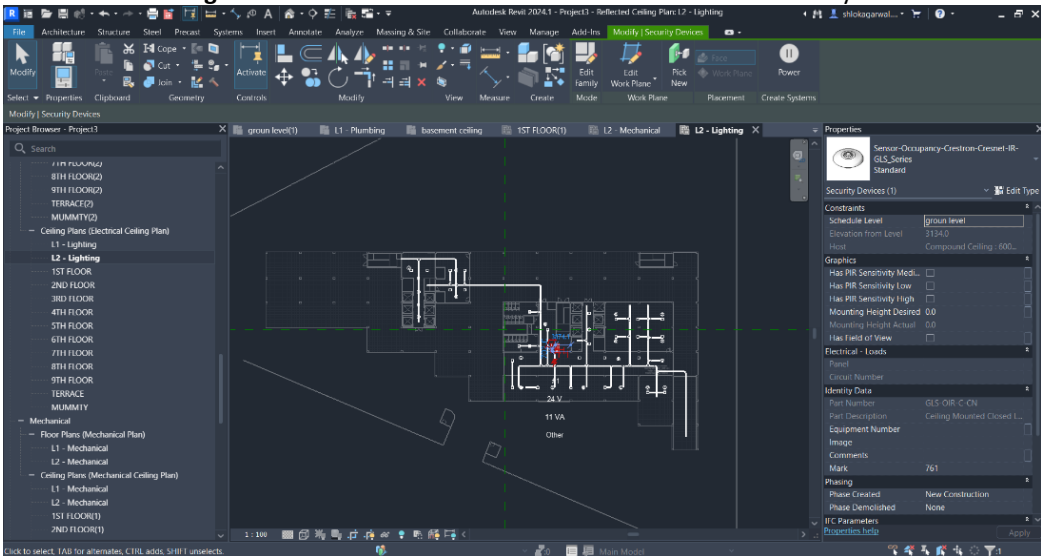

Figure 14. Ground Floor Plan – Placement occupancy sensors to monitor the input of people.
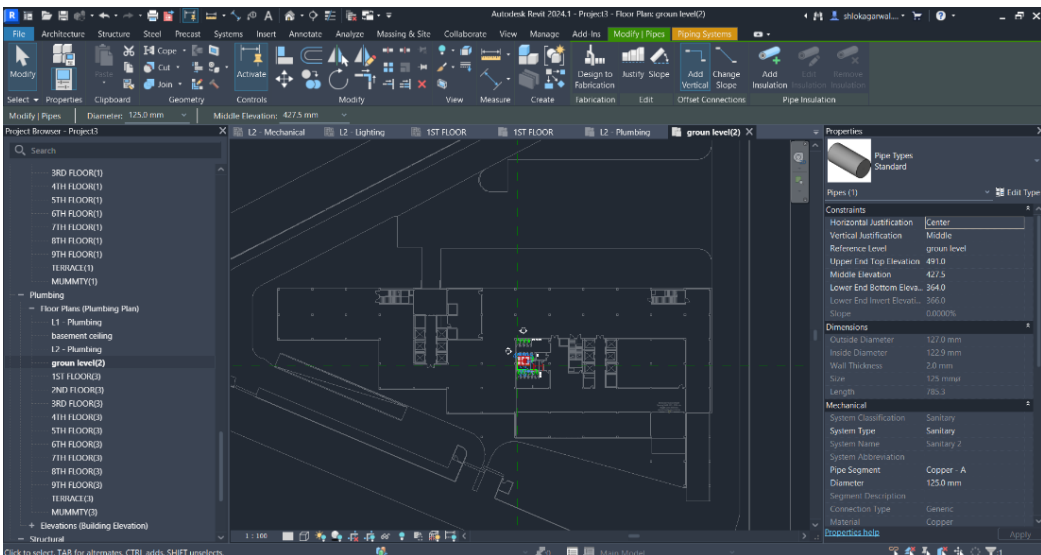

Figure 15. Washroom at ground floor with sensor based flow WB.

3.3. First Floor

The first floor of the building is especially for the employees of the building which has very strict access control with the use of RFID at every door and turnstile at the lobby as shown in Figures 16, 17 and 18. This floor is also under very high surveillance due to the record rooms and activities. The overall wiring frame model of the building is shown in Figure 19.
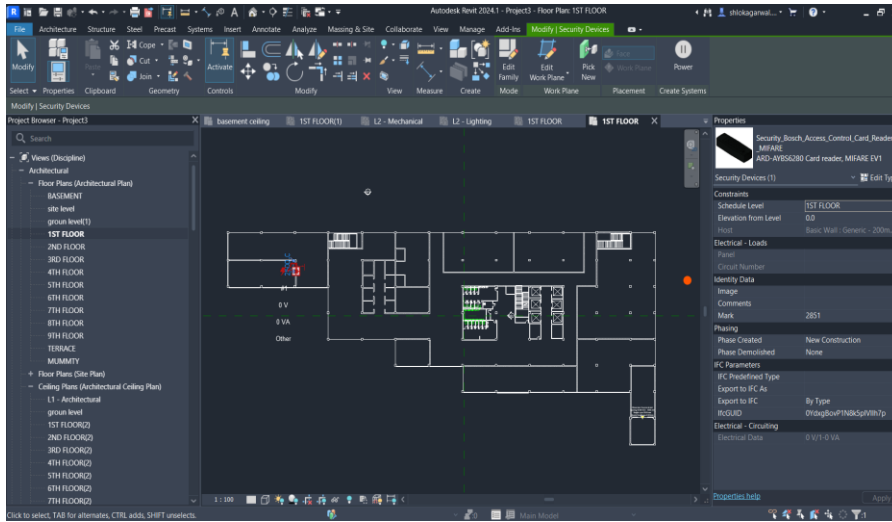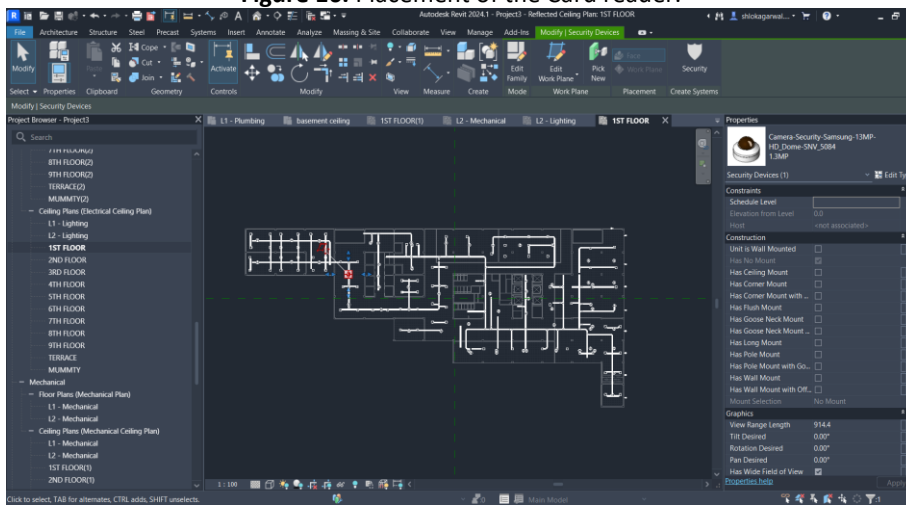
Figure 16. Placement of the Card reader.

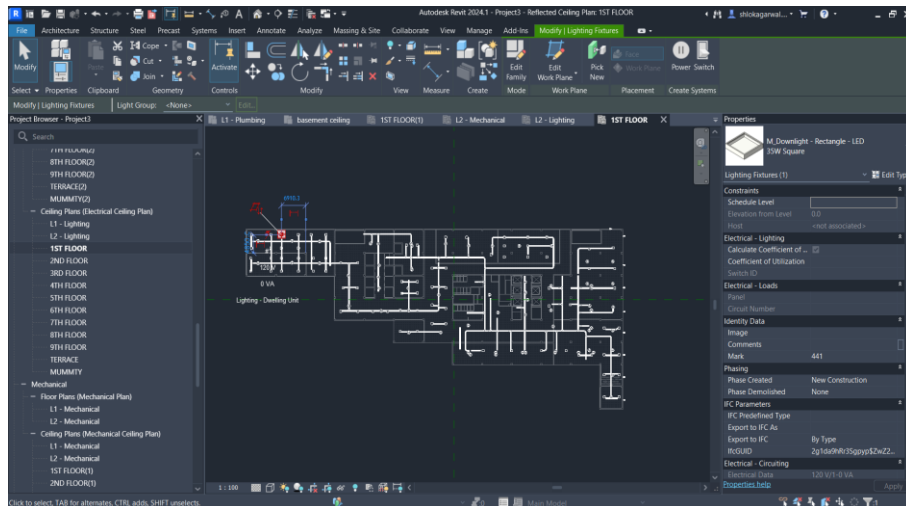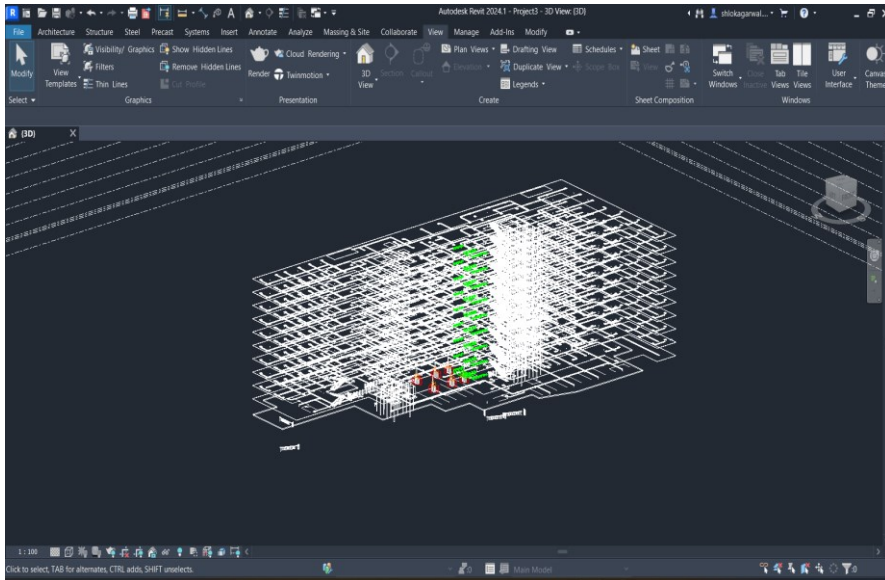**Figure 17.** Placement of the Camera.

Figure 18. Placement of the motion based light on the ceiling.

Figure 19. Complete model with all the BMS components (This view does not show the architectural and structural elements of the building).

4. Conclusions and Future Recommendations

The advent of Building Information Modeling (BIM) in the Architectural-Engineering-Construction Sector proves to be beneficial for planning Building Management Systems (BMS). By incorporating BMS into BIM modeling, the project benefits from streamlined planning processes, resource savings, and faster decision-making. This integration also aids in detecting clashes between several building components and building automation systems, which is crucial for ensuring efficient building design and operation. In this study, functionalities such as access control and surveillance were explored with BIM. However, in future, other building automation systems such as Fire safety, Acoustics, HVAC, Plumbing etc. can be seamlessly integrated, enhancing overall efficiency and effectiveness of building management systems. This study focused on access control and surveillance, future integration of other automation systems like Fire safety, Acoustics, HVAC, and Plumbing holds promise for enhancing overall efficiency and effectiveness of building management systems.

Acknowledgements

Conflict of Interests

The Author(s) declare(s) that there is no conflict of interest.

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