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Design and Integration of Smart MEP Systems using BIM for A Proposed Building

Pranay Kurve[1], Amit Tiwade[2], Pratiksha Pimpalkar[3], Vishwas Hadke[4], Sumit Umare[5] Praful Rode[6] Sagar Deogirkar[7]
final year student, Civil Engineering Department, Priyadarshini College of Engineering, Assistant Professor, Civil Engineering Department, Priyadarshini College of Engineering, CAD Centre, Dharampeth, Nagpur. Maharashtra India. Email pranaykurve9191@gmail.com

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Abstract: This study explores the use of Building Information Modelling could help address this problem for a residential building in Nagpur, Maharashtra. The building will be five stories tall, built with RCC. It covers an area of 15m × 24m. Each floor will have 360 sq. M. Of space making a built-up area of 2,160 sq. M. We used Autodesk Revit 2024 to create a model of the HVAC system, which has a capacity of 42 TR and includes 659 meters of ductwork. We also made a model of the distribution system with a connected load of 138 kW and 216 light points. The plumbing system we designed includes a water demand of 24,300 litres per day and 491 meters of supply pipe. For the firefighting system, we included 180 sprinkler heads and 653 meters of pipe. When we checked for clashes, we found 47 conflicts. We solved 44 of these issues before construction even started. The results were really significant. Changed the way the team understood the building. This paper explains what we did, how we performed the calculations, and what other teams can learn from our project to apply to their work.
Keywords: *BIM, MEP systems, Autodesk Revit, clash detection, HVAC G+5 building, NBC 2016, ECBC 2017 Nagpur, plumbing, firefighting, smart building.*

1. INTRODUCTION

Building Information Modelling offers a different approach. Instead of each discipline working from its own 2D drawing set and hoping for the best, BIM brings everything into a single coordinated 3D model. Clashes are found on screen, not on site. For MEP systems — which in a typical residential building account for 40 to 60 per cent of project cost — the difference is substantial.

The building this project focused on is a G+5 RCC structure in Nagpur, Maharashtra, with a footprint of 15 × 24 meters. It was selected because it represents a building type that is very common across Indian Tier-2 cities, yet BIM adoption for such projects remains low. The aim was to see how far a student team could take BIM-based MEP design for this typology, from first calculations through to a coordinated model, and to document what was learned along the way.

1.1. Objectives

- The modern MEP system uses BIM for improved coordination.
- To apply clash detection and avoid rework in design.
- To integrate smart meters within the BIM model.
- To evaluate the social, economic, and environmental impact of smart MEP integration.

1.2. Scope

The study looks at the proposed building in detail across all six floors. The MEP design is developed to LOD 300, which is sufficient for coordination, quantity takeoff, and tendering, but does not include fabrication drawings. Energy simulation and post-occupancy monitoring are not included in this paper, but both are noted as areas for future work.

2. LITERATURE REVIEW

The story of BIM in construction is now largely documented. Azhar (2011) published what has gone on to become one of the most cited overviews of the benefits of BIM, where he observed that the technology always reduced both rework costs and the time taken for coordination across all the projects he studied [1]. Less well covered, however, has been the unevenness of adoption, especially in MEP design and especially in India. Jing et al. (2019) investigated the use of BIM-sensor integration for piping maintenance and found that even where models had been adopted, only around half were being actively used in operation and maintenance [2]. The model was created, the project was delivered, and the model was left on a server and never touched. Edirisinghe and Woo (2021) described BIM as a possible 'single source of truth' for building management, but observed that this could only be realised where the model was up to date and where FM staff knew how to work with it [3]. In terms of MEP coordination, Kim et al. (2015) reported on a 65 per cent reduction in clashes observed on-site where BIM-based coordination had been used effectively on a hospital project [4]. Love et al. (2014) quantified the cost of design clashes that go undetected—the ratio of design-to post-construction correction was approximately 1:10 in their findings [5]. This ratio warrants reconsideration. A clash that takes an hour to correct in Revit may take ten hours or more to correct on site. Tang et al. (2019) reviewed BIM-IoT integration and found that, while the field is progressing, the lack of standardisation is a barrier [6]. Mannino et al. (2021) developed practical Revit-Dynamo workflows for the integration of sensor data with building models, a facet directly applicable to the integration of smart MEP outlined in Section 4 of this paper [7]. Within India, the application of BIM in MEP design is limited in Tier-2 cities, with Patel and Desai (2020) citing skill shortage and lack of standardised workflows as the primary barriers [8]. This study is a direct response to this gap using a student team, commercially-available software, and a real building type to demonstrate what is possible within these constraints.

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METHODOLOGY

The workflow for this work package had six phases. We need to view these phases as an iterative process in which we go back and revise decisions, as is how real Building Information Modelling projects are done in our experience.

3.1 Data collection and base model

We started with a set of AutoCAD drawings showing the layout of the proposed G+5 building. The floor plan from 4 October 2025 shows the 15 × 24 meter area, including bedrooms, a living and dining area, a kitchen, bathrooms, balconies, a staircase, and a lift shaft. We imported this into Autodesk Revit 2024. Used it to build the architectural base model. We modelled the walls as Basic Wall families, with the bottom at ground level and the top at the floor above. In the Revit properties, we see that 56 wall elements were placed on the Ground Floor

The Project Browser was set up from the start with sections for Floor Plans, Ceiling Plans, 3D Views, Elevations, and Structural Plans for each floor, as Ground F and Fifth F. Doing this saved us a lot of time later when we needed to add the mechanical, electrical, and plumbing disciplines.

3.2 MEP modelling sequence

We modelled the electrical, plumbing, and fire-fighting systems as separate but linked parts within the same Revit project file. We did the heating, ventilation, and air conditioning system first because it usually takes up most of the ceiling space. Then we did the cable routing, followed by the plumbing system, and finally the fire-fighting system. There is a reason for doing it in this order: the same priority we use in multi-disciplinary coordination meetings, where the heating, ventilation, and air conditioning system goes first.

3.3 Clash detection

Once all four MEP disciplines had been captured, Revit's native Coordination Review was employed to carry out automated clash detection. Clashes were classified as hard (true physical intersection), soft (clearance rules), or workflow (sequencing clash). All clashes were logged, assigned to the discipline that caused the clash, and resolved by rerouting or resizing. Three coordination review iterations were required to clear all major hard clashes.

3.4 Quantity takeoff

Ductwork, piping, cable trays, conduits, and MEP fixtures were quantity-scheduled directly from the Revit model. The results from this were exported from Revit and compared with manual takeoffs performed on the same drawings. See Section 5.

3. MEP SYSTEM DESIGN AND CALCULATION

All sizing is done from basics as per the Indian standard. This is a broad overview of the calculations. The details are available in the project documents.

3.1. Building framework

Parameter	Data	Note
Area	15.0 x 24.0 m	Approved plan
Floor area	360 sq. m.	15 x 24
Height of the ground floor	3.5m	Parking
Height of the upper floor	3.0m each	Residential, F1 to F5
Total floors	G+5=6	Standard G+5 building
Total Height	18.5m	3.5+(5*3.0)
Total BUA	2,160 sq.m	360*6
Climate zone	Hot-Dry	ECBC 2017
Occupancy	30 per floor	NBC2016: 12sq. m/ person

Table 1: Building Design Parameter

3.2. HVAC – (F1 TO F5)

Cooling load is calculated using an ASHRAE method and modified for hot, dry Nagpur weather.

So, the area per ton of refrigeration for this type of climate and building is 37.16 square meters. So, the total cooling load is 2,160 divided by 37.16, which is 58.1 tons. That is what is needed.

So the installed configuration is 2 × 2-ton split AC plus 2 × 1.5-ton split AC per floor, for a total of 7.0 tons per floor or 42.0 tons across all floors. The difference between this and what is needed is intentional. We know not all rooms will always have cooling requirements at the same time, and the inverter units are running as people use them in India, not for the hottest outdoor conditions. For air, the NBC 2016 part 8 says we need 0.3 cubic meters per second for every 100 square meters in residential buildings. So, the total fresh air needed is 6.48 meters per second, which is 23,328 cubic meters per hour. The main supply duct, with swirling air at 5.0 meters per second, is 1,400 by 930 millimetres and is made from GI sheet.

Item	Qty per floor	Total 5 floors	Unit
Split AC unit (2TR)	2	10	NOS
Split AC units	2	10	NOS
Installed AC capacity	7 TR	35 TR	--
Supply ductwork	102 m	540 m	m

Table 2: Quantity Takeoff of HAVC – Residential floor

3.3. Electrical – 6 floor

Load calculation has been done as per NBC 2016 Part 8, ECBC 2017 LPD norms. The lighting power density target of 15 W/sq.m., which is the ECBC 2017 upper limit for residential buildings, translates to a lighting load of 5.4 kW per floor for a 360 sq.m floor area. Power outlets contribute 7.2 kW (20 W/sq.m.), HVAC 8.4 kW (7.0 TR × 1.2 kW/TR), and miscellaneous loads 2.0 kW, resulting in a connected load of 23.0 kW per floor. A diversity factor of 0.70 (per IS 732) yields a demand load of 16.1 kW per floor. The total demand for six floors is 96.6 kW. The main LT panel was sized 200A, 415V, 3-phase (with 25% spare as per IS 732). Sub-distribution boards were 100A, 230V on each floor.

Item	Upper floor	Ground	Total
Connected load	23.0 kW	14.0 kW	129.0 kW
Demand load	16.1 kW	11.2 kW	91.7 kW
Light points	36	15 (parking)	195 NOS
Fan points	18	0	90 NOS
Socket outlets	45	10 EV	235 NOS
AC dedicated	4	0	20 NOS
Subdistribution	1 per	1	6 NOS

Table 3: Electric load of all six floors summary

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3.4. Plumbing – 6 floors

IS 1172 states 135 litres/person/day for residential buildings. So, with 30 persons /floor across 6 floors (total 180), the daily demand is 24.3 KLD (24,300 litres). Thus, the underground sump was sized for one-day storage at 24.3 KL, and the rooftop OHWT at 12.2 KL (50% of daily demand). Supply riser was sized at 40mm NB GI pipe (IS 1239) based on a peak flow velocity of 1.5 m/s, and branch pipes to individual fixtures are 25mm NB GI. Total supply pipework is 491m across all floors. Sanitary drainage is routed through a 100mm NB PVC soil stack and a 75mm NB waste stack with 30m of branch drainage per floor, totalling 227m of drainage pipe.

A rainwater harvesting system is also provided to the building. Nagpur receives about 1,100mm of rainfall. With a roof area of 360 sq. m. and a runoff coefficient of 0.85, the annual collection potential is 337 KL, more than sufficient to offset the building's demand for non-potable water.

4.5 Fire fighting

As per NBC 2016 Part 4 and IS 15888, the building is of Light Hazard type, and thus one sprinkler head is required per 12 sq. m. (360 sq. m. per floor, 30 heads per floor, 180 heads in total). The sprinkler system is fed from a dedicated fire water storage tank of 90 KL (the NBC 2016 minimum is 25 KL; sprinkler demand calculated to 90 KL, which is the governing figure).

Two wet riser hydrant landing valves of 65mm (IS 5290) are supplied on each floor and are fed through a 100mm NB GI rising main. The fire pump set is sized at 1,200 LPM @ 7 bar. Thirty-six addressable optical

Item	Per floor	Total	Standard
Sprinkler heads (60°c, K-80)	30	180 NOS	IS 15888
Sprinkler pipework	108m	648m	IS 1239
Fire water storage	-	90 KL	NBC 2016 Pt. 4
Fire pump set	-	1,200	IS 15888
Smoke Detector	6	36 NOS	IS 2189

Table 4: Fire Fighting System Quantity

4. RESULTS AND DISCUSSION

5.1 AutoCAD Base Drawing

The original architectural floor plan was drafted in AutoCAD (Revised Date: 4-10-2024). Building footprint: 15.00 m × 24.00 m. The plan consists of Bedrooms, Bathrooms, Dining, Lobby, Kitchen, Wash, Toilet, Balcony, etc. areas placed around the central lift and staircasecore.

Figure 5.1. AutoCAD Ground floor Plan – 15m x 24m

5.2. BIM model – Revit screenshots

The following figures are actual screenshots of the Autodesk Revit 2024 project model. Fig. 1 and Fig. 2 show the finished exterior of the G+5 building, along with the site landscaping, trees, and ground-floor parking columns. Figs. 3 to 5 are the real plumbing MEP layouts in the Revit colour scheme; pink and magenta are used for sanitary drainage.

Figure 5.2 (i) back elevation 3D view with floor level in Revit

Figure 5.2 (ii) front right 3D view with floor level in Revit

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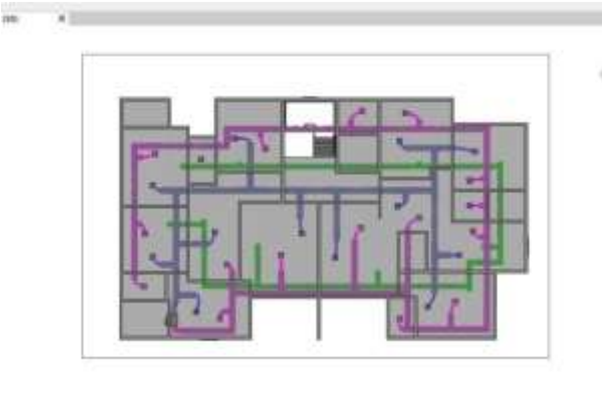

Figure 5.3 Actual Revit Plumbing layout of floor plan where pink – drainage/ hot water, green – cold supply)

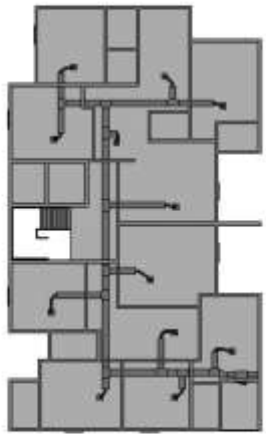

Figure 5.4 Actual Revit Plumbing layout of floor plan showing soil stack position and branch connection

5.2.1 MEP 3D model – Pipe network in full building
Figures 5.5 to 5.7 illustrate the full MEP pipe network modelled in Revit across the six floors of the building. They are real Revit screenshots: South elevation view (Fig. 5.5), North elevation plan view (Fig. 5.6), full building 3D isometric (Fig. 5.7). Colour is as per Revit's default MEP discipline colours: sanitary drainage and hot water pipes are pink and magenta respectively, the cold water supply network is green, soil and waste stack network is grey-blue, structural components and conduit are black. The status bar at the bottom of each image reads 'MEPF (Not Editable)', indicating that the MEP system is modelled in a linked file (a standard federated BIM coordination practice in Revit).

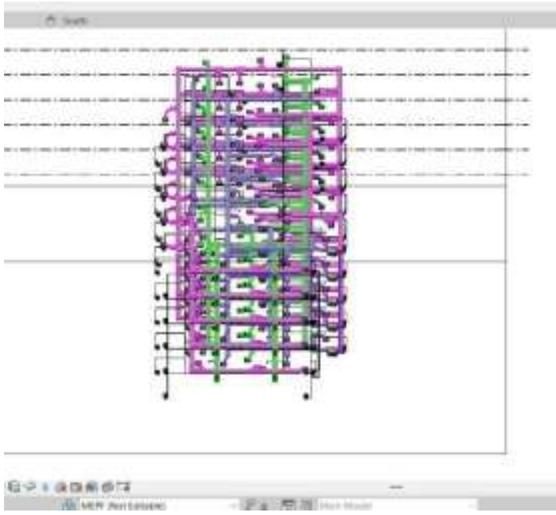

Figure 5.5 MEP pipe network- Elevation South of all 6 floor vertical rise and floor level row horizontal rows

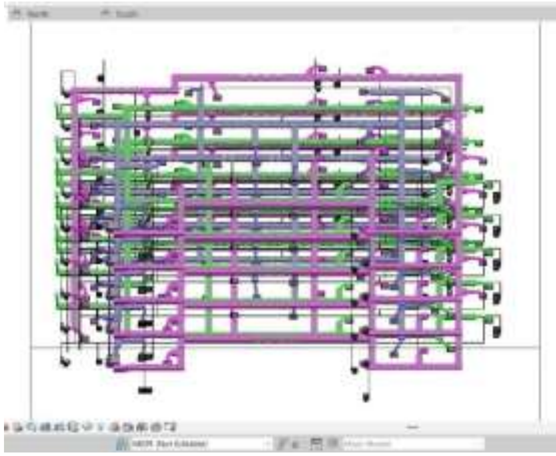

Figure 5.6 MEP pipe network- Elevation North of all 6 floors of overlaid disciplines.

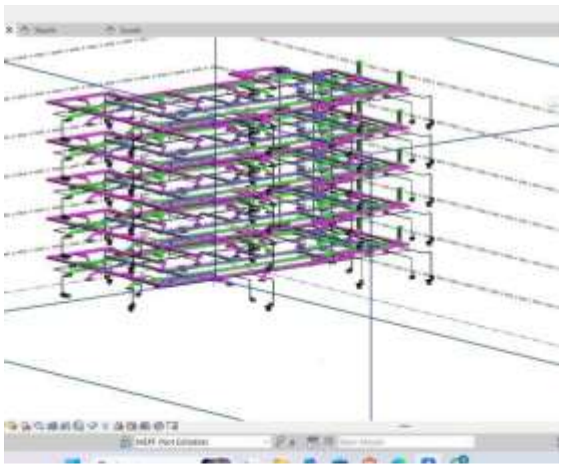

Figure 5.7 MEP pipe network- Full building 3D Isometric view of MEP of all 6 floors of overlaid disciplines.

5. CONCLUSION
This paper presents the design and coordination of the Mechanical, Electrical, and Plumbing systems for a G+5 RCC building in Nagpur using Building Information

Modelling. The authors of this paper would like to share the lessons they learned from this work.
The outcomes of this work are straightforward. The Heating, Ventilation, and Air Conditioning system has been designed for the five floors. This means we need a cooling capacity of 48.4 tons of refrigeration, and we have installed 20 units with a total capacity of 35 tons.
The electrical system has been designed differently for the ground and residential floors. The ground floor needs an electrical demand of 14.0 kW. The residential floors need 23.0 kW each. The connected load is therefore 129.0 kW, and the demand is 91.7 kW.
The building requires 20,300 litres of water per day for 160 people.
The fire safety system includes all six floors with 180 sprinkler heads and a 90 kilolitre fire water storage tank. During the coordination of the Mechanical, Electrical, and Plumbing systems with Building Information Modelling, we identified 47 problems. Forty-four of these problems were corrected before the project exited the design phase. This is significant because, in a 2D design process, the site work crews would have discovered these problems and had to redo the work, which is costly and annoying for all involved.
The floor-height and floor-count errors made during an earlier version of this work are significant enough to warrant specific mention. The HVAC calculations had been run at the wrong height for all six floors and have been updated to apply only to the five residential floors. The HVAC installed capacity decreased from 42 TR (6 floors at the wrong height) to 35 TR (5 floors at the correct height), and the total duct length decreased from 659m to 540m. The plumbing and firefighting quantities were affected by the correction to the building height. The quantities reported in this paper are corrected. Future work will comprise energy simulation using a Revit model as a base, upgrading the model to LOD 400 for detailing to fabrication level, and a BMS integration framework that supports IoT-enabled monitoring of installed MEP systems.

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[7] Jing Chen, Tang, Xiong, and Wang published a paper in 2019 on building an information modelling-sensor-based platform for maintenance of MEP piping. It was published in ICSIC. The link is https://doi.org/10.1680/icsic.64669.055. BIM is used for maintenance improvement.
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[9] The code was published by the Ministry of Power, Government of India, in the Bureau of Energy Efficiency Code 2017.
[10] The IS 1172 code was published in 1993. The BIS published it. It is known as the Code of Basic Requirements for Water Supply, Drainage, and Sanitation.