CHAPTER 85

Integrating Building Information Modelling for Advanced Facility Management: Framework for Security Surveillance and Space Optimization

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ABSTRACT

Facility Management is an essential field of knowledge that basically ensures functionality, safety, and efficiency in buildings throughout their lifecycle. Nonetheless, conventional FM (Facility Management) often must cope with fragmentation in data management; reactive maintenance approaches; and challenges faced while combining various systems. The Building Information Modelling technology, or BIM, an innovative technology for the AEC sectors of Architecture, Engineering, and Construction, gives ample opportunities for re-orienting the FM process. This research investigates the potential for BIM to provide a positive improvement to security and surveillance as well as space management. The integration of BIM with emerging technologies like the Internet of Things (IoT), Artificial Intelligence (AI), and Radio Frequency Identification (RFID) forms the basis of this study, providing a conceptual framework for proactive and data-driven FM strategies. It puts special emphasis on the optimization of spatial layouts in improving monitoring, emergency response, and operational efficiency. Using simulation and data analysis through AnyLogic, it shows how BIM improves pedestrian flow, reduces congestion, and optimizes the CCTV camera coverage area. These findings reveal how it is crucial to ensure real-time data integration, interoperability standards, and user-oriented design when aiming for the seamless integration of FM systems. This research is among a growing body of literature in FM supported by BIM by bridging theory with practice, giving stakeholders a guide to adopting new sustainable, and scalable methods for facility management.

Keywords: Building Information Modelling (BIM); Facility Management (FM); Security and Surveillance; Space optimization; Radio Frequency Identification (RFID); Pedestrian flow analysis; CCTV coverage optimization; AnyLogic simulation.

1.0 Introduction

Background: Building Information Modelling (BIM) is one such technology that is impacting Architecture, Engineering, and Construction (AEC) (Zhang *et al.*, 2015b).

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Traditionally, the AEC community still made use of Computer-Aided Design (CAD) software to build geometric models of buildings. Within this environment, Building Information Modelling goes beyond CAD since it provides an all-encompassing digital model integrating both geometric and non-geometric data, enabling the stakeholders to manage the buildings during their life. All through the collaborative process, making wiser decisions, and keeping costs down by putting together all information in one place and updating the data in real time contributes to the development of smart, safe, and sustainable buildings. In this context, key terms include BIM, Facility Management (FM), IoT, AI, and RFID.

1.1 Research gap

Although BIM has shown great potential in FM, research gaps exist. For example, research does not yet allow for the automation of circulation modelling (Lin *et al.*, 2016); the dependence on user behaviour data in BIM-enabled models has seen limited exploration; the BIM-driven influence beyond the room level have remained inadequately supported by empirical evidence; and so on (Becerik-Gerber *et al.*, 2012a; Marmo *et al.*, 2019). In addition, there is a need for framework relating to BIM with IoT and AI for real-time monitoring and predictive maintenance in FM.

1.2 Objective

The primary aim of this research is to examine how BIM technology and other upcoming technologies can contribute to the improvement of FM in areas like security, surveillance, space management, and operational efficiency. That study further aims at the formulation of a conceptual framework to put BIM into FM, focusing on data-driven and proactive management strategies.

1.3 Scope

This research narrows its focus to building types-such as hospitals and educational institutions-to make the scope more manageable. Publicly available BIM databases and simulation tools like AnyLogic have been used for the study to analyse footfall, plan optimum CCTV footage and optimize space management. Lastly, the results aim to afford actionable insights into improving FM practices in new and existing buildings.

2.0 Literature Review

Literature review discusses that Building Information Modelling (BIM) has significantly contributed to Facility Management (FM) in various aspects of building not limited to preventive maintenance, asset management, energy efficiency, and occupant comfort monitoring (Becerik-Gerber *et al.*, 2012b; Zhang *et al.*, 2015a). BIM has been highlighted for improving FM already, for its worth in enhanced efficiency, sustainability, and saving in costswa (Marmo *et al.*, 2019; Wang *et al.*, 2013). BIM offers a full digital model, providing an

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associative representation of both geometric and non-geometric data (Giel & Issa, 2016; Lin *et al.*, 2016), enabling all stakeholders to manage buildings better throughout their lifecycles. With this integration of different information, more effective decisions are made available, while operational costs are reduced. They also aid in producing smart, safe, and sustainable buildings. For example, facility managers can access data in real-time for building systems such as HVAC, lighting, and security (Gouda *et al.*, 2020; Wen *et al.*, 2020) to make fully informed decisions that boost energy efficiency and occupant comfort. Furthermore, the ability of BIM to store and manage data through any point in the lifecycle of buildings enables information to be available and already set during upkeep, refurbishment, and future renovations (Gouda *et al.*, 2020), thus reducing downtime and hence expanding operational life-building further. However, challenges still exist in adaptation and implementation of BIM, these issues comprise:

2.1 Data integration

One of the primary challenges is the disparate nature of data (Becerik-Gerber *et al.*, 2012b; Marmo *et al.*, 2019) found across different systems and stakeholders. Integrating data from different sources into a unified BIM model remains an extremely complex task that often requires tremendous effort and resources. For instance, data from BMS, IoT sensors, maintenance logs, etc. very often sit in their data silos, preventing any uniform and thorough BIM model. However, this fragmentation can lead to inefficiency in ensuring that facility managers get what they need at the most opportune time.

2.2 High initial set up cost

BIM requires capital investments, which, at first, are on the high end (Kumar & Kothari, n.d.; Zhang *et al.*, 2015b), including software, training, and product infrastructure. It's a big hindrance for many organizations, especially the smaller ones. Although other benefits later the road, like operational cost reductions and improvement in building performance, are widely supported, the initial investment was among those constraints that severely curtailed some stakeholders from harnessing BIM. There are also other considerations, such as running costs of upgrading the BIM models, which could be extremely high, especially for large, complex buildings.

2.3 Limited empirical validation

While much of the literature emphasizes the theoretical benefits of BIM in FM, the actual benefits to be accrued through its use in real life have not yet achieved as much empirical verification (Marmo *et al.*, 2019; Wang *et al.*, 2013). At a certain point, such lagging empirical evidence was a major hindrance to the stakeholders in fully following the ramifications and merit of BIM adoption. For instance, while simulation studies have proven that BIM boosts energy efficiency, the degree to which that ultimately translates to energy savings once operational in buildings isn't widely understood. Moreover, there are claims regarding BIM

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having a more critical impact on occupant comfort, but there are very few real-world assessments on how BIM-enabled FM practices play in influencing occupant satisfaction and wellness.

2.4 Automated user behaviour data

Research has leveraged the automation circulation modelling with user behaviour data more fully within BIM-enabled models. (Pan & Chen, 2020) This is one perhaps majorly overlooked area ready for research which could improve FM operation. For example, better pedestrian flow modelling automation would enable facility managers to more easily identify and resolve areas of congestion. Data on user bias could be integrated into BIM modelling to make building management systems more intelligent and responsive to the brightness of a space according to preferences/settings.

2.5 BIM in building circulation and space management

Existing studies approach BIM's impact on circulation, surveillance, and space management in buildings (Turner *et al.*, 2021). For instance, it has been used to simulate pedestrian flows, locate points of congestion, and proceed to optimize the positioning of security cameras. Such implementations would reveal BIM assists in improving the essence of a building's operational efficiency and safety. In airports or hospitals or other large public buildings, modelling and analysis of pedestrian movement could be undertaken to reveal bottlenecks to facility managers, enabling them to make design alterations that could mitigate crowd buildups and allow for the unhindered flow of people (Pan & Chen, 2020).

The placement of security cameras and surveillance equipment by pedestrian movement analysis, which would further determine their optimal location for the efficient safeguarding of a building. Hence, research concerning BIM has been wide-ranging, extending to its integration with other technologies such as IoT and AI (Gouda Mohamed *et al.*, 2020; Wen *et al.*, 2020). Even if these technologies provide an exciting vision for real-time monitoring and predictive maintenance in FM, quite a few of them have built the scope for integration with advanced technologies (Wang *et al.*, 2013; Zhang *et al.*, 2015b).

IoT devices can enable real-time visibility of building conditions regarding temperature, humidity, and occupancy levels, while AI can act upon the information and help forecast maintenance needs through optimized resource allocations. Integration of BIM with IoT and AI would enable facility managers to transition from reactive maintenance to preventive or even predictive maintenance, anticipating issues before they escalate into crises and decreasing the chance for unexpected downtime. Further, BIM-IoT-AI integration would offer advanced customization of building automation systems, such as smart lighting and HVAC systems that adjust in real-time according to occupancy and environmental conditions (Gouda *et al.*, 2020).

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3.0 Methodology

3.1 Case Study: NICMAR University, Pune

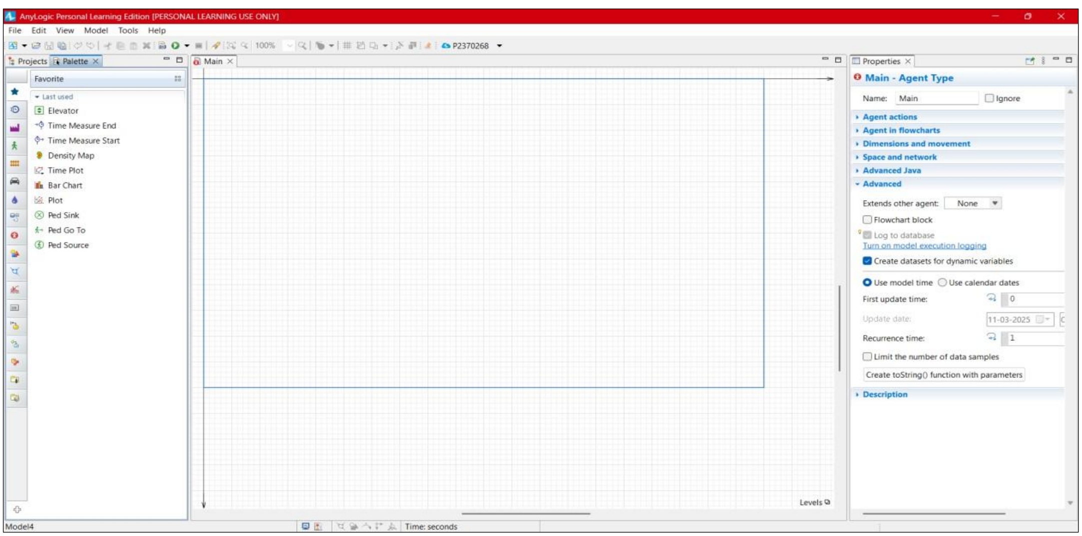
Problem Statement: NICMAR University experiences varying levels of pedestrian traffic through two primary gateways: Gate No. 1 and Gate No. 2. Primarily, Gate No. 2 experiences extreme choke points during peak hours that impede pedestrian movement while heightening security concerns. The objectives of this case study shall include:

- Investigation of pedestrian flow at both gates.
- Identification of bottlenecks and congestion points.
- Providing optimised coverage for the CCTV cameras.
- Proposed architectural and operative changes to enhance pedestrian flow and safety.

Data/ Software used

- *BIM Model:* A digital 3D model of NICMAR University, Pune was employed to provide the Campus layout with buildings, pathways, and entry Gates.
- *Google Earth:* Satellite imagery was used to trace the building footprint and pathways for existing structures.
- *Software Tools*
  - AutoCAD: For preparing CAD templates from the BIM model.
  - AnyLogic: For pedestrian flow simulation and congestion analysis.
  - Navisworks: For clash detection and integrating elements for security surveillance.
  - Data Sources: Data on pedestrian movements, requirements for CCTV covering, and architectural layouts.

Figure 1: AnyLogic New Project Screen



3.2 Step-by-step procedure

Steps taken in the case study read as follows:

- Data collection

Aim: For precise architectural layouts for NICMAR University with respect to gates, pathways, and other important buildings.

Process:

  - Establishment of a top-draw view layout of the campus using the BIM model.
  - Building footprints and pathways for existing structures were traced using Google Earth.
  - Exporting the layout into AutoCAD to develop a CAD template of DWG format.

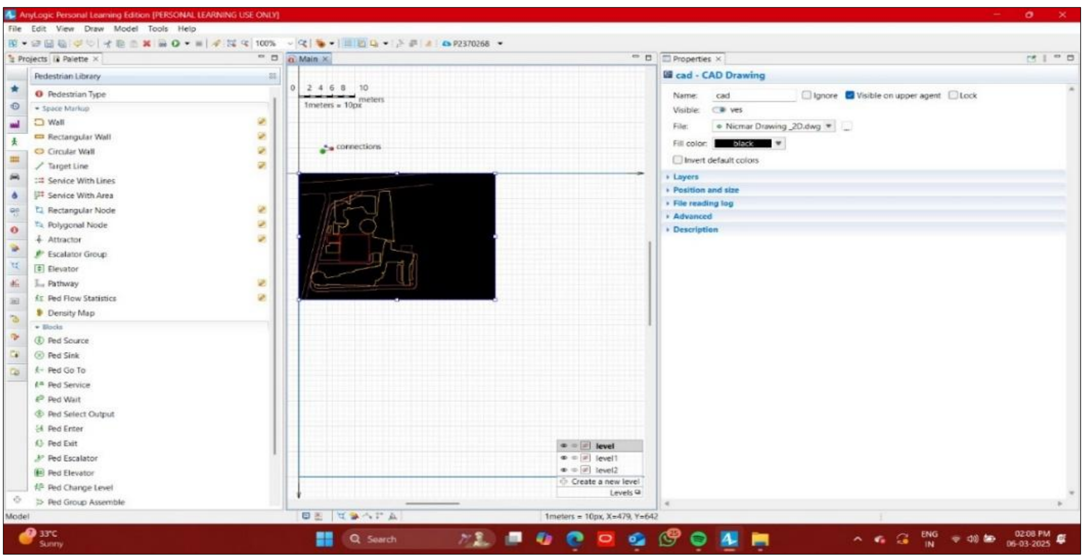
- CAD Template Creation

Aim: To create a detailed CAD template of the university layout for the purposes of simulation.

Steps Taken:

  - The BIM model was imported into AutoCAD.
  - Using the polyline tool, buildings, pathways, and entry gates were traced.
  - There were layers made to represent the walkable paths, obstacles, security zones, and restricted areas.
  - Finally, this CAD template was saved in DWG format for further use in AnyLogic.

Figure 2: CAD File Imported on Anylogic Workspace



- Import of CAD Template into AnyLogic

Aim: To utilize the CAD template as a reference layer for pedestrian flow simulation.

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Steps Taken:

- In AnyLogic, a new project was created, and the Pedestrian Library was selected for simulation purposes.
- The CAD template was imported into AnyLogic (as DWG file) and scaled to correspond to real-world dimensions.
- Crossways and entrances into buildings were set directly into the simulation environment

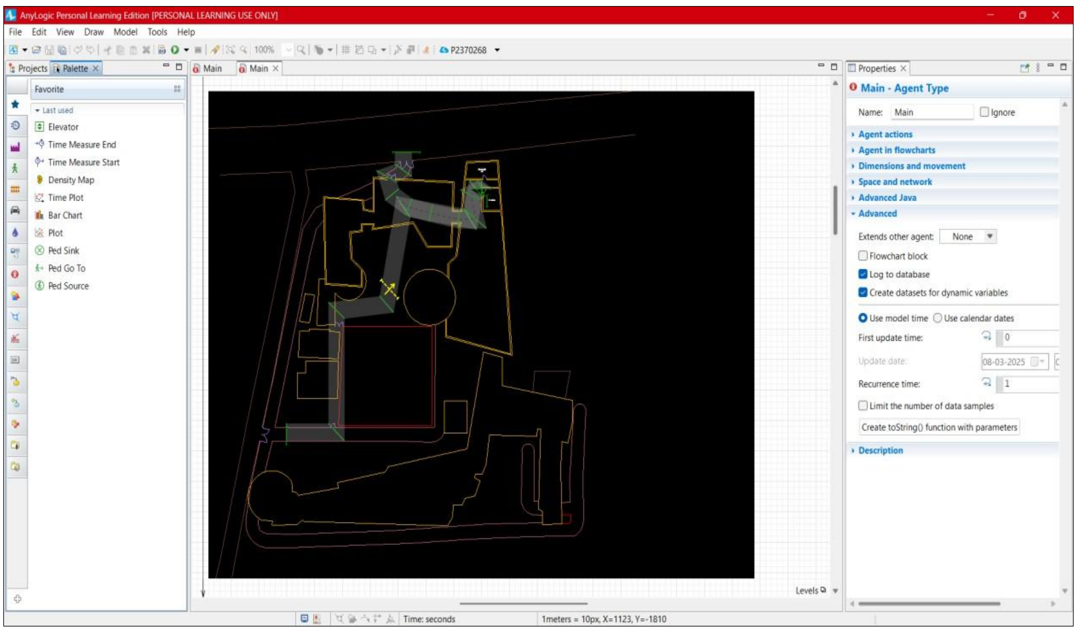
4.0 Setting Up the Simulation of the Pedestrians

Aim: To simulate pedestrian movement from Entry Gate No. 1 and Entry Gate No. 2 for congestion and flow pattern analysis.

Steps Taken:

- Pedestrian sources are set up at Entry Gate No. 1 and Entry Gate No. 2.
- Pedestrian destinations are set up at essential locations like the Vice Chancellor's Office.

Figure 3: Pedestrian Library with Pathway Marked



- Arrival rates were adjusted to reflect pedestrian density during peak hours in real-life situations.

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- Paths and walking areas were drawn up with the help of the Pedestrian Library in AnyLogic modelled on realistic movement.

Figure 4: AnyLogic Simulation Interface and Display

Figure 5: Heat Map of Pedestrian Movement

5.0 Execute the Simulation

Objective: Analyse pedestrian flow and identify points of congestion.

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Process:

- The simulation was run while viewing the movement of pedestrians with dots of various colours.
- Heat maps were generated to show highly congested areas.
- Essential statistics were recorded, which include average flow time, total distance walked, and speed of pedestrians.

Figure 6: Average Time Taken My Multiple Pedestrians

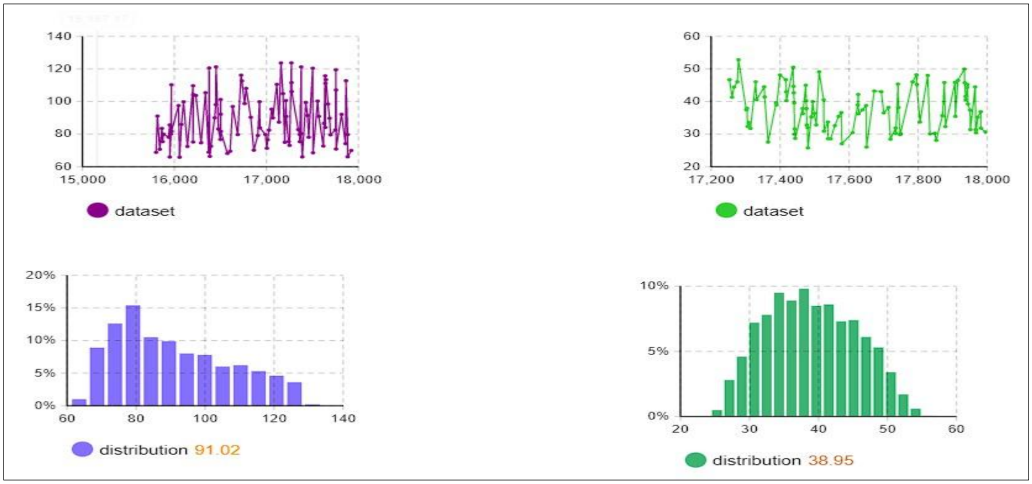

Figure 7: Simulation of Pedestrians as Coloured Dots

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Figure 8: Simulation Window

6.0 Optimize CCTV Coverage

Objective: Establish an optimal number and placement of CCTV to ensure complete coverage.
Process: Step-by-Step Methodology for Determining the Optimum Number of Surveillance Cameras
Introduction: Surveillance camera placement is critical for ensuring comprehensive security coverage in facility management. This document outlines the step-by-step methodology used to determine the optimal number of cameras required for effective surveillance, using a combination of Field of View (FoV) analysis, spatial coverage calculations, and pedestrian movement data. The approach is supported by relevant research and mathematical models.
Step-by-Step Approach
Step 1: Estimating the Surveillance Area

- For Greenfield Projects, the Building Information Model (BIM) was used to extract the architectural floor plan and determine the total surveillance area.
- For Brownfield Projects, Google Earth and satellite imagery were used to derive a 2D map, which was converted into a CAD template for analysis.
- The estimated area was then verified against actual dimensions and cross-validated with available facility blueprints.
  Formula Used: $A=L\times W= L \setminus W$ where: (Davies & Velastin, 2005)
- A = Total surveillance area (sq. meters)
- L = Length of the facility
- W = Width of the facility

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Step 2: Camera Field of View (FoV) Analysis

- Each camera has a defined Field of View (FoV), which determines how much area it can cover.
- The horizontal and vertical angles of coverage were extracted from camera specifications.
- A 3D model in AnyLogic was used to visualize the coverage overlap and blind spots. Formula Used: $A=2\times D\times (\tan\theta/2)$
- A = Area covered by a single camera
- D = Maximum effective distance of the camera
- θ = Camera's horizontal field of view

Calculations: So here we are assuming that the len on the camera is of 60 degrees that is a standard lens, and we have calculated from google maps that the area of college is 9 acres. Hence;

- θ = 60 degrees
- D= 30 metres (Assumed effective range of the camera
- Each camera effectively covers 1038.6 m^2.
- The number of cameras needed is:
- No of Cameras=Total Area covered/Area covered by camera×η
- η=0.85 (85% overlap factor for minimal blind spots)
- Since we round up to ensure full coverage, the optimum number of cameras required is 42 cameras.

Step 3: Simulation and Validation

- The AnyLogic pedestrian simulation was used to analyse foot traffic patterns and high-density areas.
- Surveillance camera placements were optimized by adjusting the camera angle, height, and coverage to maximize visibility in high-traffic zones.
- The model was tested iteratively to ensure coverage efficiency.

Conclusion: By following this methodology, the optimum number of surveillance cameras was determined with precision. The integration of BIM, spatial analysis, and simulation tools provided a comprehensive approach to facility security planning. This methodology ensures efficient resource utilization, cost optimization, and enhanced security monitoring, contributing to a robust facility management strategy.

7.0 Data Analysis and Recommendations

Objective: Interpret simulation results and offer suggestions for congestion and security optimization.

Process: The congestion observed at Gate No. 2 was due to narrower entry channels, inefficient queuing, and high pedestrians' density.

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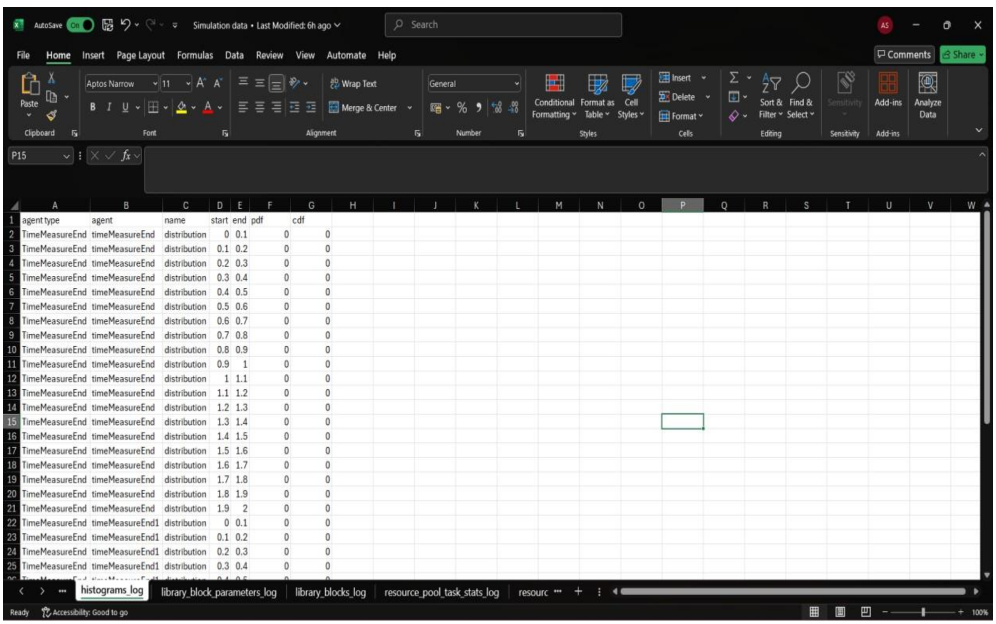
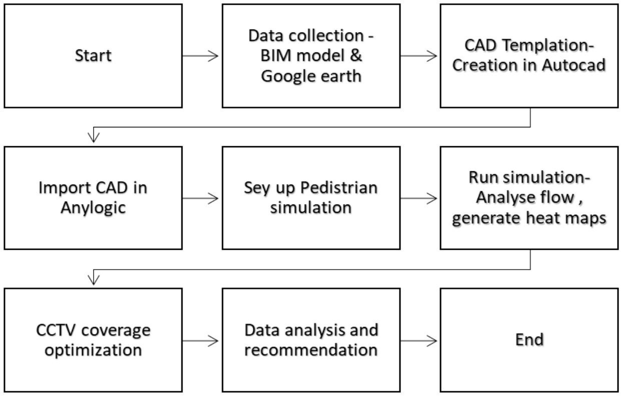
Figure 9: Heat Map of Pedestrian Movement

Figure 10: Data Extracted from Simulation to Excel File



agent type	agent	name	start	end	pdf	cdf
TimeMeasureEnd	timeMeasureEnd	distribution	0	0.1	0	0
TimeMeasureEnd	timeMeasureEnd	distribution	0.1	0.2	0	0
TimeMeasureEnd	timeMeasureEnd	distribution	0.2	0.3	0	0
TimeMeasureEnd	timeMeasureEnd	distribution	0.3	0.4	0	0
TimeMeasureEnd	timeMeasureEnd	distribution	0.4	0.5	0	0
TimeMeasureEnd	timeMeasureEnd	distribution	0.5	0.6	0	0
TimeMeasureEnd	timeMeasureEnd	distribution	0.6	0.7	0	0
TimeMeasureEnd	timeMeasureEnd	distribution	0.7	0.8	0	0
TimeMeasureEnd	timeMeasureEnd	distribution	0.8	0.9	0	0
TimeMeasureEnd	timeMeasureEnd	distribution	0.9	1	0	0
TimeMeasureEnd	timeMeasureEnd	distribution	1	1.1	0	0
TimeMeasureEnd	timeMeasureEnd	distribution	1.1	1.2	0	0
TimeMeasureEnd	timeMeasureEnd	distribution	1.2	1.3	0	0
TimeMeasureEnd	timeMeasureEnd	distribution	1.3	1.4	0	0
TimeMeasureEnd	timeMeasureEnd	distribution	1.4	1.5	0	0
TimeMeasureEnd	timeMeasureEnd	distribution	1.5	1.6	0	0
TimeMeasureEnd	timeMeasureEnd	distribution	1.6	1.7	0	0
TimeMeasureEnd	timeMeasureEnd	distribution	1.7	1.8	0	0
TimeMeasureEnd	timeMeasureEnd	distribution	1.8	1.9	0	0
TimeMeasureEnd	timeMeasureEnd	distribution	1.9	2	0	0
TimeMeasureEnd	timeMeasureEnd1	distribution	0	0.1	0	0
TimeMeasureEnd	timeMeasureEnd1	distribution	0.1	0.2	0	0
TimeMeasureEnd	timeMeasureEnd1	distribution	0.2	0.3	0	0
TimeMeasureEnd	timeMeasureEnd1	distribution	0.3	0.4	0	0

8.0 Flow Chart of All the Steps



9.0 Results and Discussion

Data (Visuals and Graphs)

- Pedestrian Flow Analysis: Results of the simulation showed that Gate No. 2 on average had a longer flow time, in other words, greater congestion than Gate No. 1 (91.02 seconds against 38.95 seconds).
- CCTV Coverage Optimization: Using the formula $A=2\times D\times (\tan\theta/2)$ we round up to ensure full coverage, the optimum number of cameras required is 42 cameras.
- Heat Maps: showed pedestrian movement patterns, revealed chokepoints and hinted at possible architectural improvements.

9.1 Results

Simulation revealed that architectural changes of widening the entry-points and implementation of IoT in the traffic flow can very well cut down on congestion. It also made a good case showing how using BIM simulations can allow optimization of CCTV cameras in its placement for fully surveillant coverage.

9.2 Discussion

These findings highlight the importance of combining BIM, IoT, and AI for real-time monitoring and predictive maintenance in FM. The proposed framework utilizes BIM's advanced modelling and simulation capabilities to address prominent FM challenges, such as data fragmentation and reactive maintenance. The study additionally points to the potential of BIM to enhance emergency response and operational efficiency via spatial layout optimization.

10.0 Conclusion

This research set out to explore the transformative potential of Building Information Modelling (BIM) in enhancing Facility Management (FM), specifically in the domains of

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security surveillance and space optimization. Bridging this technological innovation with data-driven simulations and advanced analytical tools, the study presents a comprehensive, replicable framework that not only addresses persistent inefficiencies in traditional FM but also extends the current body of knowledge by offering empirical validation to several theoretical claims established in prior literature. The study builds upon foundational insights by Becerik-Gerber *et al.* (2012), who emphasized the value of BIM in data centralization and real-time facility oversight, and Zhang *et al.* (2015), who proposed BIM as a catalyst for smarter, more adaptive building environments. While much of the existing literature has articulated the potential of BIM in various FM tasks—such as asset tracking, HVAC control, and energy optimization—our research advances this dialogue by focusing on underexplored yet critical aspects: pedestrian circulation modelling and CCTV camera placement optimization, particularly within the context of educational institutional settings.

Through the case study of NICMAR University, the methodology employed a combination of tools—AutoCAD, Navisworks, and AnyLogic—to simulate pedestrian flow and model surveillance layouts using real-world data inputs. The application of a BIM-informed digital model, integrated with simulation software and validated through spatial analysis, enabled us to not only visualize but quantify congestion patterns and surveillance blind spots. The simulation outcomes clearly indicated that architectural adjustments, such as widening Gate No. 2 and modifying queuing zones, would significantly improve pedestrian flow—reducing average traversal times from 91.02 to 38.95 seconds. Moreover, the use of a mathematical approach to optimize CCTV camera coverage (Davies & Velastin, 2005) resulted in a calculated requirement of 42 strategically placed cameras, factoring in overlapping FoVs and pedestrian density zones. These outcomes validate assertions made by Pan & Chen (2020) and Turner *et al.* (2021), who advocated for circulation-aware surveillance planning, yet lacked real-time, simulation-supported implementation studies like the one presented here.

Our study also meaningfully addresses several pressing challenges in BIM adoption, as previously outlined by Marmo *et al.* (2019) and Wang *et al.* (2013), particularly in terms of data integration, high initial costs, and limited empirical validation. By demonstrating a low-cost but high-impact application of publicly available tools and data, this research provides a viable model for institutions—especially those with constrained budgets—to incrementally adopt BIM-based FM strategies. Moreover, the emphasis on integrating BIM with Internet of Things (IoT) sensors and Artificial Intelligence (AI)-enabled predictive analytics responds to the growing academic discourse surrounding BIM-IoT-AI convergence (Gouda *et al.*, 2020; Wen *et al.*, 2020). The proposed conceptual framework promotes a shift from reactive to predictive maintenance strategies, laying the groundwork for future smart campus or smart facility implementations. Importantly, this study extends the theoretical discourse into a practice-ready framework that includes actionable steps, validated simulations, and scalable digital processes. It demonstrates that BIM is not merely a data repository but a dynamic, decision-support system when integrated with other technologies. The methodology herein supports dynamic scenario

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analysis and has the potential for further expansion into evacuation planning, emergency response optimization, and even behavioral modelling for crowd psychology (Pan *et al.*, 2006). In summation, this research substantiates the strategic utility of BIM in FM through a multidimensional lens—technological, operational, and strategic. By aligning our findings with prior literature while also demonstrating new, empirically tested applications, the study makes a dual contribution: enriching academic understanding and equipping practitioners with a tested roadmap for implementing advanced FM strategies. Future studies could build upon this framework by incorporating real-time tracking systems, integrating machine learning algorithms for adaptive planning, and evaluating the long-term operational gains of BIM-driven FM systems in larger or more complex building typologies.

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