

Intelligent Building Systems: A Progression of Sustainability and Efficiency through Remote Monitoring, Data Analytics, and Automation

Chirag Patni¹, Shravani Raikar^{2*}, Debashish Sanyal³

Abstract

Cities are confronted with never-before-seen issues pertaining to resource management, energy consumption, and environmental sustainability as global urbanization picks up speed. As a result, integrating intelligent building systems has become a game-changing way to deal with these urgent problems. The present study delves into the various components that make up intelligent building management systems, including HVAC control, computerized maintenance management system (CMMS), building management system/building automation system (BMS/BAS), data analytics and reporting, and remote monitoring and management (RMM). To maximize building performance, increase energy efficiency, and guarantee occupant comfort, each of these elements is essential. Real-time monitoring of building systems and equipment is made possible by remote monitoring and management, or RMM. This enables preventive maintenance and troubleshooting to cut down on downtime and save energy. By using big data to find patterns, trends, and anomalies, data analytics and reporting enable building operators to make data-driven decisions that maximize energy use and operational effectiveness. The core of intelligent building management is the Building Management System/Building Automation System (BMS/BAS), which integrates many subsystems like HVAC, lighting, security, and access control to optimize resource use and streamline operations. Controlling the indoor climate to maintain occupant comfort while consuming the least amount of energy is very important for HVAC systems.

Keywords: Intelligent Building, Sustainability, Remote Monitoring, Data Analytics, Building Management System, Building Automation System, HVAC Control, CMMS, Urban Development

INTRODUCTION

The rapid pace of urbanization and the escalating energy demand have underscored the imperative for intelligent building systems that synergize technology, sustainability, and comfort. Remote Monitoring and Management (RMM) technologies have revolutionized the way buildings are operated and maintained by enabling real-time monitoring and control. Data Analytics and Reporting provide insights into energy consumption patterns, occupancy trends, and system performance, facilitating informed decision-making for sustainable practices. (*World Energy0020Outlook 2018 – Analysis*, n.d., p. 1) [1] The integration of the Building Management System/Building Automation System (BMS/BAS) optimizes building operations, ensuring seamless coordination of various components. HVAC

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Control enhances energy efficiency by dynamically adjusting heating, ventilation, and air conditioning systems. (Santamouris, 2018, p. 1) [3] (Hansemann & Hübner, 2021, p. 1) [4] Moreover, the Computerized Maintenance Management System (CMMS) streamlines maintenance processes, minimizing downtime and prolonging equipment lifespan. This paper investigates the interplay of these technologies, examining their contributions and collective impact on the sustainability and efficiency of intelligent buildings.

REMOTE MONITORING AND MANAGEMENT (RMM)

Remote monitoring and management (RMM) is a type of IT software that allows managed service providers (MSPs) to monitor a workforce's devices, endpoints, and networks. (Fig 1) Remote monitoring and management are crucial in modern building management systems (BMS) and building automation systems (BAS). These capabilities enable facility managers and operators to monitor, control, and manage building systems and operations remotely, often using digital tools and platforms. (ITarian Managed Services, n.d., p. 2) [5]

Remote Monitoring

- Remote monitoring involves the real-time observation and collection of data from various building systems and components.
- This data is then transmitted to a centralized system, often hosted on the cloud, where it can be accessed and analyzed remotely.
- This allows facility managers to constantly watch building performance, even when they are not physically present on-site.

Technologies for Remote Monitoring and Management

- Cloud-Based Platforms
- IoT Devices: Internet of Things (IoT) devices
- Mobile Apps
- Data Analytics
- Security Measures

Data Analytics and Reporting

Analytics and reporting can help a business improve operational efficiency and production in several ways. Analytics is making decisions based on the data presented, while reporting makes complicated information easier to understand. (Villegas, 2022, p. 3) [6] Data analytics and reporting play a crucial role in leveraging the data collected by control systems in smart buildings to optimize operations, improve energy efficiency, enhance occupant comfort, and make informed decisions.

Here's how data analytics and reporting are applied to control systems in smart buildings

- Data Collection and Aggregation
- Data Analytics Techniques
- Energy Management and Optimization
- Occupant Comfort and Wellbeing
- Predictive Maintenance
- Fault Detection and Diagnostics (FDD)
- Optimizing Space Utilization
- Demand Response and Load Management
- Reporting and Visualization
- Benchmarking and Comparison
- Decision Support
- Continuous Improvement

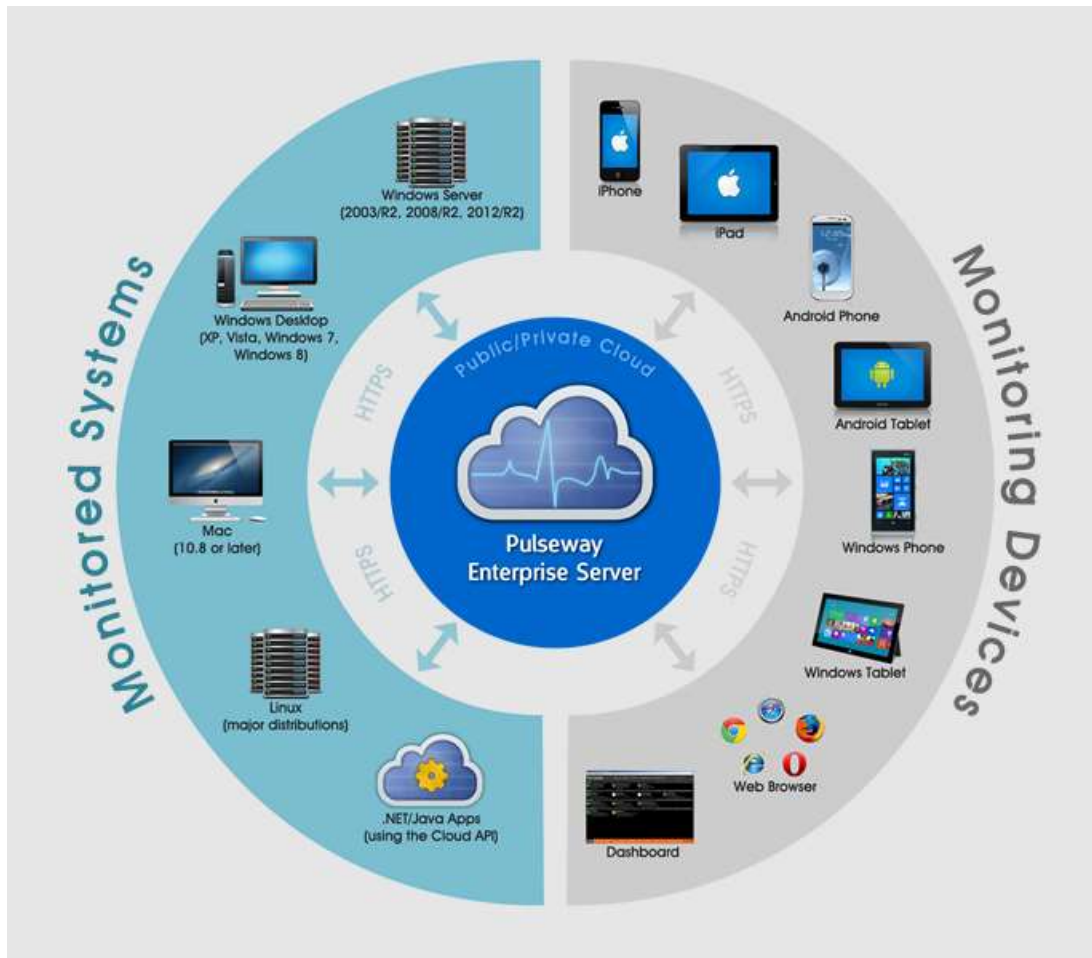


Figure 1. Monitoring System and Monitoring Devices.

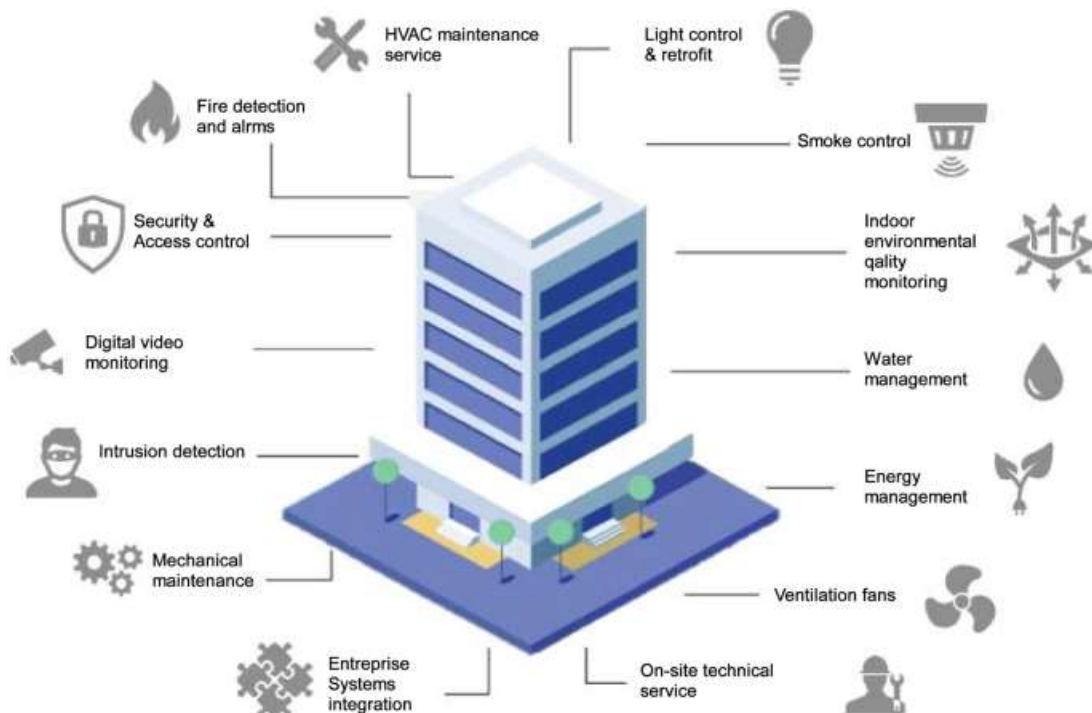


Figure 2. Principal services of a BAMS system.

Building Management System/ Building Automation System

A Building Management System (BMS), also (Figure 2) known as a Building Automation System (BAS), is a centralized control system that helps manage various building operations and functions to optimize energy efficiency, comfort, safety, and security in intelligent buildings. These systems integrate different subsystems and devices within a building to provide a cohesive and efficient environment. (*Building Management System - An Overview*, n.d., p. 4) [7]

What is an integrated building management system (iBMS)?

Like a BMS, they centralize all building systems but extend this integration to the entire building environment. Therefore, they also include access control, video surveillance, and fire prevention systems. By centralizing all the systems, both a BMS and an iBMS facilitate the management of the building and become a single point of control for the entire building.

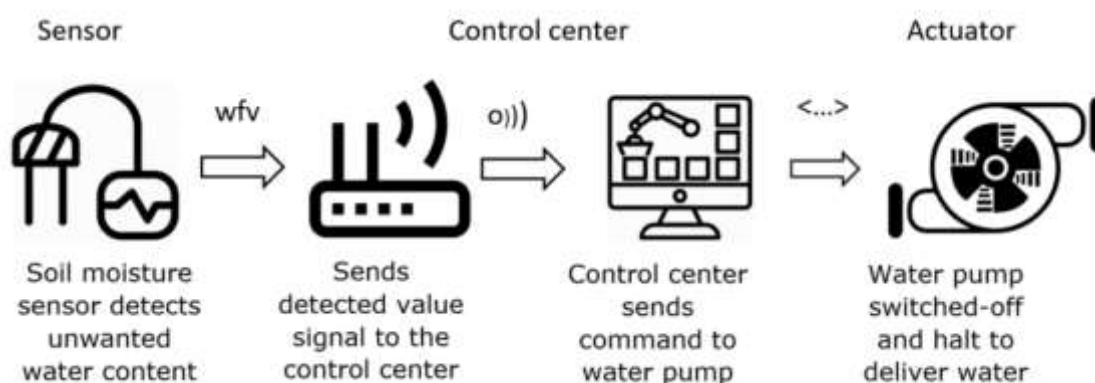


Figure 3. The Structure of the Internet of Things (IoT).

Components of a Building Management System

- Sensors and Actuators
- Controllers
- Communication Network
- User Interface
- Analytics and Data Management
- Energy Management
- Security and Access Control
- Fire Safety
- Maintenance and Diagnostics

User Interfaces

The user interface (UI) is the point of human-computer interaction and communication in a device. (Fig 3,4) The user interface (UI) of control systems for smart buildings is designed to provide users with an intuitive and efficient way to interact with and manage various building systems and devices. (Jalil, 2021, p. 6) [10] Here are some key features and components commonly found in the user interface of control systems for smart buildings:

- Dashboard Overview
- Device Control
- Scheduling
- Energy Monitoring
- Security Management
- Data Analytics
- User Profiles

- Customization
- Feedback and Reporting

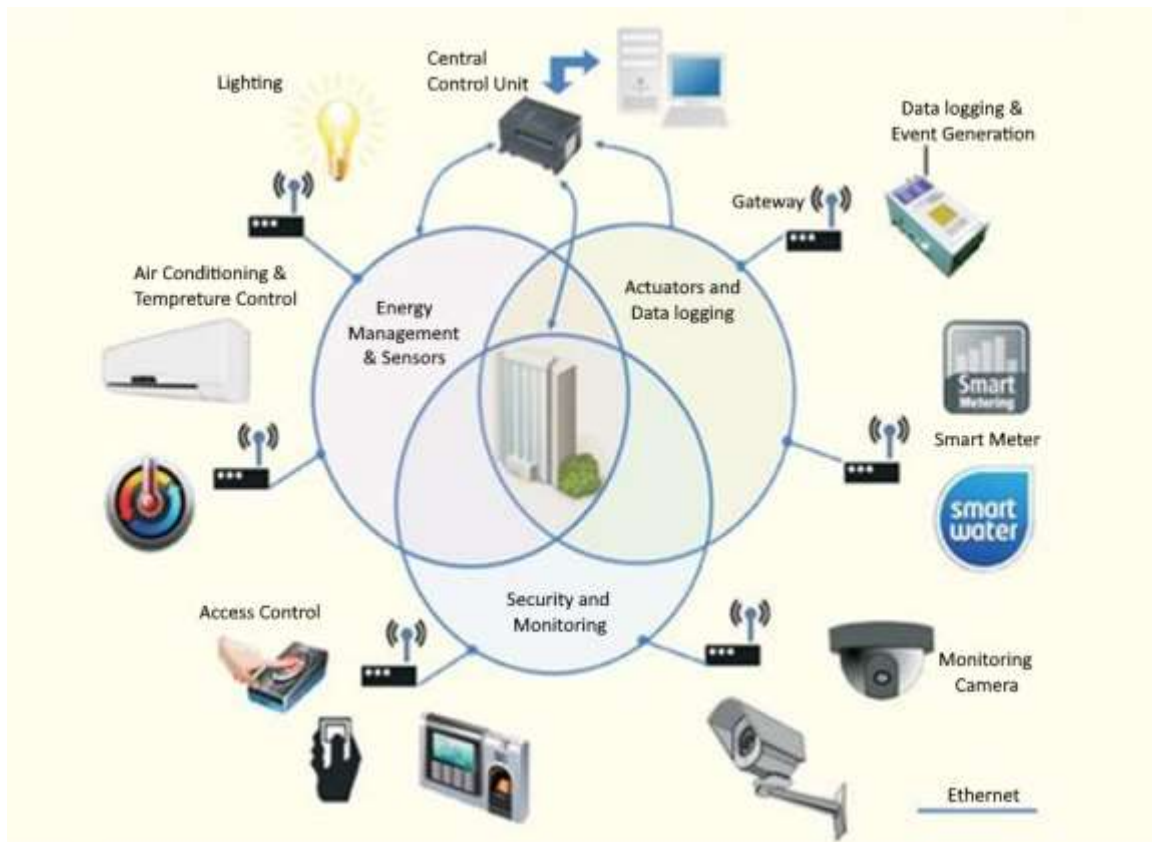


Figure 4. Facility Management Services by User Interface.

Computerized Maintenance Management System (CMMS)

A computerized maintenance management system or CMMS is software that centralizes maintenance information and facilitates the processes of maintenance operations. Maintenance management for control systems in smart buildings is essential to ensure the reliable and efficient operation of the building's various systems. Proper maintenance helps prevent system failures, reduces downtime, extends the lifespan of equipment, and ensures that the building continues to operate optimally. Here are some key aspects of maintenance management for control systems in smart buildings:

(What Is a CMMS? Definition, How It Works and Benefits, n.d., p. 5) [9]

- Scheduled Maintenance
- Predictive Maintenance
- Remote Monitoring
- Condition-Based Maintenance
- Vendor Relationships
- Documentation
- Testing and Calibration
- Software Updates and Patches
- Emergency Response Plan
- Energy Efficiency Optimization
- Training and Knowledge Sharing
- Asset Management

- Root Cause Analysis
- Continuous Improvement

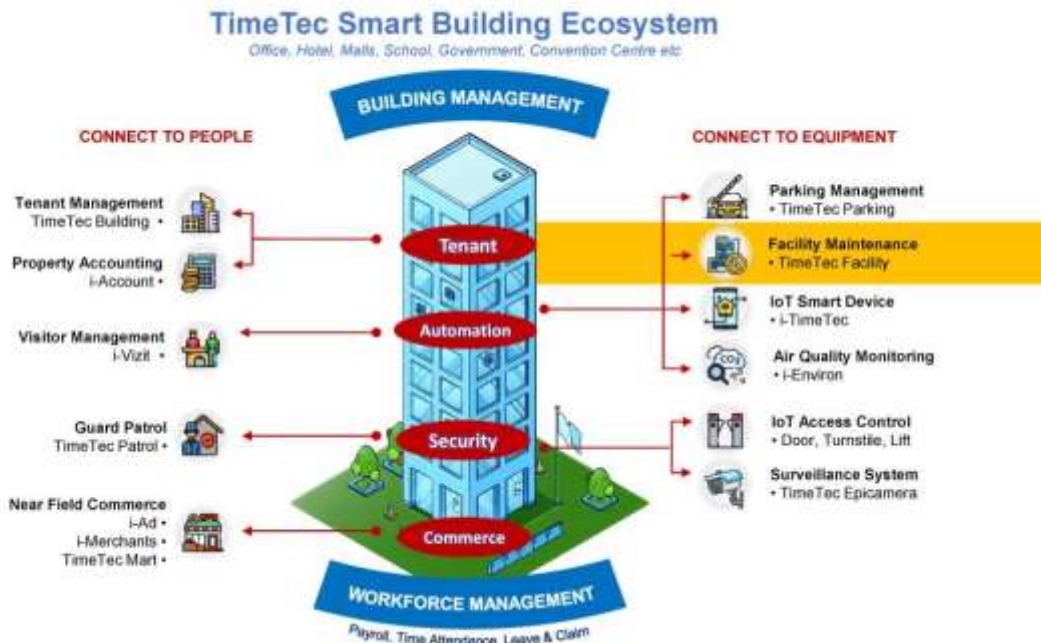


Figure 5. Smart Building Ecosystem.

HVAC (Heating, Ventilation, and Air Conditioning)

control is a fundamental aspect of building management systems (BMS) or building automation systems (BAS). HVAC control focuses on regulating the indoor environment to ensure optimal comfort, air quality, and energy efficiency. (stephanie_pounders, 2017, p. 5) [8]



Figure 6. Working of HVAC System Control.

Table: 1 Smart HVAC System Control

Components of HVAC Control	HVAC Control Strategies	Benefits of Effective HVAC Control
Sensors	Temperature Control	Energy Efficiency
Controllers	Ventilation Control	Comfort
Actuators	Occupancy Sensing	Air Quality
User Interface	Time-Based Control	Cost Savings
Communication Network	Demand Response	Equipment Longevity

Benefits of Intelligent Building Systems

There are several advantages to intelligent building systems that go much beyond traditional building management strategies. (Table 1) First off, these systems use state-of-the-art technology like IoT sensors and machine learning algorithms to optimize energy use in real time, resulting in cost savings and increased energy efficiency. Intelligent buildings dramatically minimize energy waste, which results in significant cost savings on utility bills for building owners and operators. These buildings do this by dynamically altering lighting, (Fig 6) HVAC, and other systems based on occupancy patterns and external conditions. Intelligent buildings are distinguished by their emphasis on augmenting the comfort and productivity of their occupants. These systems establish an environment that promotes increased productivity and well-being by continuously monitoring and adjusting indoor environmental factors including temperature, humidity, and air quality. Through the maintenance of ideal comfort levels, intelligent buildings promote (“Evaluating the System Intelligence of the Intelligent Building Systems: Part 2: Construction and Validation of Analytical Models,” n.d., p. 7) [2]

Emerging Trends in Intelligent Building Systems

The essential intelligent structure the identified IoT trends represent a paradigm shift in building management that will lead to operations that are more secure, effective, and data-driven. (Figure 7) Ensuring network security and improving operational efficiency through seamless monitoring and troubleshooting of building systems is made possible by secure remote connectivity. Comprehensive data collection is made possible by network-connected sensors and equipment, which helps decision-makers base their choices on up-to-date knowledge of building performance parameters. Fast visibility into interconnected systems for preemptive maintenance and optimization is made possible by centralized data storage, which also simplifies data administration and reporting. Open protocols facilitate flexibility and interoperability, enabling users to easily connect IoT devices with current systems. IoT data may be fully utilized by intelligent analytics, giving users the ability to maximize building operations and extract useful insights.

A user-friendly interface for data visualization and analysis is provided by central visual management dashboards, which improve operational transparency and decision-making. IoT-powered building automation lowers errors, decreases human interaction, and improves operational effectiveness. Predictive maintenance and proactive problem-solving are made possible by artificial intelligence and machine learning, which speed up data analysis and pattern identification. Finally, 4D insights make use of multi-layered analytics to deliver contextualized data for diagnostics and fault identification, facilitating in-the-moment decision-making and building system optimization. When taken as a whole, these patterns portend a day when IoT technology will play a major role in transforming smart buildings into ones that are more robust, efficient, and sustainable. (admin_user, 2023, p. 8) [11]

One of the best examples of an intelligent building that pushes the limits of efficiency, creativity, and sustainability is The Edge in Amsterdam. The Edge, when viewed through the lens of an intelligent building, is a comprehensive approach to building management and operation, utilizing state-of-the-art technologies to produce a genuinely smart setting. (杨鼻, 2016, p. 9) [13]

CASE STUDY

The Edge, Amsterdam

The Edge's significant use of IoT sensors and data analytics to maximize building performance is one of its standout features. (Figure 8) Throughout the structure, over 28,000 sensors have been thoughtfully placed to gather data in real-time on occupancy, temperature, lighting, and energy usage. After that, the data is evaluated to help make decisions about how to operate the facility. For example, HVAC settings can be changed based on occupancy patterns, and lighting levels can be optimized to optimum energy efficiency. Heating, ventilation, lighting, and security are just a few of the systems that are monitored and controlled by the building's integrated Building Management System (BMS). Facility managers can remotely oversee and control building functions using the BMS, guaranteeing peak performance and occupant comfort. Edge also has an advanced energy management system that makes use of cutting-edge energy-saving technologies and renewable energy sources. With a ground-source heat pump system and a rooftop solar panel array, the building minimizes its environmental impact and depends less on conventional energy sources. All things considered, The Edge is a trailblazing illustration of intelligent building design and operation, demonstrating how cutting-edge technologies may be used to produce spaces that are efficient, occupant-centered, and sustainable. The Edge is a model and standard for future innovations aiming to incorporate intelligence into the built environment as the market for smart buildings keeps expanding. (杨慕, 2016, p. 9) [13]



Figure:7 Emerging Trends in Intelligent Building System

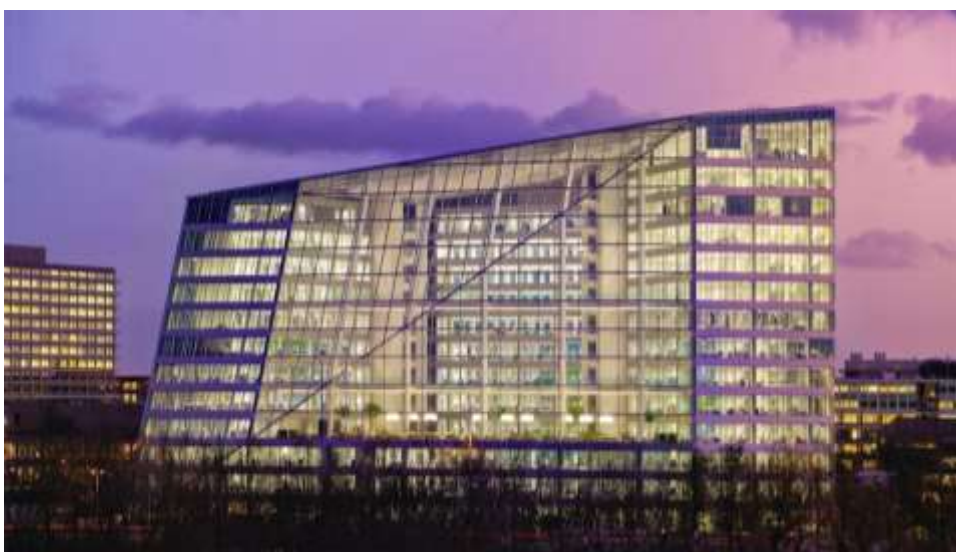


Figure: 8 The Edge, Amsterdam
Implementation of Intelligent Building Systems

Intelligent building systems are revolutionizing building management paradigms by utilizing advances in automation, data analytics, and remote monitoring. Real-time oversight of several building metrics, including energy use, air quality, and occupancy levels, is made possible via remote monitoring, which facilitates focused interventions and proactive decision-making analyzing enormous volumes of data gathered from sensors incorporated throughout the building environment, data analytics play a crucial role. Actionable insights are obtained using advanced algorithms and machine learning approaches, which enable the optimization of resource consumption, the identification of patterns for continuous improvement, and predictive maintenance.

Intelligent building systems are based on automation, which coordinates the smooth operation of subsystems including lighting, security, and HVAC (heating, ventilation, and air conditioning). Automation improves occupant comfort by creating individualized settings based on individual preferences, minimizes energy usage, and streamlines operational workflows through the use of programmable logic controllers (PLCs) and Internet of Things (IoT) devices.

Furthermore, by lowering their carbon footprint and advancing global environmental goals, the integration of renewable energy sources, energy storage technologies, and demand response tactics raises the sustainability quotient of intelligent buildings.

CONCLUSION

In conclusion, the integration of Remote Monitoring and Management, Data Analytics, Building Management System/Building Automation systems, HVAC Control, and Computerized Maintenance Management systems represents a paradigm shift in urban living. The synergy of these technologies not only enhances the operational efficiency of buildings but also establishes a foundation for sustainable practices. The findings of this research highlight the transformative potential of intelligent building systems in mitigating environmental impact, reducing energy consumption, and elevating the overall quality of urban living. As we navigate the challenges of the 21st century, the adoption of these technologies becomes not just a choice but a necessity for building a future where technology, sustainability, and comfort fuse seamlessly.

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