

CHAPTER 1: INTRODUCTION

1.1 Background of The Project.

Air Quality, Lighting, Temperature, and Humidity create the indoor environment. The assessment of these elements and their influence on the occupants' holistic and psychological comfort is CAD. CAD can be used to manage the indoor environment. When the indoor environment is inadequately managed, it will lead to negative health, comfort, and productivity. The effect of indoor environments that are not managed on health, comfort, and productivity is known as the CAD of indoor environments. The CAD of indoor environments has been the focus of research. High concentrations of indoor air pollutants such as CO₂ and PM_{2.5} are harmful to cognitive and psychological health (Fan et al, 2023; Zhou et al, 2023). Coupled with the effect of the CAD, the modern environment caused by the current lifestyles of people has made the CAD of indoor environments a priority.

Visual comfort and the ambience of the indoor environment can be managed by lighting. Comfort and the accuracy of tasks can be managed by the temperature of the indoor environment (Choi & Suk, 2021; Lan et al, 2021). When the indoor environment is adequately managed, it can also lead to reduced psychological health and improved energy efficiency.

The IQAS of indoor environments has a significant impact on the health, comfort, and cognitive of the occupants. PM_{2.5} and the gases CO₂ and (VOCs), and their particulate concentration, temperature, and humidity, are examples of the constituents of the indoor environment. Elevated concentrations of PM_{2.5} or CO₂ lead to poor concentration and cognitive performance. This is further aggravated by poor thermal comfort (Meo et al, 2024; Alkattan et al, 2022). Psychological comfort is also affected by the CAD of lighting and HVAC systems. The optimized CAD also leads to reduced psychological health and improved energy efficiency.

Management and Science University (MSU) strives for a green campus as part of its sustainability goal. As part of the goal to promote a greener learning space by enhancing the air quality and energy efficiency while minimizing carbon

footprint, developing a computer-based integrated indoor air quality system with automated control of lighting and air conditioning is vital. The Internet of Things (IoT) systems for real-time monitoring and energy management, as cited by Ramírez et al. (2023), are very popular in the recent application of green campuses. However, many existing studies still focus on only air quality monitoring or HVAC control. There is limited research that considers the integration of real-time monitoring, automated control systems, and the use of Artificial Intelligence (AI) for predictive modeling in a single framework.

Thus, this research aims to design and develop the first integrated system prototype utilizing the Internet of Things, Web Apps and AI in learning environments. The system described in this research allows real-time monitoring of the indoor air quality, changes in the environment to be controlled in advance and automatically, and the control of lighting and cooling systems to ensure the best possible balance of comfort and energy efficiency. AI-based predictive control methods are energy efficient and a minimal energy cost to HVAC system while maintaining thermal comfort (Michailidis et al., 2025; Wang et al., 2025).

1. Problem Statements

Higher education learning environments help promote comfort, support cognitive performance, and energize the occupants. However, creating an effective environment is a challenge. Presently, systems do not exist to assist in the real-time monitoring of the conditions of comfort and performance. The monitoring of dust particles, CO₂, temperature, humidity, and light is not possible. Additionally, HVAC and lighting systems do not integrate and operate separately. Consequently, comfort and performance are negatively impacted, and systems are inefficient. Predictive technologies that rely on machine learning are not present; therefore, the environment is typically responsive to changes that have already occurred. This means that systems, particularly HVAC and lighting, are not efficient, and a greater environmental impact is sustained. The operation of systems contributes an economic burden due to unnecessary costs, and a greater environmental burden of increased greenhouse gas emissions.

2. Lack of an Integrated Environmental Monitoring System.

The classroom lacks a permanent system capable of continuously monitoring environmental quality indicators of PM2.5, CO2, temperature, humidity, and lighting. This challenges the identification of environmental conditions that would compromise user comfort, as well as conditions that would negatively impact the cognitive function of users. Lighting and the HVAC systems (air Conditioning and Ventilation) are controlled separately in a manual fashion even to this day. This trivial approach has resulted in settings that are less than optimal, takes energy away needlessly, and lessens comfort.

3. Lack of Real-Time Environmental Response Capabilities

Without the ability to analyze data as it comes in and send alerts, fluctuations in air quality or temperature disrupt people at work and may cause fatigue, loss of focus, and an overall decline in work efficiency. No Predictive Control Mechanism Based on Artificial Intelligence: Current systems have very passive models, only responding most of the time after substantial changes have been noticed by the occupants of the systems at work. There is little to no active Artificial Intelligence normative predictive modeling that would forecast passive environmental discomfort and cause the system to self-adjust sub-optimally.

4. Suboptimal Energy Consumption.

Energy consumption on campus is highest for lighting and air conditioning systems. The absence of intelligent optimisation and automation systems results in inefficient energy consumption and increased operational costs and carbon footprints.

1.2 Objectives of the project.

This project aims to develop a system that provides continuous, automated management of (discomfort) VOCs, Temperature, Humidity, and Light utilizing an IoT-based automated Light and HVAC system. This project incorporates the ability to forecast environmental discomfort using Predictive (AI) Modeling, enabling the system to further manage discomfort. A web-based dashboard is also a part of this project enabling users to make environmentally conscious decisions utilizing the system's real-time data. This project strives to implement cognitive and energy

sustainability.

1. To develop an integrated environmental monitoring system.

To develop an integrated environmental monitoring system that continuously assesses the key indoor environmental parameters of gas level, temperature, humidity, and the light intensity. The system will conduct real-time monitoring and data processing and provide visualization and alerts to support timely decisions and the maintenance of optimal indoor environmental quality.

With the use of IoT-based sensor networks, the proposed system will provide continuous, reliable, and real-time environmental data and insights, allowing users and facility managers to detect, manage, and respond to variances of comfort and safety within the built environment.

Moreover, real-time alerts and online data visualization of the system will foster proactive management of the indoor environment and promote a healthy and comfortable environment that supports the cognitive productivity of the occupants and improves their well-being.

2. To design and implement an intelligent control system.

To formulate and establish an intelligent control system whose core components are automated lighting and Heating, Ventilation, and Air Conditioning (HVAC) integrated with Artificial Intelligence (AI) predictive models. This system control approach is proactive, integrating real-time environmental condition data, augmented with future condition data, to control the HVAC and lighting systems. As a result, HVAC and lighting control are optimized in the system before environmental conditions negatively impact user experience. This system approach control ensures that user experience is elevated by ensuring that environmental comfort and lighting conditions are sustained. This system control approach also ensures sustained system comfort. The integrated AI in this design system control approach also allows for sustained system control responsiveness and increased system comfort correlated with sustained system control.

3. To enhance energy efficiency and sustainability in indoor environments.

To target optimizing the use of resources in indoor settings via intelligent system automation and use of predictive control in the design, with the aim of

decreasing the carbon footprint and cutting down operational expenditures. This goal intends to target conserving energy expenditures in lighting and HVAC in the design control system by consuming energy in the system only when and where it meets the occupancy and environmental state needs. This goal also ensures that energy in the design control system is not wasted when achieving the utmost comfort in the indoor environment. This design and control approach also ensures the highest comfort is sustained. The design approach control also aims at conservation of energy, particularly aimed at sustainable green building technology integrated systems.

1.3 Significance of the project.

The value of the project can be understood through its multiple benefits to several stakeholders.

1. For Students and Lecturers: Comfort and cognitive performance of the occupants are improved by optimizing the indoor air quality, temperature, humidity, and light. This, in turn, helps the occupants to concentrate and nurtures learning activities.
2. For University Management: The project contributes to the initiatives of making the MSU campus more environmentally friendly, by saving energy and reducing the carbon footprint. The project also provides support for real-time monitoring and analysis, which improves the quality of decisions regarding the management of campus facilities.
3. For Facilities and Maintenance Staff: The project helps in the monitoring and management of the lighting and HVAC systems by the automation of AI-based predictive management and helps in eliminating human error.
4. For Research and Development Community: The project demonstrates integrated IoT-AI systems for the management of indoor environments on the Internet, and provides data for more research on smart learning spaces and environments on campus.
5. For Community and Environment: The project helps in the rational use of energy, in more environmentally friendly energy consumption and in less

environmentally friendly adverse impacts of the project. It sets an example for other institutions, smart, healthy and energy-efficient environments.

1.4 Scope of the project.

A. Documented System Features:

1. **Air Quality and Environmental Monitoring:** The system is equipped with the capability to monitor air quality including PM2.5 and CO2 as well as VOCs. The system can monitor temperature and humidity and measured values of air quality and environmental factors can be displayed on web dashboard as a real time service.
2. **System Alerts and Notifications:** The system is capable of sending alerts and notifications when environmental factors and parameters fall outside optimal and/or acceptable ranges.
3. **Prediction, Control, and Environmental AI:** The system has the capability to alter lighting and the temperature of the room based on real time environmental measurements and AI models of prediction. The predictive models of the system quantify air quality and temperature discomfort and take action to be energy efficient while ensuring comfort of the occupants.
4. **Dashboard Visualizations and Reporting:** The system has the capability to visualize data and have graphs of environmental conditions to aid in reporting and assessing discomfort of the users in the case of suboptimal environmental conditions.

B. System Exclusions:

1. **System Integration:** The system is isolated and does not integrate with any of the other management systems on campus.
2. **Outdoor Air Environmental Monitoring:** The system does not monitor any external or outdoor air quality or environmental assessment.
3. **Costing and Financial Impacts:** The system does not assess the cost impact of energy or any financial transactions.

1.5 Summary and Limitation

1. Summary of project

The project focuses on developing an integrated smart indoor environmental monitoring and control system by combining IoT, AI, and web-based applications. The system monitors environmental factors such as PM2.5, CO₂, temperature, humidity, and lighting, then processes and visualizes the collected data through a dashboard and provides alerts to support decision-making. The system also predicts environmental changes and controls lighting and HVAC to maintain comfortable conditions while improving energy efficiency in educational environments.

2. Limitation of project.

The project is designed with a prototype system, and as such, the project is limited to operating as a prototype in a research setting. The lateral thinking of the complex system design is somewhat limited as well. The working hypothesis of the system relies on the historical data of the research sensors. As the research sensors' data changes, the effectiveness of the control system may fluctuate as well.

Moreover, the system only emphasizes the indoor environmental monitoring and control system and purposely excludes integration with external environmental elements or other institutional systems such as scheduling or attendance systems. Also, the provision of automated control is limited to lighting and HVAC systems and is implemented without direct financial analysis of energy cost savings. Finally, system performance may be impacted by the hardware limitations of sensor accuracy and network and data latency.