Smart IAQ Management: Enhancing Energy Efficiency in Partially Occupied Office Buildings

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ABSTRACT

Indoor air pollution arises from multiple sources, including both the building itself and its occupants. Building materials, furnishings, and office equipment continuously emit a range of volatile organic compounds (VOCs), which can contribute to adverse health effects and discomfort among building occupants. Additionally, the activities of occupants themselves impact indoor air quality (IAQ) through the release of bioeffluents, with carbon dioxide (CO2) commonly used as a key indicator of air quality. We conclude: Indoor pollutant levels are influenced by both the number of occupants and the size of the ventilated space.

The importance of IAQ extends beyond health concerns, as it directly influences the comfort and productivity of individuals within office buildings. However, achieving optimal air quality often requires increased ventilation rates, which can be at odds with stringent energy efficiency policies. This challenge has become more pronounced in recent years due to evolving workplace dynamics, such as the widespread adoption of hybrid work models, flexible office arrangements, and shared desk usage patterns. These trends have introduced significant variability in building occupancy rates, rendering traditional HVAC system designs – often based on static assumptions about occupant density – insufficient for effectively managing IAQ and energy consumption.

To address this issue, we propose a novel approach aimed at enhancing ventilation efficiency by optimizing occupant navigation and dynamically reducing the ventilated area during periods of partial occupancy. By strategically concentrating occupants in specific zones of a building and adjusting ventilation accordingly, it is possible to lower pollutant loads associated with building materials and furnishings while still maintaining acceptable IAQ levels. This method offers a promising solution to the ongoing trade-off between energy efficiency and indoor air quality, particularly in modern office environments where occupancy fluctuates significantly.

Our approach was evaluated using a computational simulation model that integrates airflow dynamics with thermal heat transfer analysis. This model was applied to a representative office floor layout, reflecting typical occupancy patterns. A parameter study was conducted, focusing on scenarios with 50% occupancy and varying boundary conditions, to assess the potential energy savings. The findings indicate that thermal energy consumption can be reduced by an estimated 5% to 15% through optimized occupant distribution and targeted ventilation control, without negatively affecting perceived indoor air quality.

These results highlight the potential for substantial energy efficiency improvements in office buildings, particularly during periods of reduced occupancy. By reducing the ventilated space per person while maintaining adequate air exchange, energy consumption can be minimized without compromising IAQ. Furthermore, ensuring that occupancy remains closer to the design capacity of the building helps stabilize key IAQ performance indicators, reducing the frequency of ventilation control adjustments and enhancing overall system efficiency.

KEYWORDS

Indoor Air Quality, Ventilation optimization, Occupant navigation, Energy efficiency, Partial occupancy