Exploring the outcomes of Facilities Management Interventions on IAQ for buildings reopening after the cOVID-19 Pandemic: A Qualitative Study in Victoria

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# Abstract

The COVID-19 pandemic posed a significant challenge for facilities managers to adapt existing buildings with Facilities Management Interventions (FMI). This paper explores the practices and outcomes of FMIs implemented on IAQ for office reopening after the COVID-19 pandemic in Victoria through 41 semi-structured interviews with Facilities Managers, Health and Safety Managers, business stakeholders, and Infection Control experts. We found that the pandemic has prompted the implementation of portable air purifiers and CO2 monitoring in existing education and commercial buildings. However, air purification by UVGI and air pressure control measures were rarely considered. Moreover, the findings reveal practitioners’ need for smart windows and innovative tools to measure occupant health, comfort and building energy outcomes to aid the decision-making on FMIs. This research contributes to understanding the pandemic’s impact on built facilities and provides valuable insights for FM professionals and researchers.

Keywords: FMI, IAQ, COVID-19, occupant health, CO2 monitoring

# Introduction

Respiratory infection prevention was significantly overlooked in building design and operation before the COVID-19 pandemic, and the research on IAQ and ventilation was primarily focused on occupant thermal comfort, cost control, and energy performance (Morawska et al., 2021). The COVID-19 pandemic reveals that many existing public buildings are no longer safe shelters for occupants in terms of respiratory infection control (Zhang et al., 2022). While COVID-19 has had a worldwide effect, Victoria has a unique setting regarding government interventions and guidelines during the pandemic. The State of Victoria witnessed six lockdowns spanning two years, implementing commercial building closures and stay-at-home orders. Since Dec 2021, the Victoria government has issued Pandemic Open Premises Orders (Public Health and Wellbeing Act, 2021a) to facilitate office employees returning to the workplace. Victoria Workplace Orders imposed obligations on building operators to assist in reducing COVID-19 transmissions with COVID-Safe practices in the workplace, e.g. requirements or recommendations for face masking, measures to improve ventilation, and physical distancing of occupants (Public Health and Wellbeing Act, 2021b).In this context, Victorian organisations and building managers have implemented various Facilities Management Interventions (FMI) following government guidance to encourage employees to attend the office after its opening. FMIs implemented can include various measures to control indoor respiratory inflexions via three transmission routes, including Indoor Air Quality (IAQ) interventions to prevent aerosol transmissions, cleaning and disinfection to prevent fomite transmissions, and occupant density controls to eliminate droplet transmissions (Zhang et al., 2022). However, the practices and outcomes of the FMIs remain unknown. This paper focuses on the FMIs on IAQ in existing buildings. It aims to understand how the Facilities Manager (FM) and key stakeholders perceive and measure the outcomes of FMIs for building reopening. This study focused on understanding the perceptions of facilities managers and key stakeholders on FMI effectiveness in office and education buildings. This study focused on the following research questions:

1. What are the IAQ-related FMIs being implemented?
2. How do the key stakeholders perceive the outcomes of FMIs?

# Methods

## 2.1 Ethics approval

The data used in this paper was part of a project focused on managing indoor respiratory infection with Facilities Management Interventions (FMI). All procedures in this study were approved by the University of Melbourne Human Research Ethics Committee (ID: 24664). The study includes an online survey distributed to building occupants and interviews with key stakeholders. This paper focuses on the research questions based on the interview data.

## 2.2 Semi-structured interviews

This paper reports data from the qualitative investigation, in which key stakeholders working with office and education buildings were interviewed about how they have implemented FMI for respiratory infection control and improve occupant experience. All interviews were semi-structured following a protocol. The interviews were carried out from late 2022 to early 2023. A purposive sampling technique was adopted to reach out to potential participants for the study. 155 industry practitioners and experts in infection control were invited to participate in the research, and 41 individuals from 13 organisations finally consented to participate in the interview. All the interviews were conducted through Zoom. All interviews were audio recorded and then transcribed for subsequent analysis. The average interview duration was 45 minutes. The interviewees are asked about their current position and their years of experience. The participants include 25 FMs ,6 health and safety managers, 4 business stakeholders, and 6 infection control experts (N=6). 80% of the participants have more than ten years of related experience.

## 2.3 Data analysis

The interview transcriptions were imported into NVivo for thematic analysis following the guidelines given by Braun and Clarke(Braun and Clarke, 2006). First, the first author repeated the data reading for immersion to achieve a thorough understanding of the data. Second, themes and sub-themes were identified using an inductive approach to reflect the research questions. Third, the authors reviewed and refined the themes to ensure they were clear and distinctive.

# Findings

## 3.1 Portable Air Cleaners

* **PAC installations drivers**

The most widely discussed intervention was installing Portable Air Cleaners (PAC). Many participants have discussed that air purifiers were installed in 2022 on occupants’ requests. For instance, participant 4 shared the experience as follows:

“So, that kind of hierarchy was typically implemented, but they (occupants) often just request a purifier. “Could you supply me with an air purifier?” we’re happy to do that and support that request, but it didn’t always mean it was an engineering decision. It could sometimes be psychological support, or you know that people feel like there is something there to help protect them. "

Other participants spoke of installing PACs based on space type. For example, participant 33 shared that air purifiers were installed because of the change in space use and funding available as follows:

“With (building name), the Department of Education supplied three purifier units with HEPA filters for the teaching space down in the basement of (gallery name). And recently had one deployed here to the (building name) because it’s now being used as a teaching space.”

* **Infection control outcomes**

Most facilities managers suggested that measuring the health outcomes from air purifiers was challenging. As Participant 012, who worked with office buildings, reflected**,**

 “They were opening, and that we were doing everything we can and opening up, that’s really the outcome. Did we stop COVID? It’s seriously just not a measurable thing.”

Some FM participants reflected the health outcome with “number of infections” and “super spread or events “. For example,

“I think we’ve minimised the number of staff that have been unwell, or, you know, that of actually being infected with the virus within the use for facilities. By the number of staff that were reporting that. Let’s say there’d been somebody Covid positive in the office, and we did not have what you might term super spread events.”

Participant 40 said that they used infection cases as a measurement of health outcomes as follows:

“We use infections (cases). We had a reporting system that showed us. And yeah, we were able to manage it that way.”

* **Mental health outcomes of air purifiers**

Many interviewees spoke of the “psychological effect” of air purifiers on reducing occupant “perceived risk”. For instance, participant 19 shared the following:

“If people see an air purifier in a room, it might make them feel more comfortable. Realistically, when there’s one in a lecture theatre, it’s not actually serving the purpose. It’s not actually helping. It’s not suitable for that volume. But the individuals might feel better just because it’s there.”

The interviews show that FM also considered mental health, such as “anxiety” and “stress,” in measuring health outcomes from FMIs. For example, participant 31 reflected as follows:

“Of implementing throughout the outcomes all the installations we’ve done, all the systems we’ve done. It’s a healthier building… We’ve found that occupants of these buildings have a greater level of being comfortable within these buildings. So, there’s less anxiety and less stress involved. “

* **Environmental outcomes of air purifiers**

Participants also discussed the additional energy consumption and waste from PACs. For instance, Participant 8 had the reflection below:

“All of a sudden, you have got thousands of those devices (air purifiers). They all have to be plugged into a power supply so they will consume energy. They are portable devices, so once you have them to be tested and tagged as electric devices and made it to make sure that they are safe. They’ve all got a filter, which arguably might have to be replaced twice or three times a year, so somebody’s got to replace it. The filter is effectively a contaminated item. It has to be disposed of. That comes with both the labour and supply costs, along with environmental costs that go to landfills. "

## 3.2 CO2 Monitoring

* **CO2 sensors to identify poorly ventilated areas**

Some organisations in this study have installed CO2 monitoring for building reopening. Participants said that this initiative’s driver was to identify poorly ventilated areas quickly. As explained by Participant 022, “They (CO2 monitors) are to identify the higher risk, and then trigger a further response or a localised, you know, assessment and response. “Thus, CO2 monitoring technology was adopted as a fast solution for risk assessment since ventilation measurement with experiments was time-consuming. For example, participant 007 shared the experience as follows:

“We started rolling out CO2 as a proxy for ventilation because we realised it would probably take us a couple of years to physically measure (ventilation) in every space”.

* **CO2 data to provide reassurance for occupants**

Some participants spoke about CO2 monitoring as a practice to reassure occupants. For instance, Participant 25 shared the comments as follows:

“We made a commitment to put CO2 monitors into all teaching spaces. And that was a pragmatic decision. We’re already quite confident that our ventilation systems were designed and built with applicable standards when they were built. But the goal was to provide some confidence that we were just relying upon a standard that was built some time ago, but we were also going to monitor its actual operation. "

According to the interviews, the primary outcome of CO2 monitoring is that it enables the FM team to use the CO2 data to handle occupant concerns or complaints regarding indoor air freshness in the workplace. For instance, participant 13 shared the experience as follows:

“The ad hoc provision and investigations of offices usually come from concerns, staff members or students going. “I cannot open a window. Yeah, it feels hot and stuffy. Can I please get some assistance?” So, the first thing we do is we then go to measurements to measure the CO2 levels. And that would go from there, so that might be finding a way to open the window if it is practical and to do so, and that would be. Do we do it so the maintenance team can provide an air purifier for that space?”

FM participants generally have positive sentiments towards health outcomes from FMIs they have implemented. They perceived the buildings are healthier with the new installations such as CO2 monitoring air purifiers, filters etc. For example, Participant 4 shared the reflection on the outcomes of installing CO2 monitors in their buildings as follows:

“I think we’ve done something really unique. With our CO2 monitoring, I think we will be able to monitor all the teaching spaces and every occupied floor of every occupied building actively. It’s provided a level of assurance and reassurance to our community that I do not think a lot of other universities have been able to achieve, which is very pleasing.”

* **CO2 monitoring has not been adopted widely in the industry**

However, participants from FM suppliers shared that CO2 monitoring has not been adopted widely for the whole industry. For instance, participant 8 shared the reflection as follows:

“The whole industry hasn’t all of a sudden adopted CO2 monitoring for using those available input to assuring itself that it’s providing good healthy spaces for its clients if you like. … We’ve seen many installations of disinfection technology and better filtration. But some of those fundamental issues around how we distribute air in rooms, putting smart devices in place to get a sense of where the problems are in terms of CO2 monitoring. There hasn’t been anything like the wholesale implementation that I would have hoped for.”

* **CO2 monitoring was part of the pandemic response**

Some participants compared the cost of the CO2 monitoring project with the massive investment in consumables during the pandemic to procure rapid test kits, facial masks, sanitisers, etc., to make the point on the cost-effectiveness of CO2 monitoring. For example, Participant 24 shared the reflection as follows:

 “Backing January 2022, when you couldn’t get them (rapid test kits, facial masks, and sanitisers etc) anywhere, we invested two and a half million dollars in that, to get again reducing barriers for people to be able to access and test. ..So when we’re looking at what the options were, you know, (experts) certainly came into meeting conversations around air quality, and you know, expertise presenting to the decision makers saying that this (CO2 monitoring) is what actually we need to do. And then, if I can even call it a business case. But you know what it would take? How much does this cost? And I remember there being quite an interest in realising that it wasn’t that much of an expensive intervention it could, compared with what people were thinking to make that sort of investment.”

## 3.3 Ventilation rate and window opening

* **Concerns about relying on occupants for window operation**

Window opening was discussed as one of the important interventions on IAQ for buildings reopening. Some interviewees expressed concerns about potential “human errors” for occupants to operate windows. They discussed the need for automatic windows or other more efficient ways to handle window operations. For instance, Participant 003 shared the reflection as follows:

“How do we make sure that people do open the windows? …The people component is the most difficult.You need to put in place interventions that don’t require human user errors. It’s almost like when they should automatically open. Just like HVAC systems automatically work, maybe when the building opens in the morning, there needs to be technology that actually opens the windows. Then you know you are asking for people to take personal and collective responsibility, which doesn’t always happen. "

* **Thermal comfort issues with natural ventilation**

Moreover, many participants discussed the challenges in managing window operations in old buildings built around the 1960s and 1970s. The main issue of natural ventilation is the balance of occupant thermal comfort and IAQ. For instance, participant 004 shared the experience as follows:

“People don’t want to have the window open when it’s too hot or too cold; they don’t want the cold air rushing in. But you know we need it for the indoor air quality. It’s been a bit of a challenge in that regard. “

* **Safety concerns with operable windows**

Some interviewees discussed the challenges around sealed windows in older buildings. When asked about the reasons for window sealing, participants also mentioned safety concerns about window opening on higher floors of buildings. For instance, participant 013 commented as follows:

“Most windows are sealed as you go into the high buildings, primarily to avoid occupants jumping out of them. So that’s one of the biggest risks that we have. That’s why roof access is restricted, for from heights is the preventative that we’re trying..”

Similarly, participant 7 also mentioned the safety concerns about windows when discussing the effectiveness of natural ventilation as follows:

“We did some airflow measurements in the (building name), and you get quite a lot of the average heat flow through the windows, even though they’d been restricted to 125 degrees that you don’t get people jumping out the window. "

* **Environmental outcomes**

Participants suggested that there was no significant additional energy load from the HVAC interventions overall. HVAC interventions such as maximising fresh air intake increase the building’s energy consumption, as explained by Participant 9,

 “as soon as you increase fresh air into a building. If you set that at 100%, you are conditioning more air rather than recirculating existing. A. So it does naturally increase the energy consumption in the building.”

Many participants discussed the trade-off between the improved IAQ by more fresh air intake and building energy consumption. However, since the occupancy rate was generally lower than before the pandemic, building energy consumption was “evened out” compared to before the pandemic.For instance, Participant 11 shared a reflection on building energy consumption as follows:

“So energy consumption went up (with 100% fresh air). The occupancy went down, so it kind of evened out. In fact, the energy was quite low. And was it efficient? It was not efficient. But, the energy consumption levels were low because the building occupancy was low. “

Participants mentioned increased energy consumption for buildings with mixed ventilation because of more window-opening behaviour. For instance, Participant 1 shared the experience as follows:

“Our electricity bill has increased 25% in 2022 compared to 2019 because of opening windows and automatic doors etc. We have to put this now in our contingency in our budget; we have to consider the increase in electricity use.”

## 3.4 UVGI

* **Limited understanding of UVGI**

The interviews show that UVGI has not been widely considered as an alternative to air purifiers/HEPA filters among practitioners. 28 (out of 41) participants in this study responded that they had never heard about UVGI solutions for improving indoor air. For other participants, the perceptions toward UVGI are mixed. Some FMs hold positive attitudes towards the effectiveness of the technology. For example, participant 3 said:

 “So I’m going to say that (UVGI) is a system that will actually kill the virus. But that option was not presented to us by the University.”

Four interviewees negatively commented on UVGI solutions. For example, they referred to it as “infant” and “not a proven technology”. For example, participant 5 commented as follows:

“If you put the UV lamps inside the air cleaners, they do nothing. All they do is change the chemistry of the air…You shine a UV light lamp on that. You will produce hydroxyl radicals. So you’re creating a really oxidative environment. Inside environments are dangerous for all mucus services. So your eyes and everything. So, while it is effective for no question, what else will it do? That’s where I think the safety in terms of air is. Chemistry has not been proven, even though it’s been used for TB for a long time now. "

# Discussions

This study aims to identify the practices and outcomes of implementing IAQ interventions in existing buildings from the building manager’s perspective. Semi-structured interviews were conducted with 41 professionals who have first-hand experience in managing office or occupant safety in space for buildings in post-pandemic workplaces in Victoria. By exploring the voices of experienced staff, we seek to shed light on the outcomes of those interventions and identify some lessons for future development.

## 4.1 FMI practices

The literature agrees that FMI practices on IAQ for infection control include (1) air dilution by increasing ventilation rate, (2) air filtration by HEPA filters, (3) air purification by UVGI, (4) air pressure control measures(Zhang et al., 2022). This study shows that the primary focus of the practitioners was air dilution and air filtration, while the other two types of measures were rarely considered.

The findings show that Portable Air Cleaners (PAC) have been installed widely in education and office buildings. The programs and funding from the Department of Education and universities followed the intervention in teaching space. By contrast, installing PACs was mainly driven by occupant requests in office building settings. Moreover, many participants emphasised the psychological effects rather than the effectiveness of infection control. According to the literature, PACs can provide a practical and cost-effective method of cleaning indoor air for buildings that lack mechanical ventilation systems, especially for confined spaces with windows closed(Zacharias et al., 2021). However, there is a controversy about the effectiveness of mechanically ventilated buildings compared to other intervention options, such as increasing the ventilation rate. For instance, some studies found that the air turbulence caused by mechanical ventilation might decrease the efficiency of PACs (Ren et al., 2021; Zacharias et al., 2021), but other studies found that the placement of PAC and increasing ventilation rate can significantly enhance the effectiveness (Blocken et al., 2021). Moreover, the studies show that the effectiveness of PACs is affected by the place of positions (Bluyssen et al., 2021) (Blocken et al., 2021) and effective operation and maintenance (Makhsous et al., 2021). Nevertheless, it appears that ventilation type and the effectiveness of air purifiers on airborne transmission were not significant factors considered by practitioners in this study.

While increasing the ventilation rate was agreed upon as a primary intervention for mechanical ventilation, this study shows that practitioners face challenges managing building ventilation with operable windows. The findings echo the literature on the thermal comfort challenges with natural ventilation and unpredictable outdoor conditions (Luongo et al., 2016). Moreover, the participants expressed concerns about relying on occupants for window operations. Although there are already smart window technologies proposed in the literature, using control techniques such as traditional rule-based control (RBC) and the latest predictive control (MPC) (Chen et al., 2023, 2020; Colmenar-Santos et al., 2022), more practical and cost-efficient window control strategies are required, considering the thermal response of buildings with natural ventilation.

The interviews also show that the pandemic has prompted the adoption of CO2 monitoring techniques in some organisations. In the literature, the CO2 level has been used to determine the outcome of air dilution based on the well-mixed air assumption(Gammaitoni and Nucci, 1997). However, when air filtration or purification is used, particles can be eliminated by filters or UV lamps without reducing the CO2 concentration; thus, airborne viruses do not necessarily link with the CO2 level. The interviews validate the benefits of CO2 monitoring in commercial buildings in assessing airborne infection risks and monitoring overall air quality for occupant health. The pandemic appears to have accelerated its adoption in the market, but it has not been adopted widely for office buildings. More research is required to explore the cost factors and optimal solutions for CO2 data collection and use.

However, air purification with UVGI and air control measures were rarely discussed in the interviews and revealed perception gaps between practitioners and researchers. For example, in the literature, the effectiveness of the Ultraviolet Germicidal Irradiation (UVGI) technique in healthcare settings has been well established (Nardell, 2016; Reed, 2010; Walker and Ko, 2007). For example, Wells et al. showed that the UVGI system could disinfect micro-organisms in 1942, and research about UVGI also clustered in the 1980s and 1990s for battling TB in clinical settings (Noakes et al., 2004) and the 2003 SARS pandemic(Reed, 2010). In recent studies, researchers even hold that the current threshold is “overly conservative” and has degraded the efficacy of upper-room UVGI intervention based on experimental evidence (Sliney and Stuck, 2021). However, the interviews reveal that practitioners in Victoria have a limited understanding of this technology. Moreover, some interviewees expressed significant concerns about the safety of UVGI technology in commercial buildings.

## 4.2 Perceived Outcomes

In the literature, health and economic outcomes are the key concerns for health-related intervention decision-making(Mason et al., 2018; Moberg et al., 2018; Wang et al., 2021). As shown in Fig.1., this study shows that practitioners perceived IAQ Intervention outcomes, which can be classified into (1) Health outcomes, (2) Economic outcomes, and (3) Environmental outcomes.



Fig.1. Perceived FMI outcomes

This study shows that the health outcomes of building occupants were the primary focus of the practitioners, and occupant confidence emerged as a major theme. However, practitioners faced challenges in measuring the health outcomes of the FMIs. In the literature, the effectiveness of FMIs was measured by some technical measures such as infection probability, infection risk, or hazard ratio in the air (Zhang et al., 2022). By contrast, practitioners primarily reflected the health outcome with some clinical measures such as “number of infections” and “super spread or events”, while others focused on mental health outcomes measured by “anxiety” and “stress”. Moreover, interviewees generally have positive sentiments towards health outcomes from FMIs on IAQ. For example, they perceived the buildings to be healthier with the new installations such as CO2 monitoring air purifiers, filters, etc.

The economic outcomes of the FMIs were relatively less discussed. Although some interviewees mentioned “business case”, it seems that the cost-benefit analysis was challenging since the benefits of those interventions were not quantified by organisations. By contrast, the study shows that interventions were more adopted as an “Emergency Response”, where cost factors were a secondary consideration. For example, interviewees compared the cost of CO2 monitoring with the cost of providing facial masks and sanitisers to occupants, meaning that CO2 sensors were procured as part of the pandemic response project. Moreover, many participants mentioned PACs were installed on occupant requests for comfort rather than cost-benefit analysis or risk assessment.

This study shows that practitioners are neutral about the environmental outcomes of the FMIs on IAQ overall. Although they suggested no significant additional energy load from the FMIs on IAQ, the additional PACs inevitably consume more energy and generate waste, such as filters. Moreover, participants expressed concerns about energy consumption and window operations for buildings with mixed ventilation. However, there was no quantitative analysis of energy outcomes from the FMIs.

The study reveals that practitioners lack the tools to measure FMI outcomes effectively. There were trade-offs between occupant health (CO2 level), thermal comfort, and building energy performance. This is consistent with the literature. For instance, enhanced natural ventilation significantly reduces microbe survival in aerosols and viral transmission in the air, which benefits occupant health (Dabisch et al., 2021; Schuit et al., 2020); however, it might undermine occupant thermal comfort since occupants are more sensitive to indoor temperatures rather than other air quality indicators such as CO2 concentration(Miranda et al., 2022). On the other hand, increasing the mechanical system ventilation rate inevitably increases energy use and thus reduces building energy efficiency. Therefore, the quantitative trade-offs between occupant health, comfort, and building environmental performance are required.

#  Limitations

This research has some limitations. First, most participants (39/41) in our study resided in a single city and experienced the exact implementation of lockdown measures during the pandemic. Future work with other samples should be conducted to confirm and extend our findings. It is worth mentioning that our study relied on self-reported information from interviewees. This study might have unavoidable social desirability biases (SDB) (Bergen and Labonté, 2020). Our participants may be more optimistic about the outcomes of the interventions because they were being interviewed by researchers who work regarding FMIs. Nonetheless, participants also reflected a range of positive and negative views about the outcomes. Furthermore, our research drew only from building management perspectives. It is possible that staff members’ perspectives could be different from those of occupants who use the space. Therefore, we conducted another survey study from the occupant’s perspective to triangulate the findings.

# Conclusions

This paper presented an interview study to identify IAQ interventions’ practices and perceived outcomes from workplace management perspectives. We found that the pandemic has prompted the implementation of portable air purifiers and CO2 monitoring in existing education and commercial buildings. However, the findings show that portable air purifiers were installed driven by occupant requests and management strategies to boost occupant confidence rather than technical assessment for infection control. Moreover, the interviews validate the benefits of CO2 monitoring in commercial buildings in assessing airborne infection risks and monitoring overall air quality for occupant health. More research is required to explore the cost factors and optimal solutions for CO2 data collection and use. Furthermore, the findings echo the literature on the thermal comfort challenges with natural ventilation, and more practical and cost-efficient window control strategies are required, considering the thermal response of buildings with natural ventilation. This study also highlights practitioners’ need for smart window solutions in buildings ventilated with operable windows and practical risk assessment tools to balance building energy, occupant health and comfort in post-pandemic workplaces. This paper contributes to the knowledge of building operation and IAQ management.

# Declaration of competing interest

The authors declare no known competing financial or personal relationships that could have inappropriately biased the work.

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