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Original Article

Could Mobile Air Supply Unit Enhance Airflow Distribution in Office Environments?

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Abstract

Effective airflow management in office settings is crucial for good indoor air quality and occupant comfort. Poor air circulation can lead to health issues like increased respiratory infections and decreased productivity. This study examines the effectiveness of mobile air supply (MAS) units in enhancing airflow distribution within an office, comparing them with a primary air-conditioning system. A computational fluid dynamics (CFD) simulation using the Renormalization Group (RNG) k-ε turbulence model based on Reynolds-Averaged Navier-Stokes equations predicted airflow distribution. The model showed high accuracy, with an average relative error of 6.6%. The installation locations of MAS units did not significantly affect airflow around occupants. While MAS units can locally enhance airflow, their overall effect on office air distribution is minimal compared to the primary air-conditioning system. The highest velocities were up to 3 m/s near workstations, which diluted particulates but also raised thermal discomfort concerns. Units placed behind obstacles like furniture showed poor air mixing and ineffective distribution. The study highlights the importance of strategically positioning MAS units to optimize air distribution without compromising comfort. Future research should explore particle dispersion within these configurations and extend the use of mobile units to various building types, aiming to improve indoor air quality across different environments. Such research would support adaptive ventilation strategies that enhance air quality and energy efficiency, aligning with the United Nations Sustainable Development Goal (SDG) 3: Good Health and Well-being.

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1. Introduction

Most people spend a significant portion of their time indoors, whether at home, in offices, schools, workspaces, etc [1]. Maintaining good indoor environmental quality (IEQ) is essential for providing occupants with a conducive and healthy environment. According to the National Human Activity Pattern (NHAPS), an individual spends up to 87% of their day indoors, including in office environments. The World Health Organization (WHO) has highlighted the health effects of indoor air pollution, particularly in developing countries. They reported that approximately 2.5 million deaths annually are associated with prolonged exposure to infectious particulate matter (PM) in indoor environments in rural and urban areas, accounting for 4-5% of the total deaths among a 50-60 million population [2]. Besides, WHO data reveals that 6.7 million human deaths occurred in 2024, some of them getting infected by diseases including stroke, ischaemic heart disease, chronic obstructive pulmonary disease (COPD), and lung cancer [2].

In recent years, the emergence of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-COV-2), also known as COVID-19, has heightened global awareness regarding the importance of IEQ in mitigating airborne infections [3]. WHO statistics from the October 2022 report show 621 million infections and 6.5 million deaths due to COVID-19, emphasizing the critical need for optimized ventilation to reduce airborne particle concentrations and lower infection risks. Although vaccination is a crucial method to mitigate COVID-19, with initial efficacy up to 95%, studies indicate a 20-30% reduction in vaccine effectiveness within the first six months post-vaccination [4]. Hence, optimizing the ventilation in a room improves IEQ and reduces airborne particle concentration, which reduces the risk of individuals acquiring airborne infections. Optimal IEQ addresses health concerns and enhances human well-being and productivity [5]. Reports suggested that good IEQ increases worker health and productivity by 15-20% [6]. Poor IEQ in the office environment has been identified as causing several diseases that affect human health, including sick building syndrome (SBS). According to Norhidayah et al. [7], poor IEQ will cause several symptoms of SBS, such as itching, eye irritation, headache, unusual tiredness, and dizziness. Besides that, Norhidayah et al. [7] It was also reported that the symptoms experienced by the users will eventually reduce productivity due to several factors, i.e., tension, irritability, nervousness, difficulty concentrating or remembering things, and depression. More severely, poor IEQ will potentially cause Cardiovascular Diseases (CVDs), according to Singh et al. [8] and Peters et al. [9] extensive exposure to PM with a size of 2.5 µm will increase the probability of humans experiencing sickness, i.e., cardiac arrhythmia, heart failure, systemic inflammation, etc., related diseases. There are a few factors that affect the IEQ in an office environment, i.e., ventilation rate, temperature, humidity, air quality, which includes concentration of PM, Volatile Organic Compounds (VOC), and Carbon Dioxide (CO_2) [10]. Based on the American Society of Heating, Refrigerating and Air Conditioning (ASHRAE) Standard 55, optimal indoor conditions should maintain temperatures between 20-25˚C, relative humidity (RH) within the range of 30-60% [11]. Warcogki [12] performed research and determined that temperatures outside the temperature range may lead to thermal discomfort that potentially affects the productivity of the occupants in the office environment. The concentration of PM 2.5 must be less than 12.5 µg/cm^3, PM 10 less than 14 µg/cm^3, CO_2 concentration must be less than 1500 ppm, and VOC concentration must be less than 400 ppb [13].

Since then, many air-conditioning manufacturers have introduced mobile air supply (MAS) units or air purifiers. These units are portable yet effective as supplemental ventilation elements, developed to reduce indoor pollutants and provide clean air to occupants, thereby decreasing the airborne infection risk [14, 15]. The primary filtration mechanism in these units is a high-efficiency particulate air (HEPA) filter, which traps particles larger than 2.5 µm. A particle with a diameter smaller than 5 µm could remain airborne and spread with the airflow [16], potentially increasing the risk of airborne infection if the particles carry viruses. Conversely, particles larger than 5 μm tend to fall faster due to the gravitational force, usually traveling no more than 1 m from the source [16]. The effectiveness of a MAS unit is highly dependent on several factors, including the presence of existing ventilation, the number of operating hours, the capacity of the MAS unit in relation to the size of the room, the capacity of the built-in air conditioning systems, filtration rates, and the location of the MAS unit within the space [17]. Apart from the filtering function, a MAS unit could create unidirectional airflow, which acts as an air barrier to prevent airborne contaminants from being transported into the targeted area.

Numerous studies have examined the impact of MAS units on airflow distribution in indoor environments to mitigate airborne transmission [18] evaluated the effectiveness of MAS units with HEPA filters in controlling indoor particle concentrations in homeless shelters. While these units effectively reduced particle levels, maintaining continuous operation posed a significant challenge. Similarly, Thottiyil Sultanmuhammed Abdul Khadar, Sim [19] observed that MAS units are effective in reducing the risk of seasonal respiratory infections, indicating a positive outcome on indoor air quality. A recent numerical study also revealed that MAS units can decrease particle penetration into a patient's protective zone by 82% compared to scenarios without MAS activation, significantly enhancing protection in a burn patient ward [20]. Surprisingly, a study reported that the use of a MAS unit fitted with HEPA filters could reduce the viral concentration indoors, but it does not lead to a reduction in COVID-19 prevalence [21]. The COVID-19 pandemic increased awareness among the public that a good ventilation system must be ensured in an indoor environment to prevent the spread of the virus. One of the approaches determined by the previous researchers is installing a UV light with a 254 nm wavelength. This helps to reduce the survival probability of the airborne virus up to 12 % after occupants are exposed for 10 minutes [22]. According to Abbaspour et al. [23], integrating a HEPA filter in the mechanical ventilation system can reduce the risk of airborne contaminants being transmitted by 28-50 %. Besides that, Burridge et al. [24] reported that installing a HEPA filter into the ventilation system will reduce the $PM_{2.5}$ by 40-60 %. However, they added that the use of the MAS unit could lead to a sense of security [21]. Vogelsang et al. [25] highlighted that while MAS units effectively reduce bacterial counts within the airflow reach in an operating room, finding the optimal position for these units often proved challenging. Besides that, frequent cleaning and replacement of the HEPA filters in the MAS unit are needed to maintain the efficiency of the MAS unit in controlling the air quality and reducing the concentration of airborne contaminants. According to Lowther et al. [26], the additional cost for the HEPA filter replacements is up to 50 USD. Finally, the MAS unit, which has a large filter size, may potentially consume large amounts of energy due to a large supply of air velocity to dilute the concentration of airborne contaminants.

The installation of an additional MAS unit to control the airflow in the office environment is rarely examined. Yet, it is crucial to ensure human thermal comfort and reduce airborne infection risk. Given the limited research in this domain, the present study investigates the effect of MAS units in affecting airflow distribution in the office environment through a series of case studies, each varying the unit's location. Besides that, there is also limited study on the location of the MAS unit to be placed that will provide the optimum ventilation rate. To the best of the author's knowledge, this study aims to investigate the optimized location for the MAS unit to be placed to optimize the ventilation rate of the office environment. Besides that, this investigation extends the understanding of MAS unit effectiveness beyond healthcare and residential settings, providing insights that could lead to better health outcomes and productivity in office environments.

2. Methodology

2.1. Numerical simulation

A simplified 3D model of an office environment was constructed using computer-aided design (CAD) software, while ANSYS Fluent, which was a type of computational fluid dynamics (CFD) software, was utilised to conduct the numerical assessment of the airflow interaction within the space [27]. Inspired by the findings of Ren et al., who reported that the vertical downward ventilation system placed in the middle of the office environment could achieve a particle removal efficiency up to 59.3% [28]. Therefore, a similar downward ventilation was adopted for this study. The 3D model of the office is presented in Fig. 1.

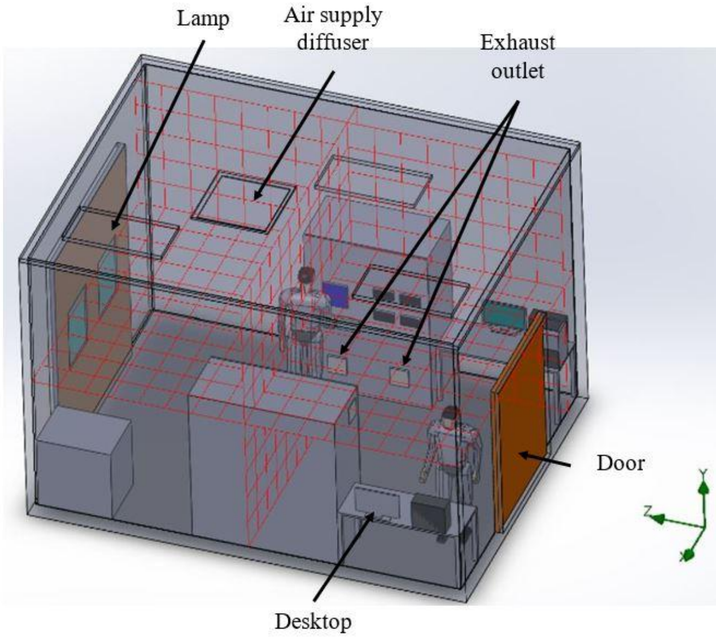


Fig. 1: 3D model of an office environment in a furnished condition.

The office has a size of 5.3 m (L) × 4.1 m (W) × 3.5 m (H). The office has two workstations, each with a desktop on top of the desk. The air in the office is supplied by a 2.5 HP air conditioner, which can produce a volume flow rate of 13.5 m^3/min. The air supply diffuser is integrated with pleated fabric filters made from polyester, designed to capture particles ranging from 10 to 50 microns in diameter. This type of filter is suitable for general indoor environments, such as offices, housing, or institutions.

Before proceeding with the simulation, the CFD model of the office environment was meshed into unstructured tetrahedral elements. The unstructured tetrahedral mesh elements were chosen due to the adaptability of the tetrahedral elements to complex geometrical shapes. Besides that, unstructured tetrahedral mesh elements can ensure high-quality mesh refinements in high gradient regions. A fine mesh refinement was applied at critical areas such as the air supply diffuser, exhaust outlet, manikin, desktop, lamp, and other furniture. Such selection is appropriate for meshing the complex model using fewer elements while providing a precise result [29]. According to Chen et al., for accurate airflow predictions near the wall region or boundary layers, the growth rate between mesh layers should be set to 1.2 [30]. Also, the dimensionless wall distance between mesh layers should be maintained below 5, with enhanced wall treatment function activated [31]. According to Ahsan [32], the enhanced wall treatment applied with the k-epsilon turbulence model helps to investigate the flow of water with high Reynolds number in a 3D pipe and is able to provide more accurate near-wall prediction results, which are suitable for flows involving separation and reattachment. To further test the grid sensitivity analysis, GIT was performed for the mesh elements with 100,000 to 3.2 million elements. According to Lee et al. [33], GIT was an essential process to obtain the optimal grid design of the CFD model by identifying the constant patterns shown in the velocity profile that indicate the domain had achieved grid independence. To minimize errors in the predicted outcomes, the Grid Convergence Index (GCI) for the case study is recommended to remain below 5% [34]. GCI was used to identify the relative error between two different sets of elements [35]. Equation 4 below shows the formula that is used to compute the GCI [36].

$$GCI(u) = \frac{F_s \varepsilon_{rms}}{r^p - 1} \tag{1}$$

where F_s denotes the safety factor with the value of 3, ε_{rms} means that the relative difference between subsequent solutions, p means that the order of convergence with a value of 2, and t is the ratio of the number of fine grids to that of coarse grids. The factor of safety, *Fs*, was set based on accumulated experience on CFD calculations, which represents 95% confidence for the estimated error band. The equation of ε_{rms} was described as below:

$$\varepsilon_{rms} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{u_{i,course} - u_{i,fine}}{u_{i,fine}}\right)^2} \tag{2}$$

where u denotes the airflow velocity. The dimensionless wall distance, y+, was set below 2 to ensure the near-wall mesh was sufficiently fine.

A comparative study by Wong et al. validated that a GCI of 4.01% with 3.2 million tetrahedral elements was sufficient for accurate airflow simulation in an indoor environment of similar size of 6 m (L) × 5.5 m (W) × 3 m (H) [31]. In the present study, the gap around the office door connecting to adjacent areas was minimal, leading to the assumption that air exchange with external regions is negligible.

A total of four case studies were conducted by varying the location of the MAS unit. These parametric studies were performed based on the possibility of installation, without affecting or obstructing the workers' tasks in the office. The exact locations of the MAS unit are shown in Figs. 2 (a) – (d).

The air supplied by the air-conditioning unit has a velocity of 5.3 m/s, with a turbulent intensity of 20% and an air temperature of 23°C. The MAS unit is a Daikin MCX55VMM model, featuring an electrostatic high-efficiency particulate air (HEPA) filter designed to capture fine airborne particles. It operates with a power consumption ranging from 8W to 37W, requiring a single-phase power supply of 220- 240V / 220- 230V. It was prescribed with a velocity of 1.26 m/s, with a turbulent intensity and air temperature of 20% and 23°C, respectively. A 20 % turbulence intensity will ensure that the range of the temperature in the vicinity of the office environment is always maintained, and ensure a good thermal comfort to the occupants [37]A zero-gauge pressure was set at the exhaust outlet. Table 1 tabulates a large percentage of the detailed boundary conditions for the CFD setup in the present study.

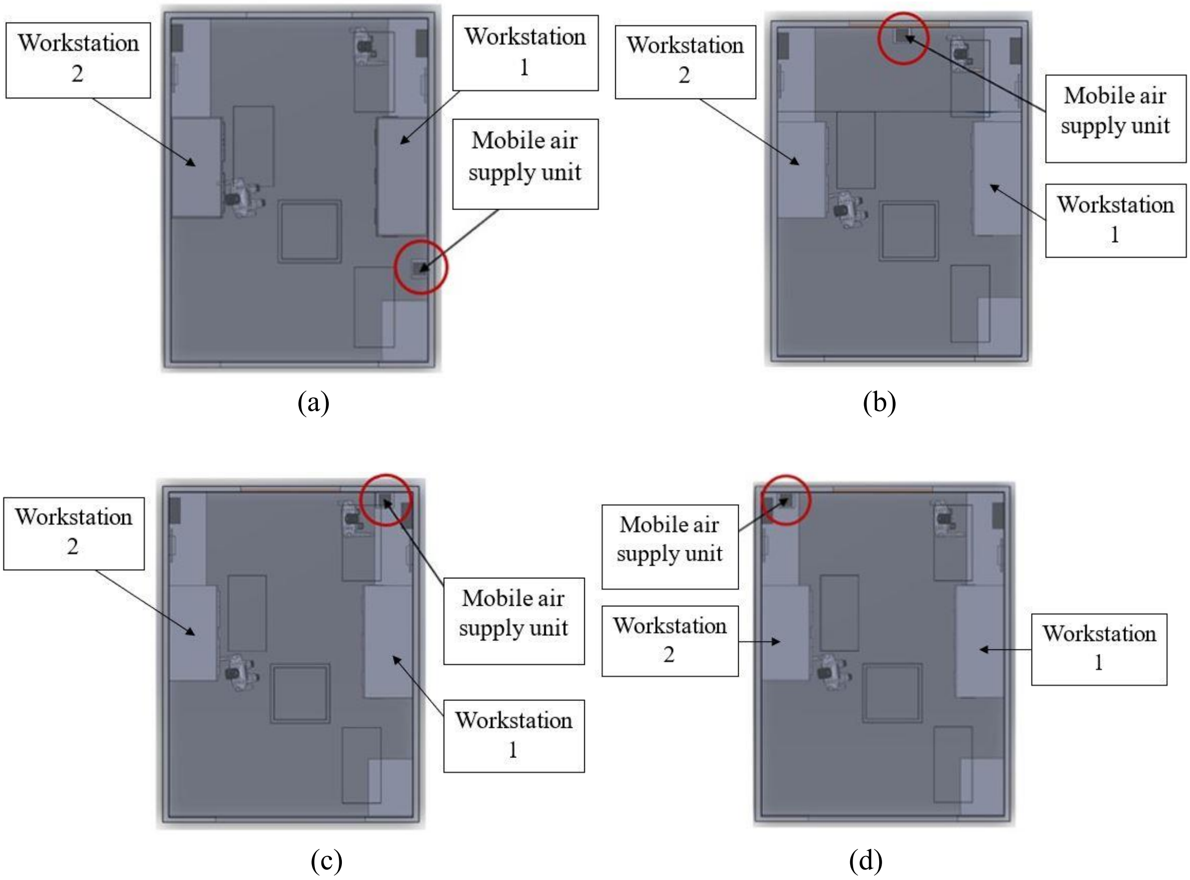


Fig. 2: Placement of MAS unit at (a) 1 m away from workstation 1, (b) at the back of two workstations, (c) near the table of workstation 1, and (d) near the table of workstation 2.

Table 1: Detailed boundary conditions of the CFD setup for an office environment.

Location	Boundary Conditions	Setup
Air Supply Diffuser	Velocity Inlet	Velocity magnitude: 5.3 m/s Direction of airflow: Normal to the boundary Turbulent intensity: 20% Temperature: 296 K (23°C) Power Range: 8-37 W Power Supply: 220-240 V/ 220-230 V
MAS Unit	Velocity Inlet	Velocity magnitude: 1.26 m/s Direction of airflow: Normal to the boundary Turbulent intensity: 20% Temperature: 296 K (23°C)
Exhaust	Pressure Outlet	Gauge pressure: 0 Pa
Manikin	Wall	Wall motion: Stationary wall Wall condition: No-slip Heat flux: 116 W/m^2
Desktop	Wall	Wall motion: Stationary wall Wall condition: No-slip Heat flux: 0 W/m^2

A Renormalization Group (RNG) k-ε turbulence model was used to simulate the airflow distribution in the office environment. The reliability of this turbulence model for indoor airflow simulation has been verified in a past study [38] and validated using the onsite measurement data. According to Wong et al. [31], they performed an airflow velocity analysis with an RNG *kε* turbulence model and SST *kω* turbulence model and obtained relative errors of 8 % and 9 %, respectively. Although Tan et al. [35] reported that a turbulence model that has a relative error of < 10 % is acceptable; however, the lower the relative error, the more accurate the simulation results, making the RNG k-ε turbulence model more preferred. The governing equations for the RNG k-ε turbulence model were shown as in Eq. (3) and Eq. (4) [39].

$$\frac{\partial}{\partial t}(\rho k)+\frac{\partial}{\partial x_i}(\rho k u_i)=\frac{\partial}{\partial x_j}\left(\alpha_k \mu_{eff}\frac{\partial k}{\partial x_j}\right)+G_k+G_b-\rho\varepsilon-Y_M+S_k \tag{3}$$

$$\frac{\partial}{\partial t}(\rho \varepsilon)+\frac{\partial}{\partial x_i}(\rho \varepsilon u_i)=\frac{\partial}{\partial x_j}\left(\alpha_\varepsilon \mu_{eff}\frac{\partial \varepsilon}{\partial x_j}\right)+C_{1\varepsilon}\frac{\varepsilon}{k}(G_k+C_{3\varepsilon}G_b)-C_{2\varepsilon}\rho\frac{\varepsilon^2}{k}-R_\varepsilon+S_\varepsilon \tag{4}$$

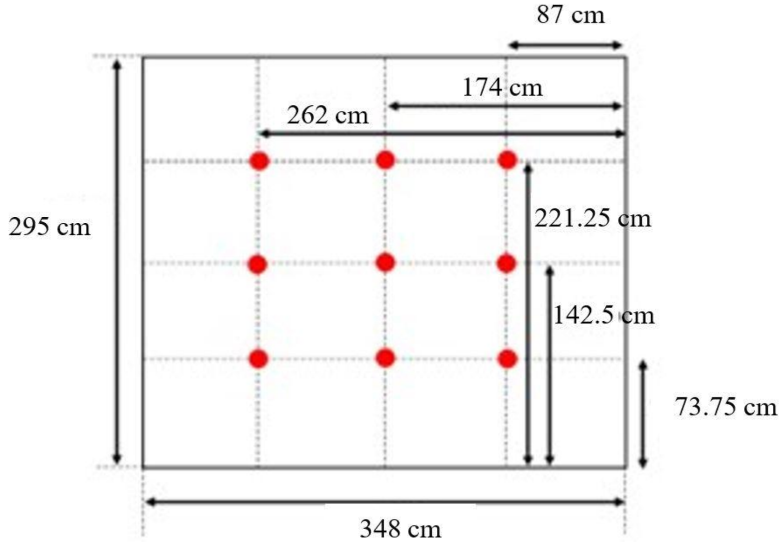
In the governing equation above, ρ represents fluid density, t represents time, k indicates turbulent kinetic energy, ε means the turbulent dissipation, u_i represents velocity component, X_i represents the coordinate, μ_{eff} represents the effective viscosity, S_k and S_ε denotes the user-defined source terms, Y_m represents the contribution of the fluctuating dilatation in compressible turbulence to the overall dissipation rate, G_k denotes the generation of turbulent kinetic energy due to mean velocity gradients, R_ε represents an additional term in ε equation and Gb means that the generation of turbulence kinetic energy due to buoyancy. Additionally, $C_{1\varepsilon}$ and $C_{2\varepsilon}$ are constants, and α_k and α_ε represent the Prandtl numbers for k and ε. Furthermore, the Discrete Phase Model (DPM) is based on the Lagrangian force balance equation which was used to track the particle movement as Eq. (5) shown below [39].

$$\frac{du_p}{dt}=F_D\left(u-u_p\right)+g\left[\frac{g}{\rho}(\rho_P-1)\right]+F_a \tag{5}$$

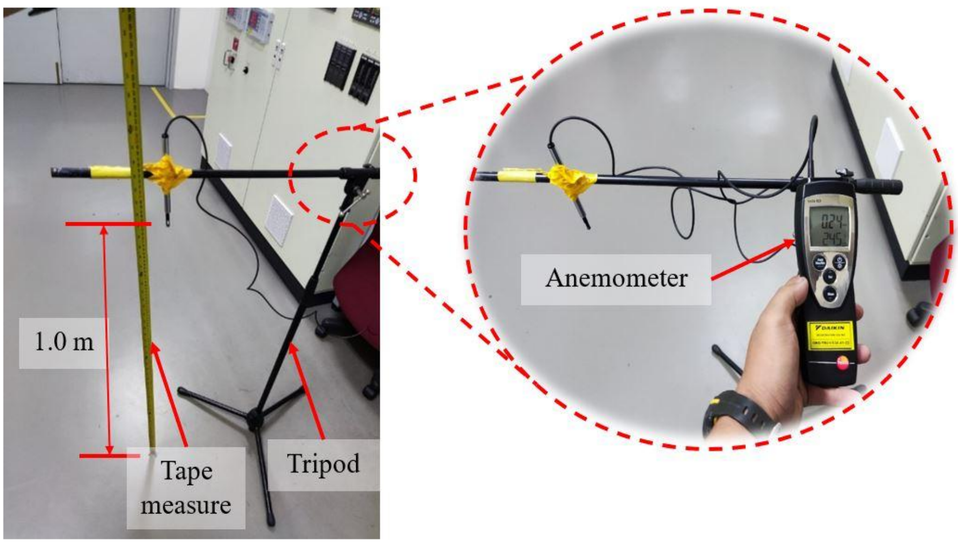
where u_p and u represent the particle velocity and air velocity, respectively; $F_D(u\text{-}u_p)$ denotes the drag force per unit of particle mass; ρ_p and ρ stand for particle and air density, respectively. g represents the gravitational acceleration; and Fa signifies the additional forces per unit mass. The value of the gravitational acceleration, g used in this study is 9.81 m/s^2. The indoor air has a density, dynamic viscosity, and kinematic viscosity of 1.209 kg/m^3, 1.816×10^{-5} Ns/m^2, and 1.502×10^{-5} m^2/s, respectively [40]. No-slip and adiabatic conditions were prescribed on all walls and ceilings. The initial conditions were set to a stable room temperature with uniform air distribution to facilitate a steady-state simulation. The Semi-Implicit Method for Pressure-Linked Equations (SIMPLE) algorithm was utilized for pressure-velocity coupling, ensuring robustness in handling incompressible flow scenarios. The convergence criterion was set as 10^{-9} for the energy equation, and 10^{-4} for other equations.

2.2. Onsite Measurement

A digital anemometer (Model: Testo 425) was used to measure the air velocity and temperature at the air supply diffuser. The anemometer was mounted on the tripod to ensure the stability of the obtained data. The accuracy of the anemometer is ±5% and ±0.5°C for air velocity and air temperature, respectively. The measurement instrument was outsourced and calibrated before the commencement of field measurement. The present study compared airflow velocities using nine monitoring points established across four case studies. The approach for determining the sampling points was retrieved from the study of Kamar et al. [41], which is based on the cleanroom performance testing principles outlined in ISO Standard [42]. A similar approach was employed in previous studies to validate the airflow velocity and air temperature distribution [35,43]. Relative humidity variation was considered negligible in this study, as the fluctuations were minimal, around 1%. The locations of sampling points and the anemometer setup on a tripod stand are shown in Figs. 3(a) and 3(b), respectively.



(a)



(b)

Fig. 3: (a) Generated sampling points for air velocity measurement, (b) Setup of air velocity measurement using tripod.

The calculation of the minimum of number of sampling points, n is given by the equation below:

$$N = \sqrt{A} \tag{6}$$

It is identified that the total area of the office environment model is 10.266 m^2 and minimum 4 sampling point is needed. However, 9 points are determined for the measurement to obtain a more accurate result. During the measurement, the measurement points are monitored sequentially and the average from 3 readings of each measurement point is taken to obtain a more accurate reading. The setup of anemometer's probe which placed on a height of 1.0 m above floor level was as shown in Fig. 3(b). This height has been reported as the critical height for indoor environments, which is identified as the breathing zone of occupants in seated or lying-down positions [44]. The anemometer takes approximately 15 seconds to reach steady state after each measurement and before the next measurement can be taken. In the comparative analysis, the average relative error between measured data and simulated result for air velocity in case 1, case 2, case 3, and case 4 were 7.6%, 9.1%, 4%, and 5.8%, respectively. All the errors fall below 10%, indicating the simulated airflow result agrees well with measured airflow data [35]. This validation confirms the reliability of the simulation model in replicating and predicting the airflow dynamics within the office environment.

3. Results and Discussion

Fig. 4 presents the 3D streamline plots showcasing the airflow trajectory and velocity for each configuration of the MAS unit.

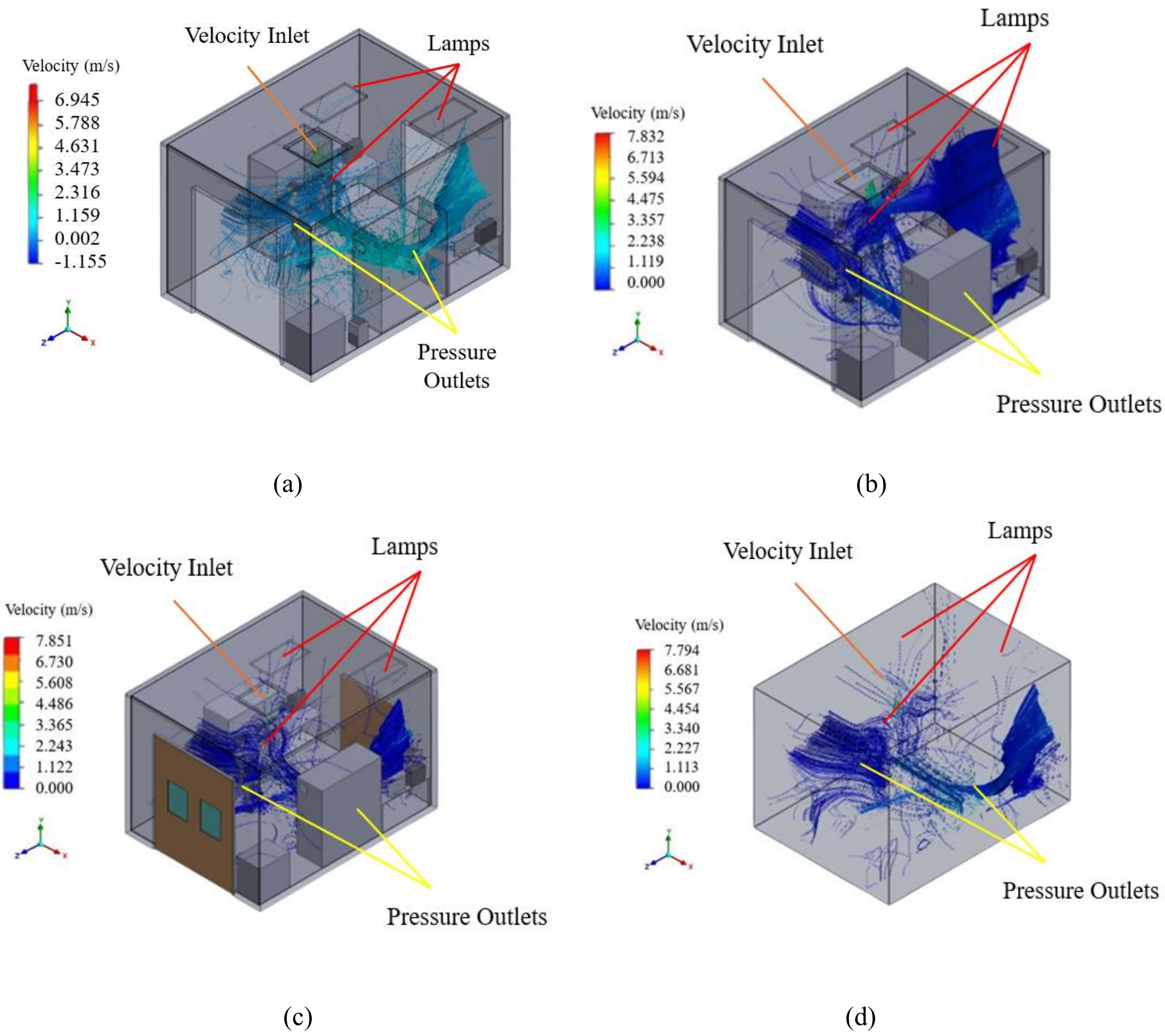


Fig. 4: The airflow trajectory for the MAS unit at (a) 1 m away from workstation 1, (b) at the back of two workstations, (c) near the table of workstation 1, and (d) near the table of workstation 2.

Based on the observation in Fig. 4(a), placing the MAS unit 1 meter away from the workstation results in airflow velocities that reach up to 3 m/s. This high velocity is due to its proximity to the vertical downward air supply diffuser, which facilitates effective mixing of air streams within the office. This configuration can be particularly advantageous in scenarios where targeted air circulation is needed to effectively dilute the accumulated particulates or stale air. However, such high airflow velocities may lead to thermal discomfort, including unpleasant draft sensations. This potentially affects occupants' comfort and productivity [45]. Conversely, when the unit is located at the back of the office environment, airflow can be obstructed by furniture such as tables and chairs at the workstation. This leads to less effective airflow distribution throughout the vicinity of the office environment [46]. As shown in Fig. 4(b), positioning the unit behind two workstations provides a more evenly distributed airflow throughout the office at a reduced velocity of 0.43 m/s. This setup offers broader coverage but may not effectively handle high concentrations of airborne contaminants. Hence, it is identified that the placement of the MAS unit in case 1 has a higher efficiency in diluting the stale air particles than case 2 with a higher air velocity. However, placement of the MAS unit in case 2 may help to maintain a better thermal comfort than case 1, which helps to increase the productivity of work of occupants.

As demonstrated in the airflow velocity contour in Fig. 4(c), the MAS unit near the table of workstation 1 results in restricted airflow due to obstructions from office furniture. This location limits airflow reaching crucial areas near the human manikin at workstation 1. This indicates that furniture layout needs to be considered in the placement of additional air supply units. Conversely, as observed in Fig. 4(d), placing the unit near workstation 2 directs an airflow of up to 2 m/s towards the lower body of the human manikin at workstation 1. This setup benefits from direct impacts from both the overhead and supply diffuser, enhancing airflow distribution around the manikin's lower extremities. However, while effective locally, this setup may not sufficiently address air quality issues across the broader office environment. Therefore, it is identified that case 4, as shown in Fig. 4 (d), had a more adequate airflow distribution than case 3, as shown in Fig. 4(c), due to the MAS unit placement covering the human manikin near workstation 2 and the lower body of the human manikin near workstation 1.

The present study shows that the air supplied from the primary air supply diffuser predominantly controls the airflow distribution in the office environment. It delivers a flow rate nearly twice that of the MAS unit, leading to a dominant influence over the overall air movement. The strong airflow extends beyond the immediate vicinity of the diffuser, contrasting with the more localized impact of the MAS unit. This approach effectively enhances airflow within approximately 1.5 meters of its location. This localized impact aligns with findings from previous studies where MAS units provided a protective zone of around 1.3 meters [29]. This ability is especially beneficial in addressing specific zones within the office that may require additional airflow due to obstructions, layout constraints, or localized air quality issues. Past studies have suggested that MAS diffusers could significantly alter the airflow distribution in indoor environments with generally low air movement. This effect is particularly noticeable when the existing ceiling-mounted diffusers provide air at low velocities, such as 0.45 m/s [47, 48]. In such scenarios, adding a mobile unit can markedly alter the airflow dynamics, compensating for the insufficient air circulation provided by the primary system. The contrasting impact of MAS units in different airflow scenarios highlights their adaptability and the need for strategic deployment depending on the existing air movement conditions within the office. Hence, the positioning of additional MAS units is critical, especially for areas blocked by obstacles, to ensure an adequate airflow distribution throughout the vicinity of office environments.

Human activities such as walking, bending, or turning can significantly modify the local airflow dynamics. For instance, a human with a walking speed of 1 m/s could elevate secondary airflow up to 1.12 m/s [49]. On the other hand, human turning could increase the induced airflow up to three times the turning speed [50]. These induced airflows can lead to the recirculation of settled particles, which impact the effectiveness of the designed airflow patterns. Besides that, it can also lead to uneven air and temperature distribution within the office [51]. To optimize indoor air quality and ensure effective airflow distribution, it is recommended to strategically place MAS units in areas where primary airflow is insufficient or obstructed by office layouts and furniture. Additionally, considering the significant impact of human activity on airflow, office designs should facilitate minimal disruption to airflow paths. This approach promotes more stable and uniform air distribution. Hence, this will further reduce the particle settlement within the vicinity of office environments. From the results obtained in Figure 4, it is informed that the MAS unit should be placed in the area that is distant from the vertical downward ventilation system. This ensures the adequacy of the airflow distribution throughout the environment's vicinity. Next, this is to prevent the recirculation of the contaminated airflow, which potentially causes the occupants to be infected by an airborne virus.

4. Conclusion and Recommendation for Future Work

The present study has validated the RNG k-ε model for simulating airflow turbulence in an office environment. The comparative analysis demonstrates good agreement between the simulated results and measured data, with relative errors ranging from 4.0% to 9.1%, which shows a good agreement in terms of airflow validation. Based on the relative error results, case 3 will be utilized as a case study because its low relative error gives a high accuracy of the results. Utilizing a mesh of 3.2 million elements, yielding a GCI of 4.01%, was adequate for effectively assessing airflow patterns. The study indicates that while MAS units can enhance local airflow, their impact is generally insignificant enough to alter the airflow distribution controlled by the primary air-conditioning system. In cases where the units achieved high velocities, particularly in scenarios 1 and 4, they successfully localized circulation but highlighted potential thermal discomfort issues due to the intensity of direct airflows. This indicates a need for further investigation into how such setups can be optimized to avoid adversely affecting occupant comfort. Conversely, the configurations in cases 2 and 3, which featured lower airflow velocities, encountered problems with effective air mixing and distribution. These issues were largely due to obstacles such as furniture blocking or redirected airflow, underscoring the importance of considering office layout and furniture placement when configuring air supply units.

Future studies should focus on optimizing the placement and settings of MAS units to balance effective air distribution with occupant comfort. Artificial Intelligence (AI) integrated technologies that will be able to learn from the past trend of concentration of airborne contaminants and self-modifying of the airflow patterns based on the real-time conditions should be used in future studies. Additionally, AI-integrated technologies that will automatically generate a new design for the office environment that could optimize the ventilation rate based on past trend data on airborne contaminants concentration should be taken into consideration in future studies. Investigating alternative configurations or adaptive control systems that respond to real-time environmental data could mitigate the issues of thermal discomfort and inefficient air mixing. The behaviour of particle dispersion, which was not considered in this work, should be a focus of subsequent research. Understanding how particles disperse and settle within different airflow configurations can help design more effective ventilation strategies, particularly in environments with high contaminant loads. Extending the application of MAS units to other building environments such as residential homes, schools, hospitals, and commercial buildings could provide insights into the versatility and effectiveness of these units in diverse settings. Each building type presents unique challenges and requirements for air quality management, and studying these variations can lead to more customized solutions. Additionally, implementing IoT sensors with the real-time monitor function of air quality can enable the dynamic adjustment of air supply units in real-time, aligning with sustainable building practices and occupant well-being. Finally, an IoT-integrated alarm system should also be integrated into the ventilation system to provide alerts to the user during the event of uncontrollable high airborne contaminant concentration.

Declaration of Conflict of Interest

The authors declared no conflict of interest with any other party on the publication of the current work.

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