ANALYSIS OF AIRFLOW IN SEMI-OUTDOOR CAFÉ SPACES THROUGH CFD SIMULATION

A CASE STUDY OF RIPAH COFFEE & EATERY

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ABSTRACT: *Cafés play a significant role in Yogyakarta's urban culture, functioning not only as places for coffee consumption but also as spaces where people work and stay for extended periods. The evolution of café typologies, including semi-outdoor settings, highlights this trend. Despite the rapid growth of the café industry, certain architectural details, such as airflow, are often neglected during design and construction. Proper airflow is essential for maintaining space quality and adhering to existing standards. This study evaluates the airflow quality of Ripah Coffee and Eatery through Computational Fluid Dynamics (CFD) simulation, extracting data such as wind velocity to assess compliance with established standards. The findings provide valuable insights and recommendations for practitioners and academics in the architectural field.*

Keywords: *Airflow, Café, CFD Simulation, Semi-Outdoor, Yogyakarta*

INTRODUCTION

The cafe culture in Yogyakarta has exponentially grown through the decade. Cafes in Yogyakarta have ascended beyond a place to chat and have a coffee, it now acts as a space where people would work and stay for a long period of time. According to Larasati et al. (2022), research published in the Journal of Urban Culture Research, cafes in Yogyakarta have become important collective venues that stimulate individual innovation and community participation. Ripah Coffee and Eatery is one of the cafes where people are delighted to stay a bit longer to socialise and do work. Surwiyanta (2023) discusses the organisational culture of Yogyakarta's local coffee shops, highlighting their importance in facilitating a variety of activities, including work and long-term visits. This study emphasises the adaptability and multifunctionality of these spaces, which meet the changing needs of urban residents. Other than coffee and the foods these cafes offer to customers, comfort plays a significant role in determining whether these customers would like to stay in the cafe for an extended period. Comfort in a general idea would refer to things such as the interior design of the space which are vividly noticeable such as lighting, decorations and the arrangement of furniture. But oftentimes there are some aspects that are overlooked and unnoticed by the public. Airflow quality is one of those aspects that plays an important role in crafting a comfortable space.

To achieve a qualifiable airflow quality, a simulation is needed to be conducted. CFD is one of the simulations to assess the thermal comfort of such spaces. CFD stands for Computational Fluid Dynamics, which is a branch of fluid mechanics that uses numerical analysis and data structures to solve and analyse problems involving fluid flows. CFD uses algorithms and computational methods to simulate the behaviour of fluids (liquids and gases) and how they interact with surfaces and each other. In architecture, CFD is able to assess the airflow of a space by simulating how the hvac system works. CFD (Computational Fluid Dynamics) simulations are highly relevant in assessing the thermal comfort of a space due to their ability to model and analyse the detailed behaviour of airflows, temperature distribution, and heat transfer within an indoor environment. CFD simulations can be used to test different design configurations, including the placement and operation of vents, diffusers, and heating/cooling sources. This helps in optimising the design for better thermal comfort and energy efficiency. CFD allows for the simulation of various "what-if"

scenarios, such as changes in occupancy patterns, alterations in building usage, or different climatic conditions. This capability enables facility managers and engineers to proactively plan and adjust strategies to exemplary air quality.

Ripah Coffee and Eatery holds an interesting value as it is a prime example of a semi-outdoor cafe. This paper will dive into the comparative analysis of each different typology of space by assessing the results of each respective CFD simulations.

PROBLEM FORMULATION

As the cafe industry experiences rapid growth, the intricate architectural aspects within the designing process of these spaces are oftentimes overlooked, especially airflow quality. Additionally, designers and architects in these fields have diversified the concept of such cafes. Cafes are now not limited to only indoor and outdoor settings but are now expanding semi-outdoor settings. As a result, outdoor and semi-outdoor cafes are now on the rise. However, the thermal comfort assessments for such spaces are still lacking even though it is actually a necessity in creating a comfortable space. Additionally, technology has allowed practitioners and designers to assess such aspects in order to produce more qualified and exemplary designs hence the urgency to simulate such spaces or designs through CFD (Computational Fluid Dynamics) is more crucial than ever before. Therefore, the problem statements obtained are as follows:

1. What aspects of a semi-outdoor cafe affect the airflow quality
2. How CFD simulation could provide a comprehensive airflow quality analysis

RESEARCH OBJECTIVES

The objectives of this research are as follows:

1. To identify and evaluate the key factors influencing airflow quality in semi-outdoor cafes
2. To employ Computational Fluid Dynamics (CFD) simulation for a comprehensive analysis of airflow quality in semi-outdoor cafes.

LITERATURE REVIEW

- **Airflow Quality**

According to Hobeika et al. (2023), airflow quality is defined as the effectiveness of air movement in diluting and removing pollutants from indoor spaces which ensures a healthy environment. Airflow quality is considered to be a crucial component of IAQ (Indoor Air Quality), which includes factors such as presence of air pollutants, humidity and temperature. Additionally, there are categories of indicators in assessing airflow quality which are dose-related (e.g., concentration of pollutants), building related aspects (e.g., ventilation) and occupant related (e.g., perceived air quality). In an effective airflow, pollutants are adequately removed and diluted from the environment. Watson et al. (2013) explained that in conducting airflow quality analysis, international standards (e.g., ISO standards) must be adhered to ensure consistency and reliability of air quality measurements. Calibrating proper instruments is vital to achieve accurate and traceable results, which are crucial for both regulatory and compliance and research purposes.

- **CFD (Computational Fluid Dynamics)**

Computational Fluid Dynamics (CFD) is a critical tool in modern engineering and research, simulating fluid flow, heat transfer, and other processes using numerical methods. CFD involves solving the Navier-Stokes equations, which describe the motion of fluid substances. These equations are derived from conservation laws: conservation of mass, momentum, and energy. The complexity of these equations often requires numerical methods for practical solutions. Chung (2002) provides a foundational overview of CFD, discussing the historical development and basic numerical methods used. The book highlights the importance of discretization methods, such as the finite difference method (FDM) and the

finite element method (FEM), in converting continuous equations into solvable algebraic forms. Key contributions to these methods have enabled the simulation of complex fluid dynamics problems in engineering and physics.Despite its strengths, CFD faces computational cost and high-fidelity model requirements. Current research focuses on refining algorithms and utilising high-performance computing to improve the accuracy and efficiency of CFD simulations. Anderson (1995) examines CFDs future prospects, focusing on its integration with experimental methods and the development of more resilient and adaptive algorithms.

- **Semi-Outdoor Environment**

According to Bayoumi (2018) semi-outdoor spaces are spaces that serve as a connection between totally indoor and fully outside areas. These spaces typically include features such as partial enclosures or shade components that provide some level of weather protection while yet allowing for natural ventilation and interaction with the outdoors. Verandas, balconies, courtyards, and atriums are a few examples. In terms of thermal comfort and adaptation, Nakano and Tanabe (2004) argued that thermal comfort is an important consideration when designing semi-outdoor spaces. These spaces allow for natural ventilation, which can significantly improve thermal comfort by increasing air circulation and decreasing reliance on mechanical cooling systems. Occupants can adjust to changing thermal conditions, increasing their overall comfort and well-being.

- **Spatial Comfort**

Spatial comfort in architecture relates to occupants' feelings of well-being and contentment in a built environment. It includes several variables such as thermal comfort, visual comfort, aural comfort, and ergonomic design. Temperature regulation, natural and artificial lighting, noise control, air quality, and space organisation are all important factors in determining spatial comfort. A multi-sensory approach to architectural design, which considers the interaction of airflow and other sensory variables, can improve spatial comfort. Spence (2020) highlights the significance of designing places that appeal to several senses, including thermal, visual, and auditory comfort, in order to create a more holistic and pleasant experience for inhabitants.

- **Airflow Standard**

The Indonesian National Standard (SNI) regulates airflow quality criteria, particularly those for semi-outdoor areas. The SNI offers comprehensive guidelines for maintaining indoor air quality through standards such as SNI 03-6572-2001, which covers "Tata Cara Perancangan Sistem Ventilasi dan Pengkondisian Udara pada Bangunan Gedung" (Procedures for Designing Ventilation and Air Conditioning Systems in Buildings). This standard outlines specific requirements for airflow speed in semi-outdoor environments to ensure comfort and health. The key aspects include:

1. Minimum and Maximum Airflow Speeds: The standard specifies the range of acceptable airflow speeds to ensure that spaces are neither too draughty nor too stagnant. Maintaining airflow within this range helps in achieving thermal comfort and preventing discomfort caused by excessive air movement or lack of ventilation.
2. Ventilation Design: The standard provides guidelines on the design and placement of ventilation systems to optimise airflow patterns. This includes recommendations on the size and location of windows, vents, and other openings to facilitate natural ventilation.

METHODOLOGY

- **Data Gathering**

To gather comprehensive data for this research, a field visit to Ripah Coffee and Eatery was conducted. Primary data collection focused on the building's physical characteristics, including the number and types of openings, such as doors and windows, which significantly influence airflow and natural ventilations. Mapping is also considered

the arrangement of furniture and structural elements that might affect air circulation, highlighting potential areas of poor ventilation. Secondary data collection aimed to gather contextual information relevant to the airflow analysis. This included average wind velocity in the area surrounding Ripah Coffee and Eatery, obtained from historical weather data and local meteorological reports, providing insights into external airflow influences. Additionally, the building's orientation and location were examined to understand its interaction with prevailing winds and solar exposure.

Secondary data will also be gathered through a literature study to supplement the findings of observational data. The necessary instruments for data collecting activities include notes, maps of the observed location, smartphones, and cameras. The research variable is as follows.

Table 1 Research Variables and Parameters

Fixed Variables	Control Variables	Parameters
Building Orientation	Ventilations	Openings
		Wind Velocity
Indicators		
Airflow Speed Standards According to Lippsmier (1997) and Indonesian Ministry of Health (1998) According to Lippsmier (1997), the standard for indoor airspeed is as follows: a. 0.1 – 0.25 m/s: Comfortable without the feeling of air movement. b. 0.25 – 0.5 m/s: Comfortable with a slight feeling of air movement. c. 0.5 – 1.0 m/s: Light air movement is felt. d. 1.0 – 1.5 m/s: Light to uncomfortable air movement. e. Above 2.5 m/s: Unpleasant air movement requiring air conditioning. Meanwhile, according to the Indonesian Ministry of Health regulation (MENKES: NO. 262/MENKES/SK/II, 1998), comfortable indoor airspeed ranges between 0.25 m/s and 1.15 m/s.		

Source: Author, 2024

Evaluation Method

The evaluation method in this study utilises Autodesk CFD (Computational Fluid Dynamics) software to determine the wind speed entering the semi-outdoor space at Ripah Coffee and Eatery.

DATA AND ANALYSIS

The building utilised for this study is Ripah Coffee and Eatery, located at Jl. Umbul Permai No. 100, RT.01/RW.21, Lojajar, Sinduharjo, Kec. Ngaglik, Kabupaten Sleman, Daerah Istimewa Yogyakarta 55581, with coordinates of -7.727913868489126, 110.38428159537534. This establishment features both an indoor seating area and a semi-outdoor space. The semi-outdoor area is designed with numerous openings, allowing for sufficient airflow into the space.

Figure 1. Building Location
Source: Google Earth, 2024

Figure 2. Semi-Outdoor Space at Ripah
Source: Author, 2024

The subject of this study is the semi-outdoor space at Ripah Coffee and Eatery, which measures 5 metres in width and 10 metres in length, totalling an area of 50 square metres. The floor of this semi-outdoor space is elevated 80 centimetres above ground level. The building is predominantly oriented to the north, with the shorter sides facing east and west. There are four openings dividing the front and back areas of the semi-outdoor space, each categorised as W1, with dimensions of 250 cm in height and 120 cm in width. On the north side, there is a door and several windows, but they do not significantly impact the airflow simulation and are therefore excluded from this study. The southern side is composed of concrete walls with no openings or ventilation. This spatial configuration provides a controlled environment to assess airflow dynamics using computational fluid dynamics (CFD) simulations. By focusing on the semi-outdoor area with its specific dimensions and openings, the study aims to accurately determine the airflow quality and its implications for occupant comfort.

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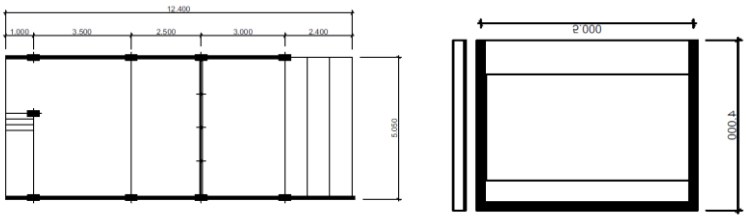

Figure 3. Floor Plan (Left) Section (Right)
Source: Author, 2024

Figure 4. East Façade
Source: Author, 2024

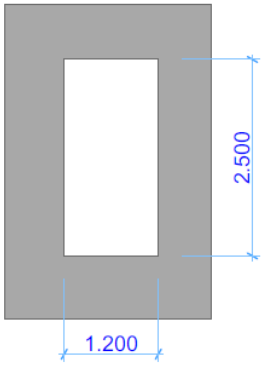

Figure 5. W1 Opening
Source: Author, 2024

SIMULATION RESULTS

After conducting the simulation to determine the air velocity passing through the semi-outdoor area, it was found that, with an incoming wind speed of 5 km/h from the western side of the building, the air velocity within the semi-outdoor area of the café ranged from 6 m/s to 7 m/s. The simulation involved setting the western side as the inlet for the wind, which influenced the airflow patterns throughout the semi-outdoor space. These findings provide crucial insights into the airflow dynamics and their implications for thermal comfort and air quality within the space.

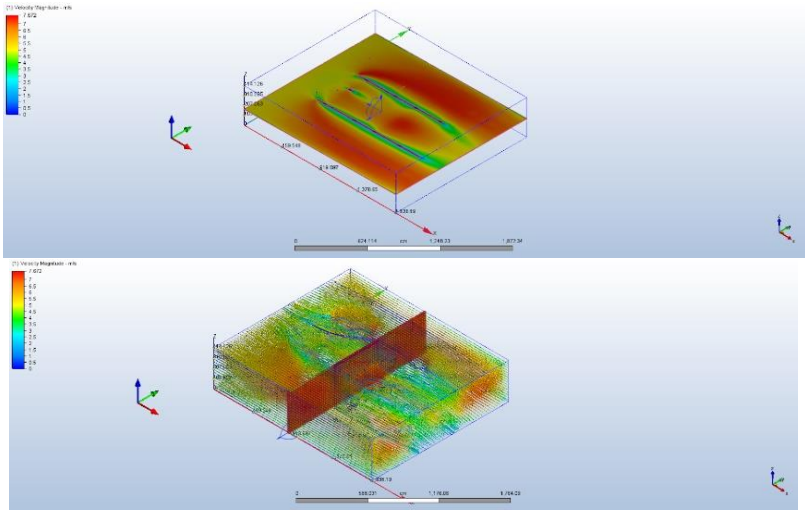

Figure 6. Wind Velocity Result (Top) Wind Direction and Trace (Bottom)
Source: Author, 2024

RESULTS ANALYSIS

Based on the results of the Computational Fluid Dynamics (CFD) simulation, the wind entering the semi-outdoor area of Ripah Coffee and Eatery reaches an average speed of 6.5 m/s. This finding indicates that the air velocity significantly exceeds the comfortable indoor airspeed range specified by the Indonesian Ministry of Health (MENKES: NO. 262/MENKES/SK/II, 1998), which is between 0.25 m/s and 1.15 m/s. The recorded airspeed surpasses the upper limit of this standard by approximately 5.35 m/s.

Furthermore, the simulation results reveal that the air velocity also exceeds the maximum indoor airspeed standard set by Lippsmier (1997), which caps at 2.5 m/s. According to Lippsmier, air velocities above this threshold fall into the category of unpleasant air movement, thus indicating that the semi-outdoor area at Ripah Coffee and Eatery experiences airspeeds that are likely to be uncomfortable for occupants.

The implications of these findings are significant for the design and usability of semi-outdoor spaces in similar settings. Excessive airspeed can lead to discomfort, impacting the overall user experience and potentially deterring patrons from using such spaces. It highlights the necessity of incorporating design modifications or additional features to mitigate high air velocities and enhance occupant comfort. Strategies may include altering the layout, introducing windbreaks, or modifying the openings to regulate airflow more effectively. These adjustments would align the airflow within the semi-outdoor area with established comfort standards, ensuring a more pleasant environment for users.

Table 2. Comparative Analysis

Simulation Result	Standard (m/s) MENKES: NO. 262/MENKES/SK/II/1998	Details
6.5 m/s	0.25 – 1.15 m/s	Contravene

Source: Author, 2024

CONCLUSION

The CFD simulation results for Ripah Coffee and Eatery's semi-outdoor area demonstrate that the wind speed, averaging 6.5 m/s, substantially exceeds the comfort thresholds established by both the Indonesian Ministry of Health (MENKES: NO. 262/MENKES/SK/II, 1998) and Lippsmier (1997). The airspeed surpasses the MENKES comfort range (0.25 m/s to 1.15 m/s) by approximately 5.35 m/s and Lippsmier's maximum indoor airspeed standard (2.5 m/s), categorising it as unpleasant.

These findings highlight the critical need for design modifications to mitigate high air velocities and enhance occupant comfort. Effective strategies might include altering the spatial layout, incorporating windbreaks, or adjusting openings to better regulate airflow. Implementing such changes will help align the airflow characteristics of the semi-outdoor space with established comfort standards, thereby improving the user experience and making the space more conducive to patronage. This research underscores the importance of considering airflow dynamics in the architectural design of semi-outdoor environments to ensure they provide a comfortable and pleasant atmosphere for users.

RECOMMENDATION

Based on the previously conducted simulation, it is evident that the excessive air velocity within the semi-outdoor area of the cafe is primarily due to the numerous openings that allow substantial amounts of wind to pass through. To address this issue and ensure compliance with air velocity standards, it is recommended to redesign the openings to limit and control the wind entering the semi-outdoor space. One effective solution is to install a window type W2 measuring 120x250 cm, equipped with louvres or brackets spaced 5 cm apart with a width of 5 cm. This design will help to regulate the airflow, reducing the wind velocity to acceptable levels. Additionally, implementing buffers such as columns at the front-most part of the western facade can serve as windbreaks, further mitigating the wind speed entering the space. These modifications are expected to align the air velocity within the semi-outdoor area with established standards, thereby enhancing the comfort and usability of the space.

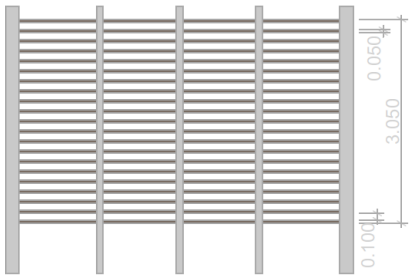

Figure 7. W2 Opening
Source: Author, 2024

Figure 8. Eastern Façade Recommendation
Source: Author, 2024

RECOMMENDATION SIMULATION

Based on the results of the Computational Fluid Dynamics (CFD) simulation, the wind entering the semi-outdoor area of Ripah Coffee and Eatery reaches an average speed of 1 m/s.after applying W2 opening with the louvre installed within it. This finding indicates that the air velocity complies with the comfortable indoor airspeed range specified by the Indonesian Ministry of Health (MENKES: NO. 262/MENKES/SK/II, 1998), which is between 0.25 m/s and 1.15 m/s. The recorded airspeed falls 0.75m/s from the minimum threshold and 0.15 m/s below the maximum threshold. Furthermore, the simulation results reveal that the air velocity also complies with the standard set by Lippsmier (1997), which caps at

2.5 m/s. According to Lippsmier, air velocities between 0.5 m/s to 1.0 m/s fall into the category of felt light air movement, thus indicating that the semi-outdoor area at Ripah Coffee and Eatery experiences airspeeds that are likely to be more comfortable.

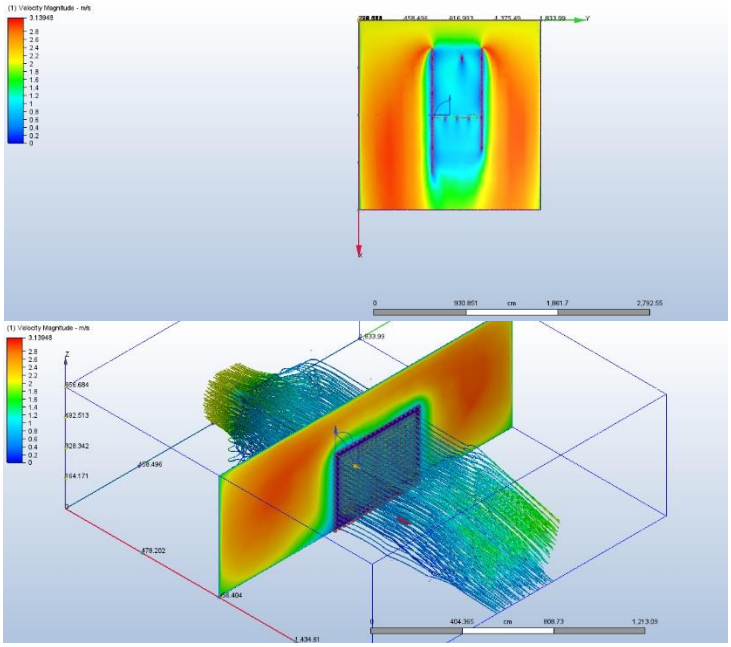

Figure 9. Recommended Wind Velocity Result (Top) Recommended Wind Trace and Direction (Bottom)
Source: Author, 2024

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