JURNAL ARSITEKTUR Vol. 14, No. 2, Juli 2024, 111-128
DOI http://dx.doi.org/10.36448/ja.v14i2.3502
pISSN2087-2739
eISSN2716-3423

Exploring the Influence of Building Mass Configuration on Urban Airflow, Case Study: Pulmonary Hospital Salatiga

Vanessa Aulia Geraldine [1*], Nedyomukti Imam Syafii [2]

[1] Fakultas Arsitektur dan Desain, Universitas Katolik Soegijapranata, Jalan Pawiyatan Luhur IV No.1, Bendan Duwur, Gajahmungkur, Kota Semarang, Jawa Tengah, Indonesia, 50234
[2] Departemen Teknik Arsitektur dan Perencanaan, Universitas Gadjah Mada, Jalan Grafika No. 2 Sendowo, Sinduadi, Kecamatan Mlati, Kabupaten Sleman, Daerah Istimewa Yogyakarta, Indonesia, 55284
*Penulis Korespondensi: vanessa@unika.ac.id

Abstract: *This study investigates the influence of building mass configuration on urban airflow dynamics on a case study the development of dr. Ario Wirawan Pulmonary Hospital in Salatiga. The development involves expanding the facilities with new building additions. This development raises concerns about potential disruptions to the air circulation patterns that may have an effect on the health level of its users. This study uses Computational Fluid Dynamics (CFD) simulations with Rhinoceros for 3D model and the Grasshopper with Butterfly plugins to investigate the influence of building mass configuration on urban airflow dynamics. By comparing the existing hospital conditions with the proposed developments, this study show the changes in air circulation direction and wind speed. The results of this study indicate that the development of the hospital causes a decrease in wind speed in development. The average value of the existing wind speed is up to 0.7 m/s faster compared to the new development condition. The study result highlight the importance of strategic planning and building design to ensure the optimal air circulations within healthcare facilities.*

Keywords*: building configuration; air circulation; CFD simulation; hospital*

Artikel diterima	:	18 Januari 2024
Artikel diperiksa	:	07 Maret 2024
Artikel disetujui	:	28 Mei 2024
Artikel dipublikasikan	:	31 Juli 2024

1. Introduction

Hospitals play a multifaceted role such as extending beyond the provision of care solely for those afflicted with ailments to encompass a broader clientele seeking enhancement of both mental and physical well-being. The meticulous design of hospitals is imperative, not only to address the healthcare needs of patients but also to optimize the health conditions of all visitors. The architectural planning of hospital facilities necessitates a comprehensive consideration of environmental factors, as favorable environmental conditions exert a profound influence on the harmonious equilibrium of the psyche, physique, and spirit, thereby enhancing the recuperative journey of patients and promoting the well-being of visitors.

Optimizing air circulation emerges as a critical consideration in enhancing environmental conditions within hospital buildings. Adequate air circulation is deemed optimal when it demonstrates the capacity to effectively facilitate wind penetration across the entire space, thereby mitigating the presence of deleterious stagnant air (World Health Organization, 2021). Therefore, the hospital must have a supportive environment where the quality of air circulation should be decent.

The ongoing development of Dr. Ario Wirawan Pulmonary Hospital in Salatiga involves expanding its medical facilities by augmenting the number of patient rooms and incorporating new hospital facilities. The introduction of new structures necessitates careful consideration, as it can potentially impact the existing air circulation patterns. Therefore, the development proposals must meticulously account for and address air circulation dynamics to prevent any detriment to the current environmental conditions, ensuring that the expansion enhances, rather than diminishes, overall environmental health.

The building arrangement significantly influences the immediate surrounding environment and creates a unique microclimate in a specific area. Building layout is consist of regular, irregular and structural configuration. The building configuration is based of its size, shape and the proportion with the surroundings (Hariyadi & Sarwadi, 2009). Furthermore, the shape of the building could be divided into two types based on its shape, namely simple shapes and complex shapes (Rizqi & Prayitno, 2020). These building forms can be identified from a line made of two points where the line stays in the plane or passes through the plane.

The microclimate in urban areas can change based on the building arrangement and layout in the urban area. The microclimate temperature in a city can be increased or decreased (Sugangga et al., 2018). Also, city configuration can change wind movement and wind flow, so the thermal conditions in the area have a close relationship with the city configuration (Sugangga et al., 2018). The size of the building's influence on airflow depends on the orientation, shape, proportion, and height, and the arrangement of the building mass will affect the wind direction, wind speed, and shadow area on thermal comfort in outdoor and indoor spaces (Lechner, 2014). Also, wind incident direction and building separations also significantly affect wind circulation in urban areas (Iqbal & Chan, 2016).

1.1. Outdoor Wind Comfort and Safety Study

In determining the comfort level of pedestrian winds, it is essential to know the effect of wind on the outdoors to be a clear guide for designers for building projects and urban planning. Research has shown that poorly designed building arrangements can lead to discomfort (Jiang et al., 2020). The table below shows the main wind comfort categories developed for the city exterior environment:

Table 1: Urban wind comfort table

Category	Wind Velocity	Description
Frequent sitting	2.5 m/s	Acceptable for frequent outdoor sitting use.
Occasional sitting	4 m/s	Acceptable for occasional outdoor seating e.g. General public outdoor spaces, balconies and terraces intended for occasional use
Standing	6 m/s	Acceptable for entrances, bus stops, covered walkways or passage wavs beneath buildings
Walking	8 m/s	Acceptable for external pavements, walkways
Uncomfortable	> 8 m/s	Not comfortable for regular pedestrian access
Unsafe	15 m/s	Unsafe wind conditions for both pedestrians And cyclists

(Source: City of London Cooperation, 2019)

1.2. Salatiga, Indonesia Climate Condition

Indonesia’s geographical location on the equator makes Indonesia have tropical climate. According to Lippsmiere in Nasrullah said that the tropical climate of Indonesia has very high relative humidity (RH) (sometimes reaching 90%), quite a lot of rainfall, and the average annual temperature generally ranges from 230C and can rise to 380C (Nasrullah et al., 2015). In the “warmt” season. Nielsen in Illiyin formulates design principles in the tropics by dividing it into two areas, namely the hot dry zone and the warm, humid zone (Illiyin, 2018). Based on the division of the area, Indonesia is included in the warm, humid zone. The tropical climate in Indonesia influences architectural design as an adjustment to user comfort. If buildings in Indonesia are not adapted to the tropical climate, it can affect human comfort. For example, if the air conditions are not pleasant, it will disrupt human productivity, and human productivity will decrease because the air is too cold or too hot or tends to be too cold (Karyono, 2013).

Salatiga city has a relatively cool microclimate with an average monthly temperature of 23.5°C, at its hottest conditions during the day; this area has a temperature of 28°C and the coldest conditions at night with a temperature of 20°C. The average hourly wind speed in Salatiga experiences slight seasonal variation throughout the year. The windiest month of the year in Salatiga in

August, with an hourly average wind speed of 10.9 kilometers per hour (Cedar Lake Ventures. Inc., 2022). The most dominant wind direction in Salatiga is the wind coming from the Northwest - NW and the Southeast – SE (Cedar Lake Ventures. Inc., 2022).

Thus, based on the above illustration, the development in dr. Ario Wirawan Pulmonary Hospital in Salatiga shows an important challenge in optimizing air circulation in the hospital environment. When new buildings are introduced and the existing layout is changed, there is a risk of disrupting current air circulation patterns, which may adversely affect environmental conditions within the hospital environment. The formulation of the problem revolves around the need to ensure that the development proposal considers the dynamics of air circulation comprehensively to maintain and improve environmental health standards within the hospital.

The study places itself in the context of research on hospital design, environmental health, and urban microclimate dynamics. Previous research has highlighted the importance of optimal air circulation in healthcare facilities, emphasizing its role in promoting patient recovery and also reducing risk to healthy person. This study aims to determine the effect exploring of building mass configuration at the dr. Ario Wirawan Pulmonary Hospital in Salatiga, to find out whether after adding a building the air circulation improves or gets worse.

2. Methods

The research was conducted by evaluation– quantitative method. Quantitative uses numbers, starting from collecting data, interpreting data acquisition, and exposing research results (Arikunto, 2013). The evaluation method is a process of analysis and identification of data valid for assessing feasibility that has been compiled in a plan (Kantun, 2017).

This research will study the impact of different building arrangements and find a better wind environment. This research will compare two distinguished models, the existing and development conditions. The existing model will be based on the existing hospital conditions, while the development conditions model will be based on the design proposals.

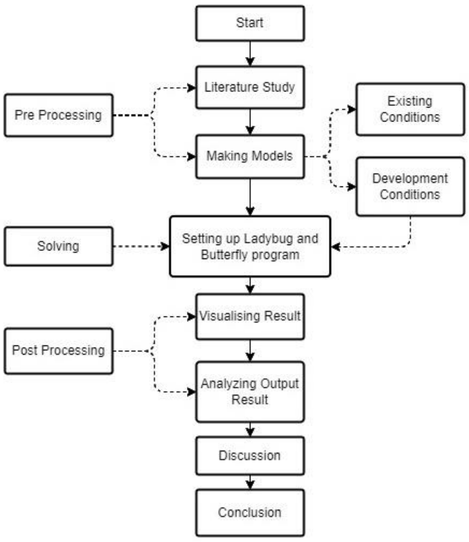

Figure 1. Research flowchart
Source: author analysis, 2022

This research will use Rhinoceros as a modeling tool which will be continued with CFD analysis methods from Grasshopper enhancements, Ladybug with Butterfly sub plugins. The study began by making a model of Rhinoceros. It then runs the OpenFOAM engine via blue CFD on the device. Furthermore, to conduct CFD simulation analysis, researchers will use one of the tools parts of the Ladybug Tools, namely Butterfly and will be solved using the RANS (Reynold-averaged Navier Stroke) turbulence equation. The RANS turbulence equation is used to determine the pattern of wind flow (WF) and wind speed (V) statically or stably. Then to make an analysis of the output results of the simulation will use the Microsoft Excel application as the output of the results. Utilizing Rhinoceros computer application and Butterfly CFD add-on (OpenFOAM engine), this research will be divided into three stages, (1) pre-processing, looking for input and data limits, (2) solving, setting up the program and (3) post-processing, analyzing the output results.

The simulation begins by creating a 3D model of the hospital area with a 1:1 ratio using the Rhinoceros application. Two versions of the 3D model were created, namely the existing version and the development version. Both models will only consider buildings, other barrier elements such as vegetation will be ignored in this study. The mesh used in the simulation is a structured mesh with a hexahedral grid type. The minimum and maximum layer thicknesses in this study were 0.1 and 0.7, respectively, with an expansion ratio of 1.1, in order to obtain a more precise transition near the wall surface and avoid disturbing aspect ratios. The closer to the building mass, the tighter the meshing grid will be, which indicates that the greater the turbulence created by the closer the air circulation and the building mass. Different boundary conditions are carefully defined in the simulation to simulate realistic airflow scenarios. At the inlet boundary, a uniform velocity profile of 10 m/s was determined to represent the inlet airflow.

The outlet boundary condition applies zero pressure gradient, ensuring smooth flow transition. Wind speed data is taken from a height of 1 meter above ground level. The terrain used is 0.5 or is called very rough with low-rise buildings and moderate vegetation. Grid computing uses a staggered grid model where the density will be adjusted to the position of the building model and adjusted to the OpenFOAM settings to find out how much turbulence is received at each building mass.

a)
b)
c)

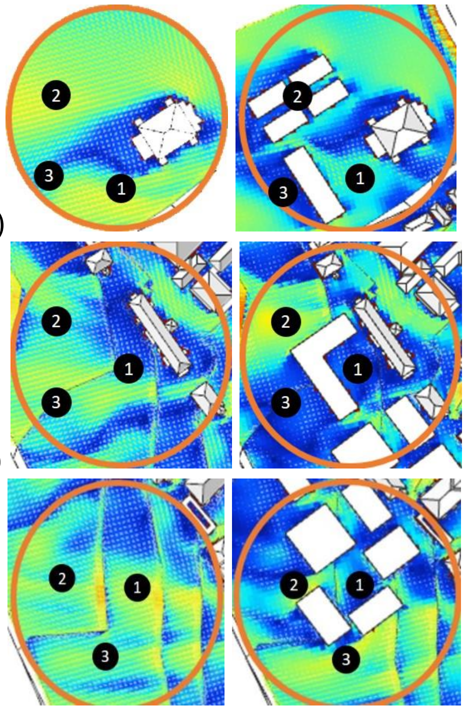

Figure 2. a) wind data collection points in residential zones; b) wind data collection points in inpatient zones; c) wind data collection points in the healthy lung zone
Source: author analysis, 2022

Data collection of wind speed and wind movement patterns is carried out by taking samples at certain critical points that are considered the most representative and have significant changes in the area in each zoning. These critical points are usually close to buildings planned to be built and also places that have a lot of outdoor activities so they need wind comfort and safety.

The simulation results on the 3D model will then be analyzed by comparing wind simulations in existing conditions and in developmental conditions. Both conditions will then be analyzed based on two different wind directions, namely the wind from the NW and the SE according to the state of the dominant wind direction in Salatiga (Cedar Lake Ventures. Inc., 2021).

2.1. Case Study

The interest area for the case study in this research is dr. Ario Wirawan Pulmonary Hospital Salatiga, located on Hasanuddin Street 806, Mangunsari, Sidomukti District, Salatiga, Central Java. It is located at the foot of Mount Semeru, Mangunsari Village, Central Java.

Figure 3. Existing of dr. Ario Wirawan Pulmonary Hospital Salatiga
Source: google earth, 2022

Figure 4. Development plan of dr. Ario Wirawan Pulmonary Hospital Salatiga
Source: author document, 2022

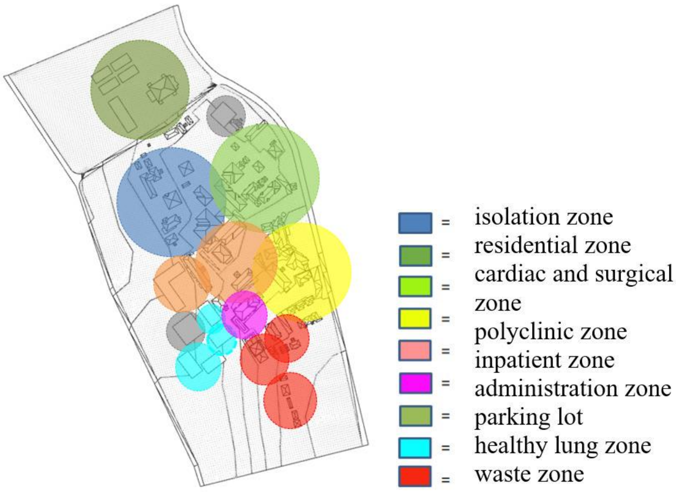

Figure 5. Zoning division of dr. Ario Wirawan Pulmonary Hospital Salatiga
Source: (author analysis, 2022)

Dr Ario Wirawan Pulmonary Hospital Salatiga is divided into several zones distinguished based on the function of the building. It was then split into nine zones based on the function of the building, including isolation zone, residential zone, cardiac and surgical zone, polyclinic zone, inpatient zone, administration zone, healthy lung zone, waste zone, and parking lot (Figure 2). However, this study will evaluate three zones that experience significant development and significantly affect the hospital's surrounding environment.

a. Housing zone: This zone serves as a place to stay for hospital managers and patient's, families who will stay overnight and other needs. Initially, there was one building in this zone, namely the education and training building. In the development process, there are additional buildings, namely guest houses and official houses. The guest house development plan consists of one building with four stories, while the official house consists of four buildings with just one story.

b. Inpatients zone: This zone serves as a treatment area for patients staying at the hospital. In this zone, there is the addition of one building, namely the inpatient building. This building is designed to have an L shape that has two floors. The inpatient building was added because the need for inpatient rooms at the hospital increased.

c. Healthy-lung zone: A healthy lung zone is an additional zone that functions for healthy people who want to improve their lung health. In this zone planning, there will be two clinic buildings with a height of one floor, a garden, and a swimming pool.

3. Results and Discussion

3.1. Housing Zone Simulation Result

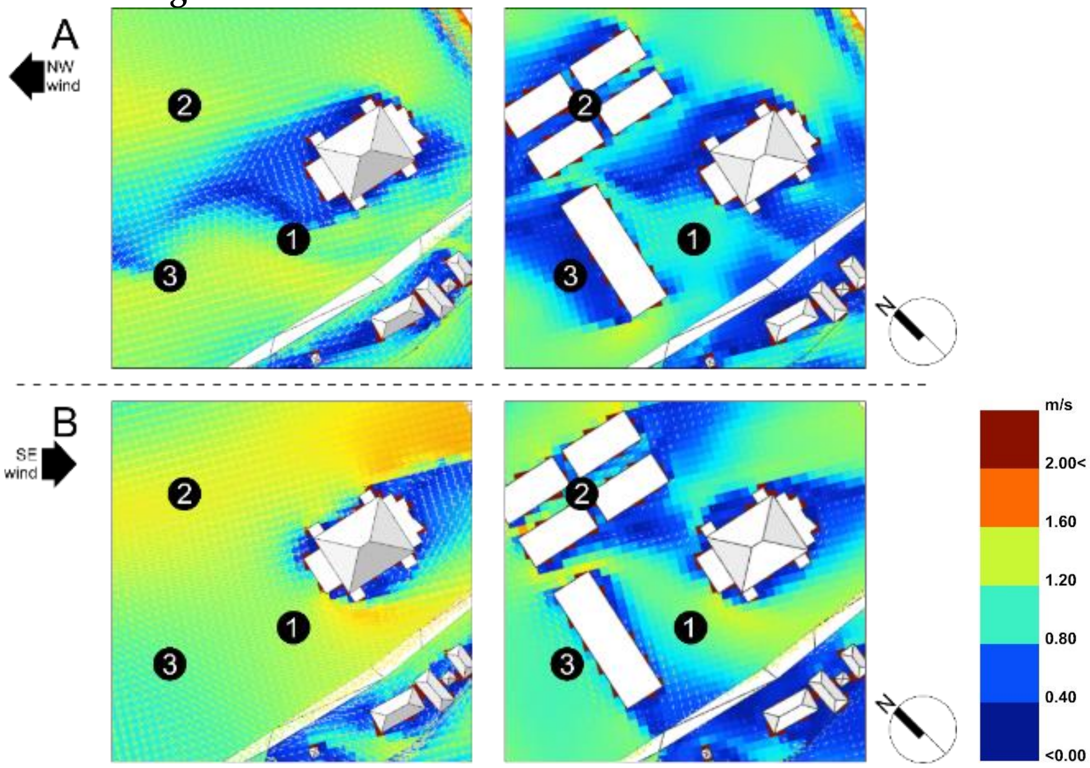

Figure 6. Impact of new development on wind flow and speed at Housing zone (top: prevailing wind from NW; bottom: prevailing wind from SE; right: existing condition; left: development condition; numbers: data extraction point)

Figure 6 (A - top) illustrates the wind environment around the housing zone exposed to prevailing NW wind. In the existing housing zone, the wind movement from the NW experienced a slight deflection of the wind direction towards the east side because the wind touched the corner of the building, which caused the wind to be divided in half and suction to the building envelope. This phenomenon shows of how buildings can influence wind flow patterns, leading to localized changes in wind speed and direction.

In the development proposals of the area that add the guest house and official houses, the previous wind speed decreased and created a negative zone, especially behind the guest house. The decrease in wind speed and the formation of this negative zone is caused by aerodynamic changes due to the addition of new structures that disrupt the natural wind flow. In the existing area at point (1), the east side of the education and training building has a wind speed of 2.93 m/s, point (2) has a speed of 3.21 m/s, while point (3) has a speed of 2.11 m/s. In the development proposals of the area, the wind movement pattern changes, which causes changes in wind speed. In the development of the point (1) area, the area between the training building and the guest house has a wind speed of 2.09 m/s, point (2) the area between the official houses has a speed of 1.27 m/s, point (3) the east side of the guest house has a wind speed of 0.79 m/s.

Meanwhile, Figure 6 (B - bottom) illustrates the wind environment around the housing zone exposed to prevailing SE wind. The SE wind speed is relatively high in the existing housing zone. The wind experienced a slight deflection due to being hit by the corner of the training building. This deflection shows the influence of building features on wind direction and speed. After adding official houses and guest houses, the wind from the SE through the space between the official houses caused the wind to bend to the west. The wind experienced a deflection in the building envelope, which caused a decrease in speed. These deflections and decreases in speed show how new construction can change wind flow dynamics, leading to local changes in wind patterns. In the existing area at point (1), the east side of the education and training building has a wind speed of 3.31 m/s, point (2) has a wind speed of 3.05 m/s, while at point (3) has a wind speed of 1.88 m/s. In the development of the area, the point (1) area, the area between the training building and the guest house has a wind speed of 2.04 m/s, (2) the area between the official houses has a wind speed of 1.94 m/s, while (3) the east side of the guest house has a wind speed of 2.03 m/s.

3.2. Inpatient Zone Simulation Results

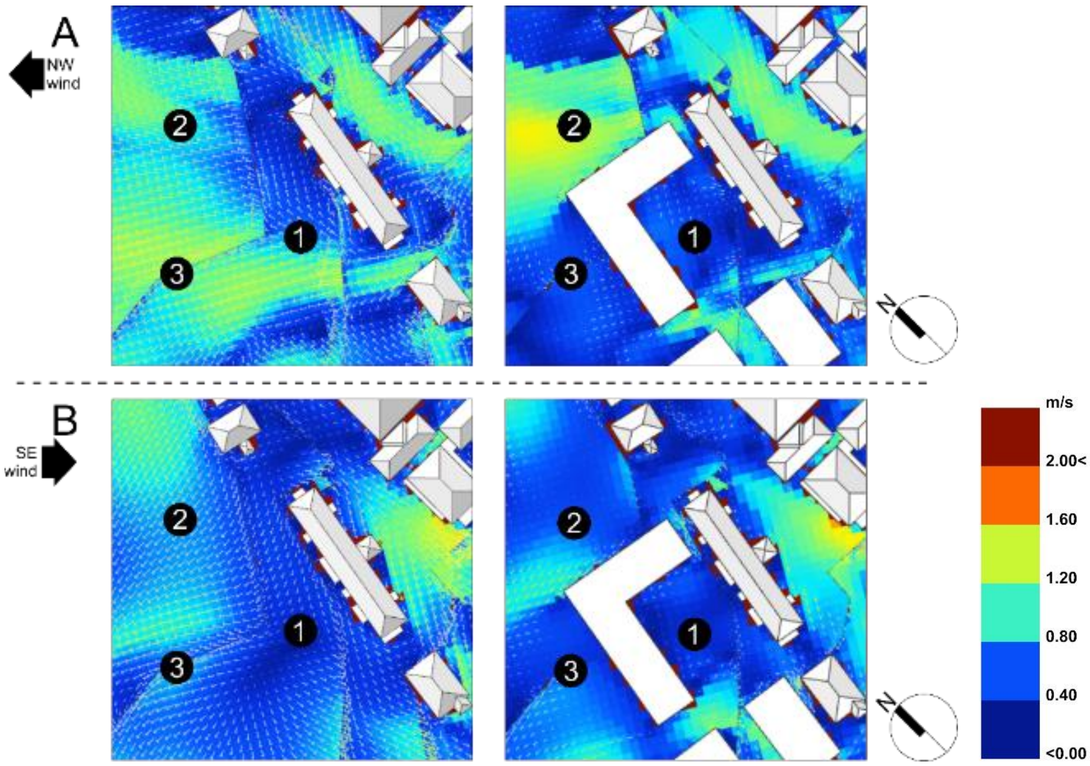

Figure 7. impact of new development on wind flow and speed at Inpatient zone (top: prevailing wind from NW; bottom: prevailing wind from SE; right: existing condition; left: development condition; numbers: data extraction point)

Figure 7 (A - top) illustrates the wind environment around the inpatient zone that has been exposed to prevailing NW wind. In the existing inpatient zone, the wind from the NW flows from lower plains through other buildings to higher levels causing the wind to increase in speed. This increase in wind speed is a result of the acceleration caused by the terrain observed in areas transitioning from lower to higher land elevations.

In the development of the inpatient zone, the new building is L-shaped and perpendicular to the direction of the incoming wind, making the wind turn to the south. This deflection of wind direction causes the inside of the building and the back of the building to have deficient wind circulation. In the inpatient zone, wind speed is measured based on critical points in areas that significantly influence and change in the inpatient zone. The observed reduction in wind speed and disturbed circulation patterns are a consequence of the building orientation and its impact on wind flow dynamics. Wind speed measurements are especially important in areas of significant influence and change within the inpatient zone. In the existing inpatient zone, wind speed is measured at main points to capture variations: point (1) with a wind speed of 1.71 m/s, point (2) of 1.50 m/s, and point (3) of 3.13m/s. S. These variations highlight the local effects of terrain and building layout on wind speed distribution.

In the development of the area where new inpatient buildings have been added, there is a change in the wind movement pattern, which causes changes in wind speed. Point (1) area development has a speed of 0.24 m/s, point (2) on the south side, the new inpatient has a speed of 3.02 m/s, area on the east side of the inpatient proposal (3) has a speed of 0.13 m/s.

Figure 7 (B - bottom) illustrates the wind environment around the housing zone exposed to prevailing SE wind. In the inpatient zone, the existing condition of the wind circulation is relatively even because there are no buildings. In the development of the addition of the inpatient building, the wind was prevented from entering the building so that it experienced wind circulation at low speed. While outside the building, slightly increased speed due to the deflection. In the existing inpatient zone at point (1) the wind speed is 0.42 m/s, at point (2) there is no building with a speed of 1.11 m/s, while at point (3) the speed is 0.68 m/s. In the development of the inpatient zone, point (1) the new inpatient proposal area has a speed of 0.25 m/s, point (2) on the south side, the new inpatient has a speed of 1.95 m/s, point (3) the area on the east side of the inpatient proposal has a speed of 0.88 m/s.

3.3. Healthy-Lung Zone Simulation Results

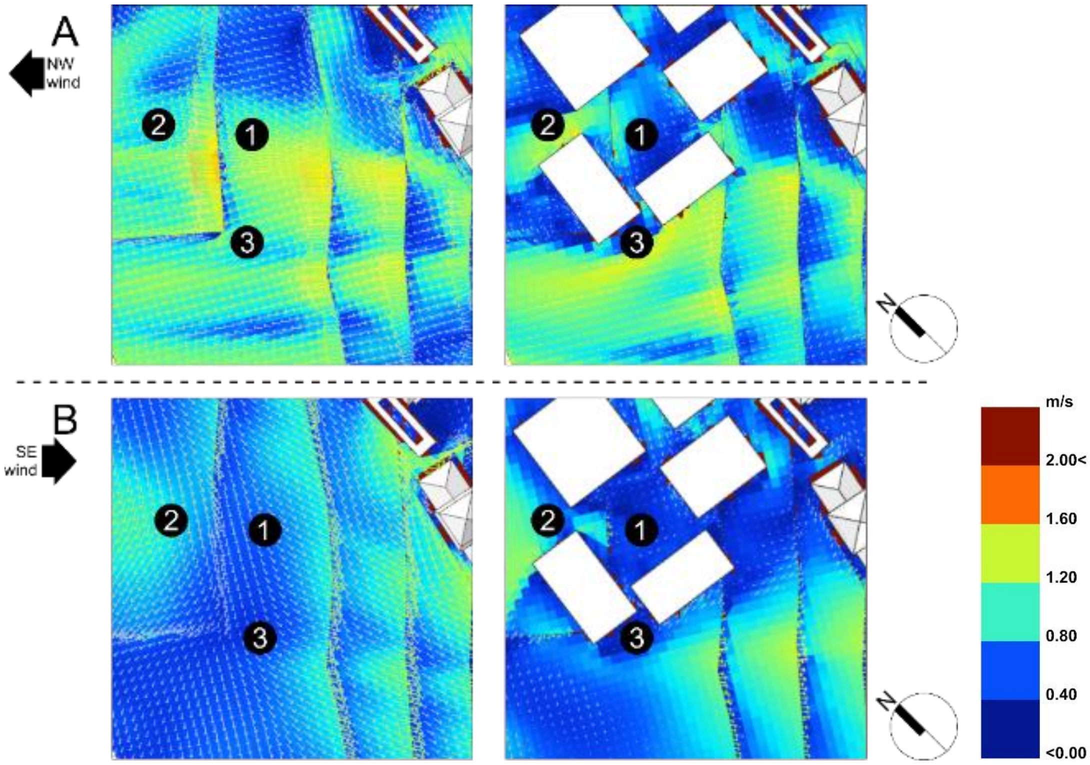

Figure 8. Impact of new development on wind flow and speed at Healthy-lung zone (top: prevailing wind from NW; bottom: prevailing wind from SE; right: existing condition; left: development condition; numbers: data extraction point)

Figure 8 (A - top) illustrates the wind environment around the housing zone exposed to prevailing NW wind. There is no building in the existing healthy lung zone. The wind coming from the NW is parallel to the increase in land height, causing the wind speed to increase. The development proposals of Healthy-lung zone that add the clinic building. The arrangement creates a courtyard. A little wind passes through the inside of the courtyard and turns outward, and causes some areas to experience an increase in wind speed. In the existing healthy lung zone, there is no building at point (1) the wind speed is 3.20 m/s, at point (2) there is no building with a speed of 2.56 m/s, while at point (3) the speed is 2.26 m/s. There is a change in wind speed in the development of the area where new buildings have been added. In developing proposals, point (1) area, the inner healthy lung zone, has a speed of 1.15 m/s, point (2) the area between the clinic building and the parking lot has a different speed of 3.18 m/s, point (3) the swimming pool proposal area has a speed of 2.44 m/s.

Regarding the variations in wind speed described above, the lines that may appear to indicate separation of wind speed levels are intended to illustrate different zones within the area under study. These zones experience different wind speed characteristics due to various factors such as the presence or absence of buildings, changes in topography, and prevailing wind direction. The mentioned wind speed variations highlight complex airflow patterns influenced by urban development and natural features.

Figure 8 (B - bottom) illustrates the wind environment around the housing zone exposed to prevailing SE wind. The wind speed changes slightly when the altitude level decreases in the existing healthy lung zone. In the development proposals, the wind is trying to pass through the gap between the clinic building and the parking building, but because the distance is narrow, the wind that manages to turn is only slightly and causes low circulation. Meanwhile, other winds turned north and experienced an increase in speed. In the existing healthy lung zone, there is no building point (1) with a wind speed of 1.95 m/s, while at point (2), with a speed of 2.25 m/s. (3) speed of 1.07 m/s. In development proposals, point (1) has a speed of 0.45 m/s, point (2) has a speed of 2.27 m/s, point (3) has a speed of 0.92 m/s.

3.4. Discussion

For analysis and discussion purposes, data collection on wind speed and wind movement patterns is carried out by taking samples from specific critical points that are considered the most representative and have significant changes in the area in each zoning. These critical points are usually located close to the buildings planned to be built and places with a lot of outdoor activities that require wind comfort and safety.

Based on the wind speed trend seen from the existing and the development in the dr Ario Wirawan Pulmonary Hospital (Figure 7), the three zones show a change in wind speed. The development proposal shows a lower wind speed compared to the existing conditions. This change was caused by the fact that there were no buildings in the existing area at the tested point initially. After the area's development, buildings were added, which caused the wind to bend and divide. The changing pattern of wind movement causes the wind speed to decrease or become an area not exposed to the wind. This study supports the statement of Estiningnytas and Kusumawanto, which states that if the wind experiences a deflection of the wind circulation because a building blocks it, it can cause the other side of the building to become a negative area or not exposed to the wind (Estiningtyas & Kusumawanto, 2013). This statement supports the statement from Sugangga about changes in the urban configuration that change causing changes in the microclimate, mainly to wind speed (Sugangga et al., 2018). This trend proves that the development proposals of dr Ario Wirawan Pulmonary Hospital design make the wind speed in the area decrease.

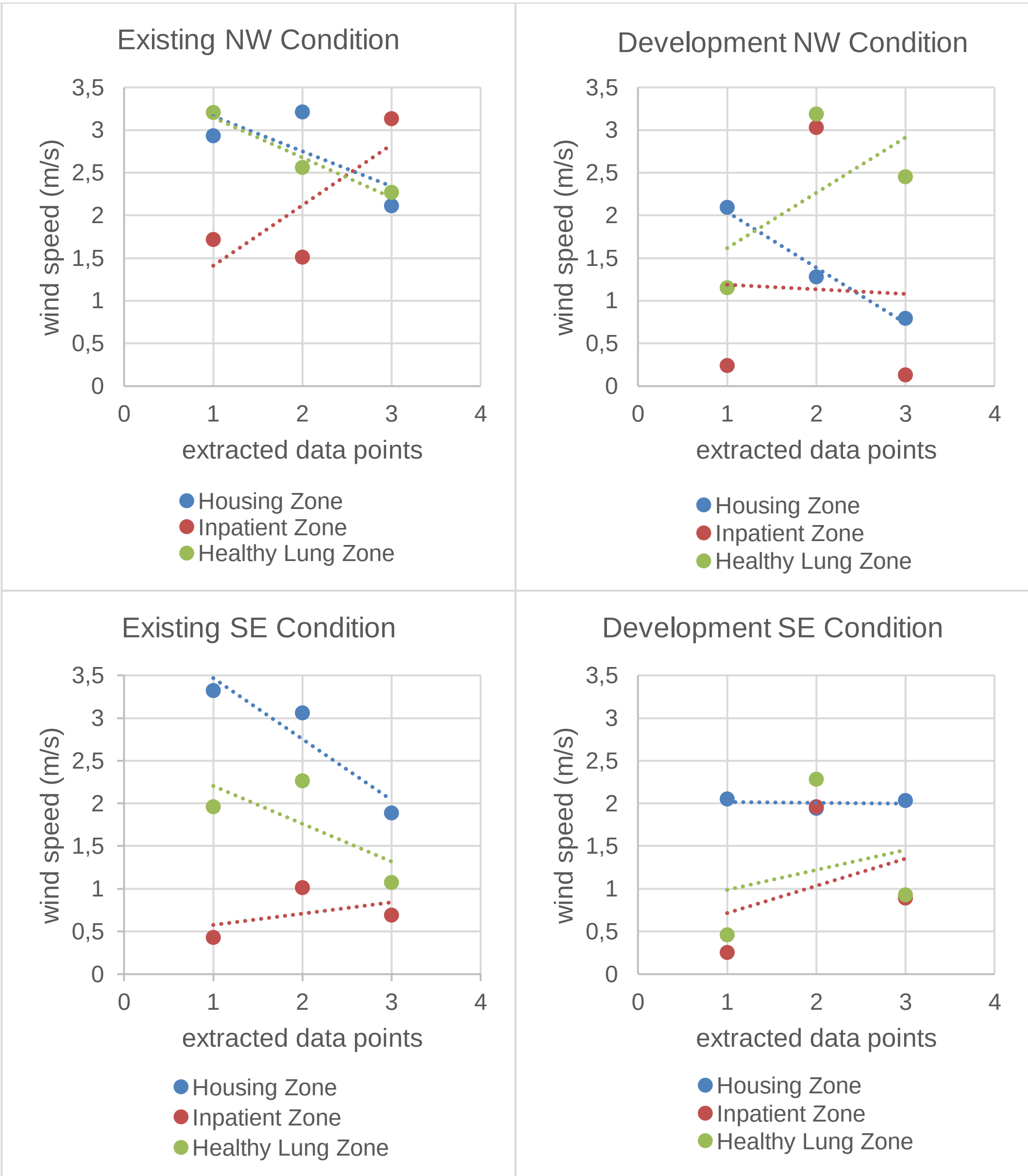

Figure 9. Wind speed diagram based on zoning exposed to prevailing NW and SE wind (top: prevailing wind from NW; bottom: prevailing wind from SE; right: existing condition; left: development condition; numbers: data extraction point)

Based on the simulation result comparation configuration seems to make quite significant changes to the wind speed in the area. The diagram shows a diminishing trend in wind speed within these three zones. Significant changes can be seen from the residential zone, followed by the healthy lung zone and the inpatient zone. Assessment of wind speed varies because it is driven by wind speed (wind effect) and temperature (stack effect) (Sakiyama et al., 2021). The results of this study support previous findings about excessive building density adversely affecting the overall outdoor ventilation, reducing air quality and outdoor pedestrian comfort (Hu et al., 2018). The reduction in wind speed will impact the comfort of the outdoor wind in each zone.

Based on the average wind speed analysis in the existing and developmental residential zones, the wind speed value is significantly reduced from 2.75 m/s to 1.69 m/s. This average wind speed follows the Dec, et al (Dec et al., 2018) statement regarding wind safety standards for humans outdoors which says that 1 m/s to 8 m/s is still considered safe for outdoor human activities. However, a decrease in wind speed will also affect the comfort of the wind in humans, which, in the residential zone, actually makes conditions uncomfortable for humans to do outdoor activities. Based on the research on wind speed in urban areas, the Wind Microclimate Guideline (Table 1) said that wind speeds below 2.5 m/s were considered too quiet for human activities. This average wind speed affects the residential zone's wind comfort, where it is estimated that outdoor human activities will often occur considering that the housing zone houses the function of temporary residences and health education facilities.

Based on the average wind speed analysis results in the existing and developments in the inpatient zone, the wind speed value is also reduced from 1.41 m/s to 1.08 m/s. Both in the existing and after development, the wind speed in the inpatient zone has a low average wind speed, which is below 2.5 m/s, so that it can cause outdoor wind discomfort because it is considered too quiet (City of London Corporation, 2019). Even though there is a decrease, the difference in the average wind speed is not too big, so it affects the safety of the wind in humans. Better natural ventilation is needed to increase patient comfort due to low metabolic rates, especially in tropical countries (Lan et al., 2017). Therefore, in this case, larger window openings are considered to increase wind circulation so the wind can enter the patient's room.

The existing average wind speed analysis and development in the healthy lung zone resulted in a significantly reduced average wind speed, from 2.22 m/s to 1.74 m/s. Compared to the other two zones, the healthy lung zone experienced the slightest decrease in average wind speed. The average wind speed in the residential zone is still included in a safe value and does not interfere with human activities outdoors, according to Dec, et al (Dec et al., 2018). For outdoor wind comfort in the healthy lung zone after development, the highest average wind speed is 2.27 m/s. According to the Wind Microclimate Guideline (Table 1), it is considered close to comfortable for outdoor human activities. Based on Thaib research, in a humid and warm climate, maximize airspeed to improve the health of the patient's body (Thaib, 2020). The healthy lung zone has the function to improve the patient's health. Therefore, it is essential to increase the wind speed in outdoor areas that will be used frequently.

4. Conclusion

This study uses a CFD simulation application to determine the effect of building layout on air circulation in the Pulmonary Hospital, dr. Ario Wirawan Salatiga. The research is conducted using a simulation method by using Butterfly software to run CFD. The geometry of the building used is the existing condition of the dr. Ario Wirawan Salatiga Pulmonary Hospital and the development proposals for the area of the dr. Ario Wirawan Salatiga Pulmonary Hospital. This study has shown several things related to its effect on air circulation in the hospital area, such as:

Simulation is carried out by looking at the movement of the wind coming from the NW and SE, which shows the current movement and a significant change in wind speed from existing to development. These changes can be seen at specific critical points that significantly impact users in each zoning.

The simulation results at critical points in three zones (housing zone, inpatient zone, and healthy lung zone) with wind conditions originating from the NW and SE in existing and development conditions having decreased wind speed. The residential zone has the most significant decrease in air velocity compared to the other two zones. The decrease in wind speed is due to many new buildings and high-rise buildings compared to the inpatient zone and healthy lungs. The addition of this building makes significant changes to the pattern of wind movement resulting from bending and dividing the wind-exposed to the building envelope. The average value of the existing wind speed in the three zones is much higher than the development wind speed of 2.19 m/s, and the development shows the figure of 1.58 m/s.

Based on the simulation, the wind speed in the area shows that the wind speed is still in the safe category for outdoor human activities. However, based on the urban outdoor wind comfort criteria from Wind Comfort Guideline, and research on wind speed safety by Dec wind speed after development proposal has not been considered in the comfortable category for outdoor activities, due to low wind speed. Therefore, in this case, the effort is needed to increase wind speed in the development proposal.

The results of this study indicate the condition of the development of the Pulmonary Hospital dr. Ario Wirawan Salatiga. The addition of new buildings in development proposals has proven to reduce the outdoor wind speed, both from the NW and SE wind directions. The addition of this building will significantly change the pattern of wind movement resulting from the increase in bending and splitting the wind-exposed to the building envelope, especially if the direction of the wind is perpendicular or diagonal to the sharp edge of the outside of the building. The addition of new buildings in existing areas with no previous buildings will obviously reduce wind speed in the area. Based on this, to keep the wind speed included in the comfortable and safe category in an area, the placement of the position and distance of the building according to wind conditions will have a significant effect on optimizing wind distribution in the hospital area. Based on the wind speed value that can be re-optimized in the hospital area, it can increase outdoor wind comfort, which is one of the criteria for achieving a healthy environmental condition.

5. References

Arikunto, S. (2013). *Prosedur Penelitian Suatu Pendekatan Praktik*. Rineka Cipta.

Cedar Lake Ventures. Inc. (2022). *Iklim dan Cuaca Rata-Rata Sepanjang Tahun di Salatiga*. Weather Spark. https://id.weatherspark.com/y/121508/Cuaca-Rata-rata-pada-bulan-in-Salatiga-Indonesia-Sepanjang-Tahun

Cedar Lake Ventures. Inc. (2022). *Iklim dan Cuaca Rata-Rata Sepanjang Tahun di Salatiga*. Weather Spark. https://weatherspark.com/y/121546/Average-Weather-in-Semarang-Indonesia-Year-Round

City of London Corporation. (2019). *Wind Microclimate Guidelines for Developments in The City of London*. City of London Corporation.

Dec, E., Babiarz, B., & Sekret, R. (2018). Analysis of temperature, air humidity and wind conditions for the needs of outdoor thermal comfort. *E3S Web of Conferences*, *44*, 1–9. https://doi.org/10.1051/e3sconf/20184400028

Estiningtyas, S., & Kusumawanto, A. (2013). *Optimasi Kenyamanan Termal Melalui Modifikasi Geometri Urban Street Canyon Studi Kasus Jalan Kaliurang Km. 4,5 - 5,8 Yogyakarta*. Universitas Gadjah Mada.

Hariyadi, A., & Sarwadi. (2009). *Studi konfigurasi bangunan pada rumah hunian pasca gempa di Bantul Yogyakarta menggunakan alat accelerometer GPL-6A3P*. Universitas Gadjah Mada.

Hu, K., Cheng, S., & Qian, Y. (2018). CFD simulation analysis of building density on residential wind environment. *Journal of Engineering Science and Technology Review*, *11*(1), 35–43. https://doi.org/10.25103/jestr.111.05

Illiyin, D. F. (2018). *Perancangan Kawasan Cagar Budaya Berdasarkan Climate-Sensitive Urban Design (Studi Kasus: Kawasan Rajawali Surabaya)*. Institut Teknologi Bandung.

Iqbal, Q. M. Z., & Chan, A. L. S. (2016). Pedestrian level wind environment assessment around group of high-rise cross-shaped buildings: Effect of building shape, separation and orientation. *Building and Environment*, *101*, 45–63. https://doi.org/10.1016/j.buildenv.2016.02.015

Jiang, Y., Wu, C., & Teng, M. (2020). Impact of residential building layouts on microclimate in a high temperature and high humidity region. *Sustainability (Switzerland)*, *12*(3). https://doi.org/10.3390/su12031046

Kantun, S. (2017). Penelitian Evaluatif Sebagai Satu Model Penelitian Dalam Bidang Pendidikan. *Majalah Ilmiah Dinamika*, *37*(1), 15.

Karyono, T. H. (2013). Kenyamanan Termal dalam Arsitektur Tropis. In *Arsitektur dan Kota Tropis Dunia Ketiga: Suatu Bahasan tentang Indonesia*. Rajawali Pers.

Lan, L., Tushar, W., Otto, K., Yuen, C., & Wood, K. L. (2017). Thermal comfort improvement of naturally ventilated patient wards in Singapore. *Energy and Buildings*, *154*, 499–512. https://doi.org/10.1016/j.enbuild.2017.07.080

Lechner, N. (2014). *Heating, Cooling, Lighting: Sustainable Design Methods for Architects*. John Wiley & Sons, Inc.

Nasrullah, Rahim, R., Mulyadi, R., Jamala, N., & Kusno, A. (2015). Temperatur dan Kelembaban Relatif Udara Outdoor. *Temu Ilmiah IPBLI*, *1*, 45–50.

Rizqi, K. A., & Prayitno, B. (2020). Optimization of building configuration in vertical residential housing towards outdoor thermal comfort: Case study of tambora flats, Jakarta, Indonesia. *ASEAN Journal on Science and Technology for Development*, *37*(2), 57–62. https://doi.org/10.29037/AJSTD.614

Sakiyama, N. R. M., Frick, J., Bejat, T., & Garrecht, H. (2021). Using CFD to Evaluate Natural Ventilation through a 3D Parametric Modeling Approach. *Energies*, *14*, 2197. https://doi.org/doi.org/10.3390/en14082197

Sugangga, M., Janesonia, K. I., Illiyin, D. F., & Donny Koerniawan, M. (2018). Thermal Comfort Assessment in the Open Space in Bandung Case Study Dago Street and Riau Street. *IOP Conference Series: Earth and Environmental Science*, *152*(1). https://doi.org/10.1088/1755-1315/152/1/012010

Thaib, R. (2020). Analisis Ventilasi Udara Alami Pada Rumah Sakit. *Jurnal Ilmiah Jurutera*, *7*(2), 12–17.

World Health Organization. (2021). *World Health Organization News Room. Retrieved from Coronavirus disease (COVID-19): Ventilation and air conditioning*. https://www.who.int/news-room/questions-and-answers/item/coronavirus-disease-covid-19-ventilation-and-air-conditioning