



## Post-Covid-19 Ventilation Strategies for Shopping Malls in Hot Humid Climate

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### Abstract

To date, many strategies have been executed to combat the COVID-19 disease, including the provision of good ventilation in buildings to reduce the spread of the virus. Open or semi-open space with good air exchange between indoor and outdoor provides better condition compared to enclosed space with mechanical ventilation. However, the design of public buildings, especially the shopping malls in hot and humid climate are mostly enclosed, with the high usage of air-conditioning systems. Due to the COVID-19 situation, it is found that the typical approach to shopping mall design needs to be revised and improved. Hence, this study is conducted with the intention to derive an initial idea regarding the new approach of a shopping mall that is able to be less dependent on the mechanical ventilation system. The method conducted for this preliminary study is a semi-structured interview with three respondents that possess experience of involving in shopping mall projects, namely the architect and mechanical engineer. The findings from the interview show that all respondents agreed that a new approach to ventilation systems should be implemented in shopping malls. They also emphasized that for shopping malls located in hot and humid climate, the usage of merely natural ventilation is impractical, especially in providing thermal comfort to the users. Hence, it is recommended to have hybrid ventilation, which combines mechanical and natural ventilation systems. This study is significant as it encourages other studies related to the new approach to shopping mall design, especially in the hot and humid climate.

**Keywords:** COVID-19; Shopping mall; Mechanical ventilation; Natural ventilation; Hot humid climate

### 1 Introduction

Severe acute respiratory syndrome Coronavirus 2 (SARS-CoV-2) is a virus that has caused Coronavirus disease (COVID-19). This disease has been spreading worldwide since 2019, and now it has become endemic, where this virus will always be in the community (Kumar & Morawska, 2019). To date, there are many studies indicate that this virus can be transmitted from one person to the other through the air inside a space (Srivastava et al., 2021). Urban morphology, population size, and building attributes also play roles in determining the spread of infectious diseases such as

COVID-19 (Tong et al., 2022). This has encouraged architects to explore new approach of design and planning in achieving a healthier environment. Among the consideration are providing natural light, good ventilation and green open areas (Waheeb & Hemeida 2022).

There are three main functions of ventilation, namely for health, thermal comfort and structure cooling. Good ventilation strategies in buildings are essential in ensuring ventilation functions are achieved optimally. The ventilation strategies can be categorized into two, which are the active and passive strategies. The active strategies include the utilization of mechanical tools to aid the airflow such as mechanical fans and air conditioning. Meanwhile, the airflow in the passive strategy is induced by the pressure or thermal differences. Several studies have insisted on the need to provide good airflow and air exchange between the indoor and outdoor in controlling the spread of COVID-19 disease. The study by Park et al. (2021) on the airborne transmission in school building indicated that under the condition of occupants, wearing masks, and the space is naturally cross ventilated with 15% window opening, the probability of infection would be less than 1%. Meanwhile, for a large office building, the usual ventilation system used is mechanical ventilation such as the heating, ventilation and air-conditioning (HVAC) system. Srivastava et al. (2021) suggested on the combination of local air cleaning with the HVAC system for the office building. The study investigated the usage of Ultraviolet-C (UV-C) disinfection device in cleaning the air that carried the SARS-CoV-2 virus. Besides school and office, a gymnasium is also a place that has high risk of spreading COVID19 disease due to the activities that involve high metabolism rates. Therefore, Wang et al. (2022) recommended the usage of a real-time metabolism-based ventilation control system at a gymnasium. The proposed system was able to decrease the infection probability of 4.3-6.3%, as well as encouraged energy savings of 13% compared to the fixed-fresh air ventilation system.

Shopping mall is a public building that also has many visitors. The current design of shopping malls is mainly influenced by the malls in the United State of America (Ibiyeye et al., 2015; Albuquerque et al., 2016; Akadiri et al., 2012). According to Federico (2008), this 'American Model' is a box lit with artificial light, and has the same thermal environment throughout the year, regardless of the changes in the surrounding environment and climate. Due to that approach of design, most shopping malls are fully ventilated with mechanical ventilation systems. The usage of such system had resulted in the enclosed approach of shopping mall design, which are unfavourable in controlling the COVID-19 disease. The virus particles spread quicker in enclosed space compared to open space. This is due to the natural ventilation factor in open space that aids to reduce the concentration of virus particles in the air (Kumar & Morawska, 2019). Chai et al. (2020) investigated the COVID-19 transmission in the shopping malls in Wenzhou, China. The findings indicated possible transmission among the visitors. With the current increase in the infectious diseases, especially via airborne transmission such as COVID-19, are the conventional ventilation systems applied in shopping malls appropriate? Hence, this study aims to investigate the appropriate ventilation strategies in shopping malls for post COVID-19 situation, particularly in the hot and humid climate of Malaysia. This is a preliminary study, which encourages more studies of post COVID-19 ventilation system in Malaysia's shopping malls.

## **2 Shopping Malls in Malaysia**

In general, shopping malls in Malaysia can be divided into three phases which the first phase is from 1970 to 1989, the second phase is from 1990 to 1999 while the third phase starts from 2000 and above. The shopping malls during the first phase were developed along Sultan Street, Tunku Abdul Rahman Street, Petaling Street and Bukit Bintang Street in Kuala Lumpur (Zaki et al., 2012). Kuala

Lumpur is the capital city of Malaysia, and well known as the main business area in Malaysia. To date, the numbers of shopping malls are continuously increasing in Kuala Lumpur. During the early phases, namely the phases one and two, the shopping malls in Malaysia are designed with enclosed approach. The mechanical ventilation system commonly adopted is fully air-conditioning system such as centralized system. Due to the hot humid climate, where the air temperature is constantly high throughout the year, the heating system is not utilized in Malaysia. However, during the third phase, which is after the year 2000, the shopping malls in Malaysia have been designed with different approach. The open concept with greenery has started to be introduced. In addition, the semi-enclosed atrium which allows natural daylight and ventilation has also started to be applied in the shopping malls during the third phase. The new approach has also allowed other ventilation system to be applied such as the hybrid ventilation system, which combines the natural and mechanical ventilation. This new approach has actually been influenced by the green movement in Malaysia, which encourages sustainable design. For example, the development of Malaysia Green Building Index. The examples of shopping malls in Malaysia during the first phase are Sungei Wang Plaza (Figure 1a) and Sunway Putra Mall, while for the second phase, the examples are Lot 10 Shopping Centre (Figure 1b), Mid Valley Mega Mall, Pavillion (Figure 1c) and Starhill Gallery (Figure 1d). After the year 2000, shopping malls with different approaches are Publika Solaris Dutamas, Bangi Gateway (Figure 1e) and Tamarind Square (Figure 1f).



**Fig. 1:** The shopping malls constructed from the year 1970 to 2020, which are (a) Sungei wang Plaza, (b) Lot 10 Shopping Complex, (c) Pavilion, (d) Starhill Gallery, (e) Bangi Gateway, and (f) Tamarind Square

### 3 Methodology

The method used for this preliminary study is a semi-structured interview. The semi-structured interview technique was chosen as it provides more opportunity to explore the respondents' opinions, and still can be tailored within the intended topics. The interviews were conducted with respondents who had been involved in shopping mall projects, namely the architect and mechanical engineer. As aforementioned, this study is just a preliminary study. Therefore, there is a limited number of respondents involved in the interview, which are three only. More respondents with variety of backgrounds will be involved in future studies. The interviews were recorded and the analyses were executed using the Nvivo software. The coding system was used in the analyses. The thematic analyses were conducted to categorize the codes into specific themes.

The interview session was divided into two sections. The first section was conducted with the purpose to identify the respondents' backgrounds, while the second section focused on the discussion regarding the shopping mall designs and ventilation systems.

The interview questions were developed based on the themes or topics that were found in the literature review, as well as to achieve the aim of this study. However, the interviews were not restricted to the developed questions only, as the semi-structured interview method was employed. The additional topics raised by the respondents were also considered in analysing the results and findings.

#### **4 Results and Discussion**

Based on the interviews, there are 28 codes identified, and they have been grouped into several categories. The frequencies of the codes being discussed by the respondents are calculated. The thematic analyses of the codes and the interview questions have resulted in three main themes namely mechanical ventilation, hybrid ventilation, and space layout design. The results and discussion of the interviews are presented according to the themes. The frequencies of each code for each theme mentioned by the respondents are provided in table form for certain examples only. Meanwhile, for the other codes, the findings are explained and summarized in text. The first respondent who is an architect with 20 years of experience in building industry are represented by R1, the second respondent who is an architect who also possesses 20 years of experience is denoted as R2, while the third respondent who is a mechanical engineer who has 10 years of experience, and also owns a company that is specialized in the air-conditioning system, is indicated as R3.

##### **4.1 Mechanical Ventilation**

The aspects discussed in this theme can be classified into four namely the types of mechanical ventilation system, the factors that influence the selection of the system, the disadvantages of the system, and the appropriate location for the system. Based on the interview, all respondents agreed that the centralized system is the usual system used in shopping malls compared to the split unit and the combination of centralized and split unit. Meanwhile, for the factors of the system selection, all respondents agreed that thermal comfort is the main factor that influences the selection of the system. All respondents mentioned that the hot and humid climate of Malaysia has caused high demand for cooling. The air-conditioning system is the fastest and easiest method to achieve indoor thermal comfort. R1 also added that the enclosed design of the shopping malls has also made the air-conditioning system as the main choice. Besides thermal comfort, the other factors listed by the respondents are escapism, community awareness and client's request (Table 1).

R1 and R2 associated the provision of air conditioning with the escapism aspect, which had attracted the communities to visit the mall due to the cooler indoor environment compared to outdoor. R1 included community awareness as the factor that also causes high demand for air conditioning usage. The high dependence on the air-conditioning system in achieving thermal comfort, the lack of tolerance to the hot environment, as well as less awareness of the importance of energy savings have made air-conditioning the most favourable system in the community. Meanwhile, R1 and R2 also stated that the client's request also influences the selection of the ventilation system. R1 connected the client's request with the exclusivity justification. Large shopping malls which are occupied with leading brand tenants will obtain high profits. Therefore, their business models are able to cover the cost of expenses involving the ventilation system. Meanwhile, R2 added that the building concept intended by the client also influences the design of the shopping mall and the type of ventilation system used. For example, smaller shopping malls that have different target users and tenants have

applied hybrid ventilation systems compared to the large and exclusive shopping malls that prefer fully air-conditioning systems.

**Table 1:** Frequencies of each code mentioned by the respondents for the factors that influence the selection of the system

Code Category	Code	Frequencies mentioned by the respondents			Total
		R1	R2	R3	
Factors that influence the selection of the system	Thermal comfort (Hot humid climate)	4	5	6	15
	Escapism	1	3	0	4
	Community awareness	2	0	0	2
	Client's request	4	3	0	7

For the disadvantages of the system, the high cost involved by the mechanical ventilation system is mainly mentioned by all the respondents. Among many types of mechanical ventilation systems, air-conditioning involves great amount of costs such as installation costs, operating cost, and maintenance costs. Indoor air quality was the second most frequently mentioned by the respondents. R1 mentioned that area which involves activity such as cooking, is more appropriate to have air exchange between the indoor and outdoor. Meanwhile, R2 insisted that toilet should not be ventilated with mechanical ventilation, as good natural ventilation is essential to bring out the odour. Three factors that influence the air quality by mechanical ventilation system have been highlighted by all respondents. They are the maintenance of the system, the air filter quality and the polluted indoor air. Besides involving high cost and affecting indoor air quality, the other disadvantages mentioned by the respondents are the utilization of space and energy. R1 and R3 stated that the centralized air-conditioning which is normally used in shopping malls has involved many spaces to accommodate the system such as spaces for air handling unit, chiller, cooling tower and ducting. Meanwhile, for the energy usage, R2 and R3 insisted on the high-energy utilization by the air-conditioning system, which is more than 40% of the total building energy consumption.

For the location of the mechanical ventilation system, there are two aspects highlighted by the respondents namely the locations of zones that require mechanical ventilation system and zones that are unnecessarily ventilated by that system (Table 2). All respondents agreed that zone with high density of visitors such as retails area, can be ventilated with mechanical ventilation, while the areas such as toilets and service rooms are unnecessarily to be mechanically ventilated. However, for the service rooms that accommodate many electrical equipment, consideration can be given for the mechanical ventilation usage. The large volume area is also discouraged to be fully mechanically ventilated as it incurs high-energy load for cooling.

**Table 2:** Frequencies of each code mentioned by the respondents for the appropriate location of the system

Code Category	Code	Frequencies mentioned by the respondents			Total
		R1	R2	R3	
Appropriate location of the system	Location of zone	1	1	2	4
	Areas that are unnecessarily ventilated by mechanical ventilation	1	3	0	4

## **4.2 Hybrid Ventilation**

The code category discussed in this theme can be classified into three namely the purpose of hybrid ventilation, the advantages and disadvantages of the system. The purpose of using hybrid ventilation highlighted by the respondents are the importance of air exchange, energy savings, as well as the requirements of Malaysia Uniform Building By-Law (UBBL) and Malaysia Green Building Index (GBI). The importance of air exchange is the most discussed by the respondents compared to the other code categories. All respondents agreed that air movement, which involves the air exchanges between the indoor and outdoor, is significant in the building. R1 mentioned on the necessity to provide openings to allow the cross-ventilation in the building. However, natural ventilation alone is insufficient to provide thermal comfort due to the low air velocity. Hence, R2 and R3 stated on the usage of mechanical fan to assist the natural ventilation. In term of energy savings, all respondents agreed that the hybrid ventilation system uses less energy compared to the fully mechanical ventilation system. Meanwhile, for the Malaysia UBBL requirement, it is already stated that certain areas have to be ventilated by natural ventilation such as the fire staircase, the habitable rooms and the toilets. The utilization of natural ventilation is also a point highlighted in the Malaysia GBI requirements. According to R1, natural ventilation is also important to get a high score in the evaluation of the GBI. Among the criteria included in the GBI evaluation scoring is energy efficiency. The Building Energy Index (BEI) is one of the components that is considered in energy efficiency scoring. By using natural ventilation, the BEI can be lowered significantly, which subsequently helps to increase the energy efficiency of the building.

The advantages of using hybrid ventilation mentioned by all respondents are the reduction of energy usage, the decrease of costs related to fully mechanical ventilation system, and the provision of good air exchange between indoor and outdoor. Good air exchange is essential in reducing the spreading of airborne diseases such as COVID-19. R1 had associated the benefits of good air exchange with the unnecessary of wearing masks, which helps to save the cost also. This subsequently has caused the visitors to prefer open areas compared to the enclosed or confined areas during the COVID-19 situation.

Meanwhile, different disadvantages had been highlighted by the respondents regarding the usage of natural ventilation. R1 mentioned the importance of understanding the surrounding condition and climate in the provision of natural ventilation. This is because, for natural ventilation, the outdoor air condition affects greatly the indoor air. The area with high levels of air pollution is inappropriate for natural ventilation application. Meanwhile, R2 indicated on the difficulty of controlling the indoor thermal condition with natural ventilation, compared to the usage of fully mechanical ventilation system such as air conditioning. This is because the outdoor air temperature and humidity influence the indoor air condition for natural ventilation. R3 mentioned the need for high cooling load to cool the indoor environment of huge space. The concern of cooling load was also raised by R2 who insisted that natural ventilation alone is insufficient to cool a building that has a large volume area such as a shopping mall. In addition, the high number of occupants at one time, the presence of many electrical equipment, as well as the enclosed building design with minimal number of openings, have also increased the demand for cooling load.

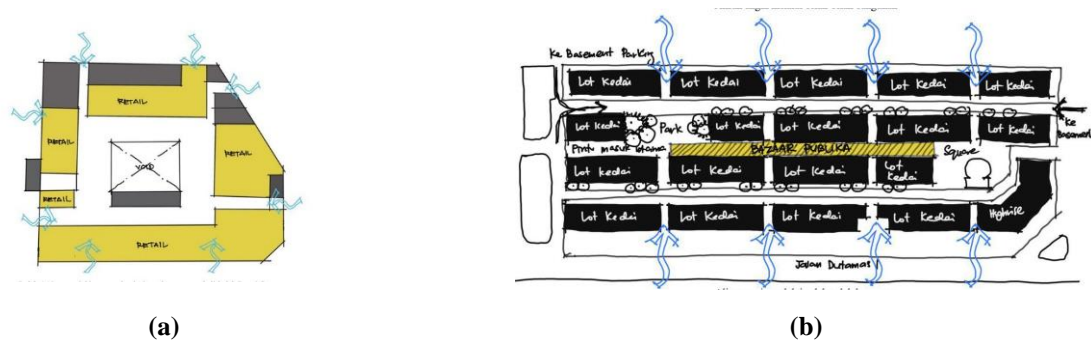
## **4.3 Building Layout Design**

The design of shopping mall also plays a role in increasing the effectiveness of hybrid ventilation system in the building. All respondents agreed that among the effective design for hybrid ventilation

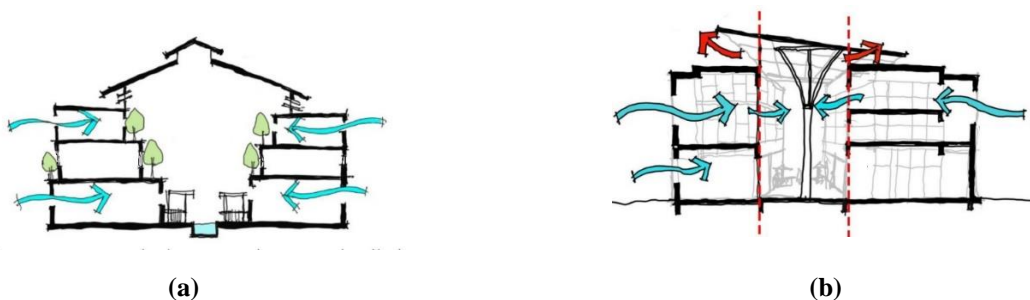
is the division into smaller or modular blocks compared to the large building block. In this way, the zoning of areas that utilize air-conditioning is only focused on smaller spaces compared to the large spaces that require greater energy consumption for cooling. In addition, air can also flow through the gaps between the building blocks, which allows for natural ventilation. R2 opined that a cluster layout of the blocks is more effective than a linear layout. This is because the cluster layout can reduce the cooling load in the space due to the smaller square footage (Figure 2).

R1 and R2 also indicated that the layout design that includes courtyard and greenery is able to provide many open spaces that can be used by the public for socializing and relaxing. According to R1, shopping mall is a building typology which is normally large in size. Therefore, from a psychological point of view, it needs intermediate spaces for visitors to rest for a while. Hence, the inner courtyard is one of the good examples for this approach. This area is naturally ventilated. The presence of vegetation also helps to cool the surrounding environment (Figure 3).

As for the internal layout, R1 mentioned that the height and arrangement of the temporary wall partitions need to allow the air to flow through the gaps in between and above them. Besides that, the gaps are also essential to allow the penetration of daylighting, which subsequently reduce the dependence on the artificial lighting.



**Fig. 2:** Example of shopping mall designs that consist of several blocks that are arranged in (a) cluster, and (b) linear layouts



**Fig. 3:** Example of shopping mall designs that encompass (a) water features and greenery and (b) semi-open atrium that allows for natural ventilation

## 5 Conclusion

This study is a preliminary study on the appropriate approach of ventilation system at shopping malls located in hot and humid climate for post COVID-19 situation. Hence, the findings from this study provide the initial recommendations, which in the future have the potential to be expanded into guidelines via more intensive and extensive studies. The findings from the interview highlighted the disadvantages of the usual mechanical ventilation system applied at the shopping malls in the hot and humid climate, as well as the advantages and drawbacks of hybrid ventilation system. The findings can be concluded that there are many factors that influence the selection of the system. The main

factor is the provision of good thermal comfort for the users, as it can attract more people to the shopping malls. Nevertheless, the client's request also plays a role especially for the shopping malls that have their own target tenants and visitors. Hence, these two aspects, namely the user thermal comfort and the request of building owners need to be considered in the design. However, being in a hot and humid climate, where the cooling aspect is very essential, the challenge faced is the ability to control the indoor environment for thermal comfort, and at the same time able to achieve various savings such as the cost, energy and space.

Therefore, this study has recommended on the utilization of hybrid ventilation, which combines the mechanical and natural ventilation systems. By combining these two systems, many benefits can be derived such as the reduction in building space and energy usage, as well as the savings of cost for many aspects such as installation, maintenance and operation costs. All the considerations mentioned above are vital even though for post COVID-19 situation. Though the controlling of indoor thermal environment is more challenging with hybrid ventilation system compared to the fully mechanical system such as air conditioning, the hybrid system still provides more advantages in the post COVID-19 situation. The hybrid ventilation system is more appropriate as it is able to provide better indoor air quality due to the air exchange between the indoor and outdoor, which helps to reduce the spreading of airborne disease.

The study also summarizes that building layout design also plays significant role in the ventilation system used. To optimal the usage of hybrid ventilation system, the building layout should be designed to have several blocks, with the courtyard and greenery in between, compared to having just one large block. This is because, the approach allows for the zoning of ventilation system to be effectively implemented. Some areas are occupied with fully mechanical ventilation system, some areas are ventilated with hybrid ventilation, and some other areas are naturally ventilated. The presence of airflow and greenery in between of the blocks also helps to cool the surrounding environment. The building blocks that implement hybrid ventilation system should also be incorporated with many openings to allow for cross-ventilation. In a nutshell, the conventional shopping mall design that has one block with large volume area is irrelevant for the post COVID-19 situation, as the hybrid ventilation system is more appropriate compared to the fully mechanical ventilation system.

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