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## **USER PERCEPTION OF NATURAL VENTILATION STRATEGY AT INPATIENT WARD, KUALA KANGSAR HOSPITAL**

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### **Abstract**

Hospitals and healthcare facilities are known to be among the most energy-intensive buildings. This concern has resulted in a resurgence of sustainability awareness in the built environment. Nowadays, many have adopted environmental strategies such as natural ventilation. It offers a low-cost alternative to remove stale air and replace fresh air efficiently through cross ventilation. Studies have shown that natural ventilation is one of the most energy-efficient solutions to improve thermal comfort and hospitals and healthcare facilities will greatly benefit from this initiative. Passive Design has been valued as a key strategy in controlling airborne infection, especially in hospital wards with limited resources. Comparatively, the installation of ceiling-mounted mechanical fans will create a negative ventilation pressure difference. This paper explores the potential of the passive design method based on the experience of inpatient ward users. The study utilised questionnaires based on the end user's experience in a naturally ventilated inpatient ward area. The survey administration method ensures the 51 respondents' anonymity is preserved especially in a healthcare setting. This investigation shows that natural ventilation provides a higher ventilation rate and is more energy-efficient than mechanical ventilation. Therefore, natural ventilation is a suitable solution in public buildings such as hospitals' inpatient wards. The outcome of this study will be paramount for designers to meet passive design objectives. Consequently, these will be the guidelines and outline information for hospital design in the future.

**Keyword:** Natural ventilation, energy efficiency, passive design strategy, inpatient ward, hospitals and healthcare facilities

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## **INTRODUCTION**

In 2021 Malaysia has allocated a sizable RM31.9 billion budget for the healthcare sector, a slight increase of RM30.6 billion from the previous year. The building sector is the sector that is responsible for the use of energy for high operational purposes. From 2005 to 2010, the trend for energy consumption in buildings in Malaysia increased by 34%. Public hospital buildings are among the buildings that utilise high energy levels (Ab. Azis et al., 2019). Hospitals and healthcare facilities are among the most energy-intensive buildings in Malaysia and are currently facing a more significant challenge due to the Covid-19 pandemic. Operating non-stop 24 hours a day, hospitals and healthcare facilities consume extensive energy sources from medical equipment, lighting, heating, ventilation and air condition (HVAC), sterilisation and others. This paper explores the potential of using natural ventilation to improve energy efficiency at inpatient wards in Kuala Kangsar Hospital. Several studies have shown that HVAC contributes 40% to 65% of the energy bill (Ahmad Ludin et al., 2020); therefore, the passive design method is believed to help in cost reduction. Natural ventilation utilises natural forces such as pressure and thermal differences to move air to pass through the building. Although this natural ventilation offers a low-cost alternative, it is efficient as it eliminates polluted air quickly compared to mechanical ventilation.

The World Health Organization (WHO) has created a comprehensive guideline concerning natural ventilation in hospitals and healthcare facilities. For instance, some of the selected health treatment facilities are mandatory to use natural ventilation. Natural ventilation has a higher ventilation rate than mechanical ventilation, therefore an effective tool for reducing the cross-infection risk of airborne diseases in hospitals. Control of these airborne infections should be maximised in health facilities with limited resources (Qian et al., 2010). A review of the literature found that the guidelines on this design explain that the general hospital's design criteria are necessary and the importance of having natural ventilation is vital (Escombe et al., 2019). So, designers need to understand the factors that can influence the performance on energy efficiency for this natural ventilation and subsequently plan better against it. Disease control and energy efficiency for natural ventilation will be realised if the designers understand the scenarios that occur in the hospital (Morgenstern et al., 2016).

Some may argue that the pattern of air movement from natural ventilation is difficult to predict and unreliable. Many studies have been conducted to understand the movement of ventilation in hospitals. These include aspects related to the design and performance of ventilation systems in hospitals for treatment through simulation. However, the simulation study results did not consider additional factors obtained at the actual study site, such as openings or windows design, mechanical fans, and user experience in the interior that can affect the ventilation pattern (Jamshidi et al., 2019). Therefore, only a handful of

studies have been evaluated concerning natural ventilation performance in actual hospitals. Todd et al. (2014) state that high natural ventilation rates will be achieved in isolation chambers and exhaust fan installations. It will produce sufficient negative pressure when the force of air production from the environment is not strong enough. Meanwhile, a study by Maraqa et al. (2016) also found that the openings from windows and doors only produce moderate natural ventilation of 28 ACH (Air Changes per Hour). Therefore, the objective of this study is to obtain data from users who use the space through the experience they feel about this natural ventilation.

### **NATURAL VENTILATION**

According to the technological point of view, natural ventilation can be classified into two: a simple ventilation system and a high-tech natural ventilation system. A simple ventilation system is operated by circulating fresh air naturally into the building. On the other hand, a high-tech natural ventilation system is operated by a computer and assisted by a mechanical ventilation system (Ahmad Ludin et al., 2020). Natural ventilation with a mechanical system is known as hybrid ventilation or mixed mode. In general, natural ventilation holds several advantages compared to mechanical ventilation, such as higher air exchange rate or ventilation rate and low-cost operation. This design for natural ventilation will provide a way for airflow in the interior, but it can also have a detrimental effect on the spread of fire and smoke that flows in the event of a fire in the building (Ab Ghani & Aripin, 2018).

Furthermore, due to the passive operation of natural ventilation, it can provide a high ventilation rate more economically (Escombe et al., 2019). Although the air change rate can be unreliable and not substantial, thorough planning in the design stage will maximise natural ventilation potential. Hospitals and healthcare facilities utilise massive energy to operate; therefore, natural ventilation is one of the passive design strategies that can help to reduce operational cost by maximising air change rate and efficiency. Moreover, planning for natural ventilation at an early design stage will reduce the maintenance cost of space cooling and thus, energy efficiency will be achieved (Palm & Kokko, 2018). Moreover, natural ventilation can result in energy consumption to be more efficient, especially if the façade of the hospital building has large openings and no additional heating is not required. Finally, well-planned natural ventilation will be able to be used to access higher levels of daylighting.

Natural ventilation is known for its capacity to minimise the risk of cross-infection of airborne disease in hospitals. Airborne infections are among the diseases experienced by all countries around the world, including Malaysia. Some examples of airborne diseases are common cold, chickenpox, measles, influenza, tuberculosis, and pertussis. But in 2019, the world was shocked by the

new strain of the virus, coronavirus or Covid-19. Although Covid-19 is not generally considered to be an airborne disease, the symptoms are almost identical to such diseases. Before the Covid-19, several studies have shown a decline in the global prevalence of mortality rate, but this number is increasing, especially in the Southeast Asian region. Airborne transmission of the disease is very high risk because anyone can contract the disease (Peavey, 2015). Thus, the World Health Organization (WHO) and the U.S. Centers for Disease Control and Prevention (CDC). CDC informed that these infections can be minimised and has recommended guidelines for infection control with three levels of control, namely administrative control, environmental control and personal respiratory protection. Natural ventilation has been shown to minimise the risk of airborne infection. Historically, 100 years ago, tuberculosis disease was treated outdoors and might be more effective than indoor settings. Furthermore, during the SARS outbreak in 2004, a large opening in hospitals and healthcare facilities was utilised to reduce the risk of infection among healthcare workers. Natural ventilation has also been performed efficiently by diluting airborne pollutants such as airborne infectious pathogens (Qian et al., 2010).

#### **STUDIES ON THE ENERGY EFFICIENCY OF HOSPITAL BUILDINGS**

The hospital building, a type of commercial building, has gained much interest from researchers to research it. Various strategies and approaches have been taken to implement energy efficiency in this hospital building because it operates 24 hours a day non-stop and uses high energy (Table 1). Strategic approaches and techniques are implemented, such as heating system improvement, ventilation use, air conditioning (HVAC), electricity use, central heating, refrigeration equipment, energy management control, thermal energy storage (TES), heat recovery, and water management (Khakzand, 2018). The same goes for financial schemes or policies/regulations. For example, the Kuala Kangsar Hospital is considered a semi-specialist hospital. Even though the 4-storeys inpatient ward in this hospital is naturally ventilated, the estimated energy consumption is over 2,000,000 kWh per month (Perak, 2020). Here we can see the magnitude of energy consumption in a district hospital; comparatively, the number will be astronomically higher at a premier or specialist hospital. For instance, a public hospital near Kuala Lumpur consume 4,000,000 kWh per month which is equivalent to RM 1.5 million in electricity bill (Ahmad Ludin et al., 2020). However, very few research have used approaches to natural ventilation that do not involve high costs. Therefore, the emphasis on energy efficiency in the hospital building is studied from the natural ventilation aspect, especially in the ward building, which is the heart of the building.

**Table 1: Approaches and strategies for energy efficiency in hospital buildings**

<b>Year</b>	<b>Location</b>	<b>Strategy</b>	<b>Author</b>
2010	Malaysia	using a high-efficiency mechanical system using a variable speed drive	Saidur, Hasanuzzaman, Yogeswaran, Mohammed, & Hossain
2016	Egypt	Application of protection from the sun, the use of window glazing, airtightness and insulation on the facade of the hospital building	Radwan, Hanafy, Elhelw, & El-Sayed
2016	China	Emphasis on policymakers on projects, technical and operational procedures aimed at improving energy efficiency	Wang, Li, Liao, & Fang
2017	China	Using a web-based online control system for chiller plant use	Ma, Zhao, Shen, & Liu
2018	Italy	Use of simulation - Using hydraulic gaskets to produce and install rotating windows and LED systems for energy saving	Silenzi, Priarone, & Fossa
2019	Spain	Perform proper maintenance by increasing the time to reduce energy consumption	García-sanz-calcedo
2019	India	The use of lot (application of light consumption) for modification of hospital building infrastructure	Reddy, Sandbhor, & Dabir
2020	Malaysia	Reduce electrical consumption so that energy efficiency is achieved	Ahmad Ludin et al.

*Source: Jamaludin Muhamad (2021)*

## **METHODOLOGY**

The first modern Kuala Kangsar Hospital was built on a 22-acre land in 1993, replacing the old hospital established during the 1890's era. This hospital is identified as a semi-specialist hospital, and the inpatient ward consists of a naturally ventilated 4-storey building. The windows in this hospital building are of the adjustable glass louvers window type. The respondents comprised of patients and staff working in the adult inpatient ward of Kuala Kangsar Hospital (Photo 1). A total of 51 respondents of 20 males and 31 females aged 18 and above were involved in this questionnaire inpatient ward (Photo 2). This questionnaire was constructed from the literature of previous studies as shown in Table 2 (see results and discussion section). The questionnaire encapsulates the importance of the placement of natural ventilation, the mechanism to control natural ventilation, the importance of natural ventilation, natural ventilation on

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work performance, benefits and location of natural ventilation. This method has effectively measured preferences, therefore providing standardised stimulus to the respondents and eliminating bias. Their responses were documented and analysed using Statistical Package for Social Sciences (SPSS) program. This study highlights the potential of natural ventilation as a passive cooling strategy and energy efficiency in hospital design. The research framework delineates the objectives, data collection methodology, data analysis and research outcomes are shown in Figure 1. This section also outlines the flow of data collection on users' experience of natural ventilation in the indoor space of the selected wards. This case study was selected as it coincides with the scope and parameters of the objectives. The decision was also bound by the strict limitations set by the Malaysian Ministry of Health.



**Photo 1:** Kuala Kangsar Hospital  
*Source: Jamaludin Muhamad (2021)*



**Photo 2:** Inpatient (ward) Kuala Kangsar Hospital  
*Source: Jamaludin Muhamad (2021)*

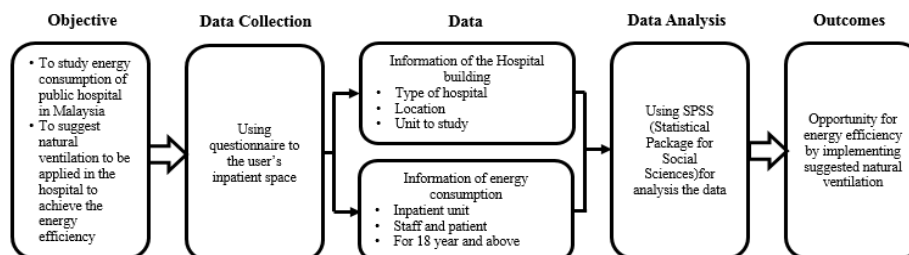


Figure 1: Research framework design  
Source: Jamaludin Muhamad (2021)

## RESULTS AND DISCUSSION

User experience was gauged through the questionnaire that was based on the six dimensions of natural ventilation strategies as listed in Table 2.

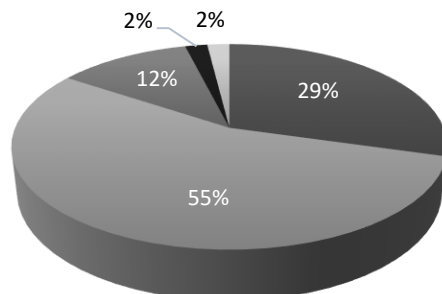
Table 2: Questionnaire construction from previous literature reviews

No	Questions	Source
1	The importance of the placement of natural ventilation	Monodraught, (2013)
2	The mechanism to control natural ventilation	Escombe et al., (2019)
3	The importance of natural ventilation	Maraqqa et al., (2016)
4	Natural ventilation on work performance	Omrany, (2016)
5	The benefits of natural ventilation	Totaforti, (2018)
6	Location influences the natural ventilation	Ang & Clements-Croome, (2013)

## STRATEGIC PLACEMENT OF NATURAL VENTILATION

Hospitals and healthcare facilities are usually built with a more stringent building code. Even though this hospital was completed in 1993, almost three decades ago, we can witness that the openings and windows were properly planned and designed. Strategic placement of natural ventilation will provide optimum ventilation rate to clients in the hospital, especially in the ward space. If full attention is not given to natural ventilation, it is feared that the potential for infection may occur.

Fifty-one respondents have submitted their response on proper planning and placement of casement windows are vital to achieving good natural ventilation in the inpatient ward of Kuala Kangsar Hospital. It was found that 55% agreed with the statement, and 29% strongly agreed that the windows are strategically located for optimum natural ventilation. 12% voted for neutral, and 2% each voted to disagree and strongly disagree (Figure 2).



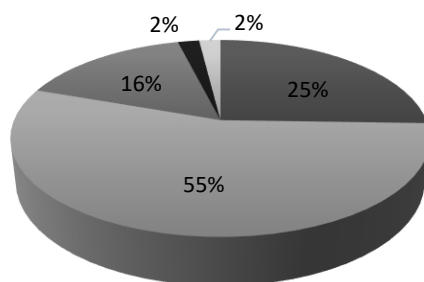
■ Strongly Agree ■ Agree ■ Neutral ■ Disagree ■ Strongly Disagree

**Figure 2:** Strategic placement of natural ventilation

Source: Jamaludin Muhamad (2021)

### MECHANISM TO CONTROL NATURAL VENTILATION

Natural ventilation relies on passive cooling strategies. In this ward, the mechanism to control ventilation rate is performed manually by regulating the opening of the casement windows. Operable windows are essential to allow fresh air circulation into the building. It can not only control the disease from being contagious but can also contribute to energy efficiency. 55% of 51 respondents agreed, and 25% strongly agreed that they could control the openings for the reception of natural ventilation in the hospital ward space. On the other hand, 16% of respondents chose a neutral stance, and 2% disagreed and strongly disagreed with the statement that the openings for the reception of natural ventilation can be controlled (Figure 3).



■ Strongly Agree ■ Agree ■ Neutral

**Figure 3:** Mechanism to control natural ventilation

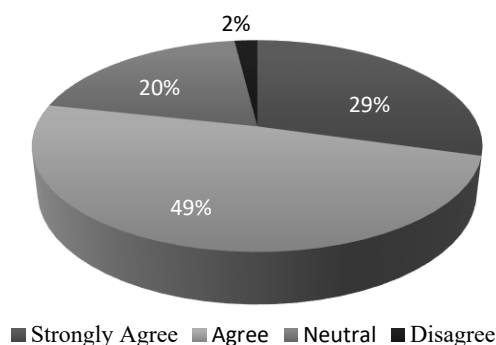
Source: Jamaludin Muhamad (2021)

### IMPORTANCE OF NATURAL VENTILATION

Natural ventilation is essential to the respondents in the ward space. Regular fresh air cycle into the ward space will help to give a sense of connection to the natural setting, thus aiding the process of healing. Therefore, 49% of respondents agreed, and 29% strongly agreed that natural ventilation is important, especially in the



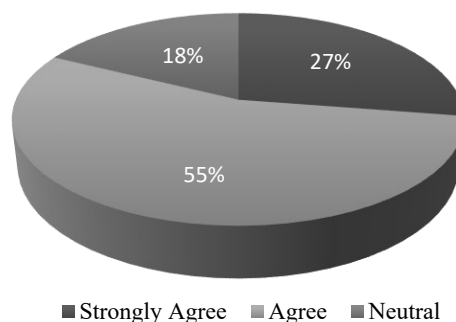
ward environment. Furthermore, 20% of respondents chose to be neutral, and only 2% of 51 respondents disagreed with the importance of natural ventilation (Figure 4).



**Figure 4:** Importance of natural ventilation  
Source: Jamaludin Muhamad (2021)

#### NATURAL VENTILATION INCREASES PRODUCTIVITY

Hospitals and healthcare facilities are operating 24 hours daily and this could lead to a stressful environment with all the swarming tasks faced by the workers. However, there is no refuting that natural ventilation benefits the users in hospital wards. 55% of respondents agreed, and 27% strongly agreed that good natural ventilation would increase productivity and work performance. At the same time, 18% of respondents chose to be neutral about the role of natural ventilation as a contributing factor for better productivity (Figure 5).

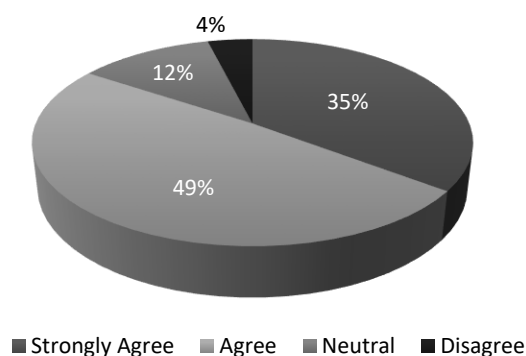


**Figure 5:** Natural ventilation increase productivity  
Source: Jamaludin Muhamad (2021)

#### THE BENEFITS OF NATURAL VENTILATION

In addition, this natural ventilation is also very important and benefits the users of the ward space. The study has shown that 49% of respondents agreed, and 35% strongly agreed that natural ventilation is beneficial. On the other hand, only 12%

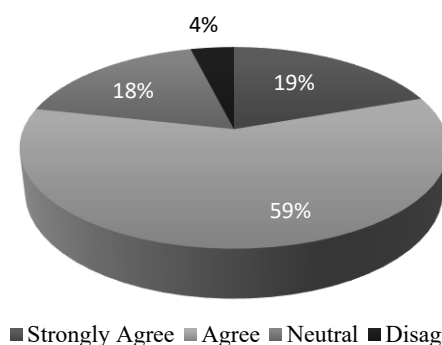
chose neutral, and 4% did not agree that natural ventilation is somewhat beneficial to them (Figure 6).



**Figure 6:** Benefit natural ventilation  
Source: Jamaludin Muhamad (2021)

#### LOCATION INFLUENCES THE NATURAL VENTILATION

In the hospital and healthcare setting, there are two main categories which are the staff and patients. The staff will carry out their duties while patients are generally in their beds. Therefore, the location of individuals carrying out activities in the ward space influences the reception of natural ventilation. The staff in this ward space provide treatment to patients and work in the workstation provided. As for the patients, they seek treatment in bed to restore their health. Thus, this study found that 59% of the respondents agreed, and 19% strongly agreed with the statement (Figure 7).



**Figure 7:** Location influences the natural ventilation  
Source: Jamaludin Muhamad (2021)

While 18% are neutral and only 4% do not agree that the presence of a person in a location will influence him to receive this natural ventilation to carry out activities (Figure 7).

## **CONCLUSION**

Based on the potential for energy efficiency, it is recommended that these six natural ventilation strategies be used as a guide in public hospitals in Malaysia. The data obtained shows the importance of natural ventilation to consumers, and at the same time, the use of energy in the ward space is more efficient and effective. Therefore, public hospitals must implement this natural ventilation that can curb the spread of disease and supply fresh air to the users, thereby increasing health. The results have shown that most respondents agreed on the potential of natural ventilation and the application of passive design strategies will help to increase energy efficiency in hospitals and healthcare facilities. Based on the six strategies addressed, natural ventilation is technically advantageous and beneficial in the healing process. Their opinions regarding assessing natural ventilation in the actual ward are crucial in complementing the ventilation performance and simulation-oriented research. Thus, it will be an essential tool to improve the overall experience. However, some new energy-saving technologies might be incompatible with the existing building and require high initial costs. Passive cooling offers a low-cost solution, and some hospitals might require minor architectural interventions to get the optimal benefits of natural ventilation. It will be a positive change to raise awareness of passive design for energy efficiency and consequently to improve the public image of hospitals and healthcare facilities in Malaysia.

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