MIXED-MODE VENTILATION IN MALAYSIA'S SHOPPING MALLS: A TAXONOMY STUDY

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ABSTRACT

The quest for building sustainability and reduction in building energy consumption has called for alternative means to cooling in buildings. Natural ventilation has been considered in this regard. However, due to its limitations, buildings are now shifting towards mixed-mode ventilation, which is a combination of the best features in natural and mechanical ventilation also offering huge advantages for reducing energy consumption. This shift will be a gratifying advantage in retail buildings since retail buildings account for the largest energy consumption in the commercial sector in Malaysia. Unfortunately, in Malaysia, mixed-mode ventilation has not been largely employed in retail buildings, particularly shopping malls. Furthermore, little information is available on malls with mixed-mode ventilation. Therefore, this study aims to explore and classify different application modes of mixed-mode ventilation strategy adopted in Malaysia's existing malls. Relevant literature was reviewed and site visitations and observations were conducted. Out of 105 malls identified in Selangor, Kuala Lumpur and Putrajaya, only six included passive strategies in their ventilation approach. These malls were identified as operating under mixed-mode ventilation and were further grouped under different categories of mixed-mode ventilation strategy. This taxonomy study provides the basis for classifying mixed-mode ventilation in retail buildings and will potentially create awareness among designers and building owners on the growing effort of improving and encouraging energy efficiency in the commercial building sector.

Keywords: building energy efficiency, mixed-mode ventilation, passive ventilation strategies, shopping malls.

1. INTRODUCTION

Growing concerns over building energy consumption has sprung responses from all building sectors to the call for sustainability. However this call, according to Yudelson [1], has received slow responses from the retail sector. Some of the reasons are the conflict of motivation between retailers and developers, and the fear of investing frivolously since there is no assurance that sustainable retail building will attract more customers [1]. Yudelson [1] argued that shopping malls particularly should take the lead in implementing energy efficiency in its design due to its huge energy consumption. This energy consumption in the retail sector is mostly for lighting, heating and cooling [2]. With environmental sustainability strongly on the global corporate plan, the retail sector is now responding to the increasing market pressure and energy efficient features have been incorporated in new retail buildings designs [1,3]. In Malaysia, the establishment of green building rating system called Green Building Index (GBI) in 2009 has promoted sustainability measures in the local building sector [4]. GBI for retail buildings was launched in the year 2013 and since then only a few shopping malls have been awarded GBI certification [4,5]. This shows the slow pace at which retail buildings are catching up with the current pressing need for sustainability. However, as owners, developers, and designers explore various ways of minimising building's operating costs and at the same time increasing their functionality and appeal to occupants, sustainable designs are becoming noticeable in retail buildings today [2] .

One aspect of building sustainability that catches ones attention in Malaysia is the introduction of passive ventilation design strategies and this can be

noticed particularly in some shopping malls around the country. Recent years have seen a new trend evolving in the design of shopping malls in Malaysia, from the fully air-conditioned conventional malls to those which integrate passive ventilation design strategies. Passive ventilation strategies rely on natural forces to introduce outdoor air into the indoor space and these can be achieved via single-sided, cross or buoyancy driven ventilation [6].Those passive design features that contribute to natural ventilation in buildings includes operable windows, central atria and lobbies, openings to corridors, and strategic architectural features [6,7]. Passive design strategies in malls are commonly implemented by incorporating a large common space that is naturally ventilated and connected to retail lots that are individually air-conditioned. This practice reduces energy consumption, improves the indoor environment [8], and allows occupants to move between different climatic conditions under the same roof [9].

This practice of combining natural ventilation and mechanical ventilation in a building is referred to as mixed-mode ventilation [10,11]. Although, this phenomenon occurs in some Malaysian shopping malls, there has been no documented study on these malls. Therefore, this study aims at exploring different application modes of mixed-mode ventilation strategy in Malaysia's existing shopping malls with the following objectives: 1) To identify shopping malls that are operating under mixed-mode ventilation; 2) To investigate and identify the specific passive design features of these malls, 3) To classify and group the identified malls under different categories of mixed-mode ventilation strategy. This study provides the basis for the classification of mixed-mode ventilation strategies in retail buildings and will potentially create awareness among designers and building owners on the growing efforts of improving and encouraging energy efficiency in the commercial sector.

The paper first presents the background of the study, followed by an explanation on the methods used in the study. It then presents and discusses the results of the study before concluding with some recommendations for future research.

1.1. Shopping Mall Design

The original concept of a mall was a place where people could converge for various activities such as cultural and shopping activities, as well as social gathering [12]. Presently, the mall's image has surpassed its initial concepts and expectations, and its potential to enhance community life has contributed to its excellent success [13]. Today, shopping malls not only compete on their product offerings, but also on creating exciting shopping atmospheres [14]. This paradigm shift has made shopping itself more than just purchasing of goods but also a form of recreation. Malls throughout the world have shared common features of aesthetics, architecture, and design.

Over the years, malls have generally been designed with a similitude to the "American model" of retail design [3,9,15]. Thus, all over the world, malls have some features of architectural design and aesthetics in common [15]. The "American model" of retail design, according to Federico [9] p.1, is "often artificially lit boxes, with uniform thermal environments throughout the year regardless of climatic conditions". He further emphasized that this artificially created environment actually encourages energy waste and at the same time creates "thermal shocks" as oppose to providing occupant with a thermally confortable environment. This thermal condition created within the malls' indoor environment was aimed at providing comfort for the occupants but according to Federico [9], they are indeed contributing to energy waste.

1.2. Malaysia's Shopping Malls

Mohd Zaki et al [16] divided the development of shopping malls in Malaysia into three stages starting from the early development which evolved around Jalan Sultan, Jalan Tuanku Abdul Rahman, Jalan Petaling and Jalan Bukit Bintang in the year 1960 to 1970, followed by bigger and more purpose malls built within the "Golden Triangle" between the year 1980 - 1990 to megamalls built within Kuala Lumpur and Klang from 1990 onwards. This growth has been rapid and within 35 years of opening the first mall in Malaysia, more than 320 malls are presently operating in the country [17]. The growth is not only in their numbers but also in their architectural features and form. Malls are now equipped with various entertainment outlets and many are famously built as mixed development by incorporating hotels, offices and residential units [16].

2. MIXED-MODE VENTILATION

Mixed-mode ventilation refers to "a hybrid approach to space conditioning that uses a combination of natural ventilation from operable windows and mechanical systems that include air distribution equipment and refrigeration equipment for cooling" [10] p.31. Mixed-mode ventilation offers huge advantages for reducing energy consumption while still maximizing comfort [18-23] and providing occupants with a means of personal control and connection to the outdoors [11]. Mixed-mode ventilated buildings perform excellently, particularly with regards to thermal comfort and air quality [10,18,21,24,25] and as a result, occupants of mixed-mode ventilated buildings have been revealed to be more productive [25]. Consequently, higher occupants' satisfaction is often recorded in mixed-mode buildings

compared to fully air conditioned buildings due to the high degree of control occupants have on their environment [10,11].

Nevertheless, mixed-mode strategies have the potential of adding complexity to a building; concern also arises in cases of concurrent mixed-mode strategy that may result in energy waste due to air-conditioning and natural ventilation operating in the same space at the same time [10,18]. Mixed-mode ventilated buildings are also faced with challenges ranging from building design issues, building operations and controls issues, fire and safety concerns, to energy code concerns [11].

2.1. Mixed-Mode Ventilation Classification

A standard classification of mixed-mode ventilation approach in the current practice still does not exist due to the continuous uniqueness of buildings. However, there exist various classification schemes that describe the integration of both natural ventilation and air-conditioning control systems [26]. An earlier commonly-referenced traditional classification of mixed-mode ventilation strategy, namely "zoned", "concurrent", and "change-over", was originally a taxonomy proposed by Max Fordham and Partners in the year 1994, It was later revised and further analysed by scholars like William Bordass [11,27,28]. Table 2.1 shows the William Bordass's classifications and description of mixed-mode ventilation strategies based on taxonomy proposed by Max Fordham and Partners.

Table 2.1: Mixed-mode classification and description. Adopted from Brager et al. [27] p 68. Diagrams sourced from CBE [29]

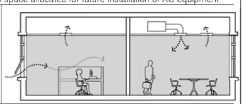
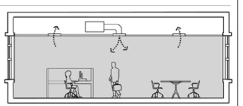
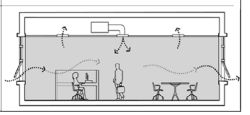
Classification	Description	
I. Contingency	Building is designed either as an air conditioned (AC) building with provisions to convert to natural ventilation (NV) or as an NV building with space allocated for future installation of AC equipment.	
II. Zoned	Different zones within the building have different conditioning strategies.	
III. Complementary	Building is designed with AC and NV capability in the same spaces. This category is further subdivided into Alternate, Changeover, and Concurrent Mixed-Mode strategies, as described below.	
A. Alternate	Building includes provisions and equipment for both AC and NV but operates indefinitely in one mode or the other.	
B. Changeover	Building "changes-over" between NV and AC on a seasonal or even daily basis. The building automation system may determine the mode of operating (AC or NV) based on outdoor temperature, an occupancy sensor, a window (open or closed) sensor, or based on operator commands.	
C. Concurrent	AC system and NV provisions operate in the same space and at the same time.	

Table 2.1: Mixed-mode classification and description. Adopted from Brager et al. [27] p 68. Diagrams sourced from CBE [29]

2.2. Mixed-Mode Ventilation in Shopping Malls

The intermittent expenses of a shopping mall can be significantly lessened by energy efficient designs and these could include day lighting and passive ventilation designs. However, due to the size and functional requirements of malls and the necessity of providing a climactically stable environment for building users, such measures are sometimes difficult to be considered [30]. The potential of mixed-mode ventilation in shopping malls on the other hand, is great and visible; Hamlyn et al. [8] and Diederichsen et al. [31] revealed that the practice of mixed-mode ventilation in malls can lead to huge energy savings without compromising the indoor environmental quality. The common practise of mixed-mode ventilation in malls is having a naturally ventilated large common space that is linked to individually air-conditioned retail lots [8].

3. METHOD

For this study, shopping malls located in the state of Selangor and Federal Territories of Kuala Lumpur and Putrajaya were considered. In combination, these 3 areas are considered as the most populated and developed areas with the most number of shopping malls in Malaysia. It is therefore suitable to be chosen as the study areas. To fulfil the objectives of this study, the following three stages of data collection were conducted:

3.1. Internet Search: Identifying Currently Operating Malls

Malls were identified from four main sources namely:

1. The Ministry of Tourism and Culture Malaysia [32] website: Five electronic books published by the ministry were reviewed. They contain various information regarding shopping experiences and locations in Malaysia. These books are:
    1. Shopping Malaysia Guidebook 2014: Welcome to the Shopping Paradise in the Heart of Malaysia.
    2. Malaysia Existing Discoveries Made Easy: Kuala Lumpur. Selangor. Putrajaya. Seremban
    3. Malaysia Kuala Lumpur: The Dazzling Capital City
    4. Selangor Map and Guide
    5. Putrajaya Map and Guide.

2. Malaysia Shopping Malls Association [33] website: The association was established in 1984 and serves as a major role in the shopping malls and high rise management development in the country. It comprises of members ranging from shopping malls to high-rise offices and condominiums. List of their membership details can be assessed through its website.

3. Asia Web Direct [34] website: Established in 1994, Asia Web Direct focuses on writing lifestyle guides on top holiday destinations across Southeast Asia, and much of the Asian continent. Information on shopping destinations and other recreational activities are detailed in the website.

4. Wikipedia [35]: A list of and link to shopping malls operation in every state in Malaysia can be found on this web page.

3.2. Internet Search: Identifying Malls with Passive Design Strategies

All identified malls were further investigated to identify those that incorporate passive design strategies (e.g. openings, vegetation etc.) in their designs. To do this, three sources were exhausted which are:

1. Malls' individual website: A thorough study of each website on the description of the malls' designs was conducted. A detailed description of the mall's architectural form and organisation of the functional spaces was either found in the "About us" or "Description" section of the website.

2. Propwall.my: While some malls have their description explained in their website, some others have not. Therefore, a search was carried out on Propwall.my, which is an online open-content collaborative property encyclopaedia. It is Malaysia's most advanced property search website that provides marketing and research solutions to property agents, developers, and investors. Information and detailed description of shopping mall properties was acquired from this website.

3. Google search: This is the most-utilized search engine in the world. Apart from word search, Google Search provides many other features including descriptions, time zones, maps and locations, home listings, images videos etc.

3.3 Site Visitation: Identifying Malls with Passive Ventilation Strategies

After identifying those malls that incorporate passive design strategies, a site visitation was conducted to each of the identified malls between the months of June and July 2015. The purpose of this visitation was to identify those with 'passive ventilation strategies' (e.g. fixed openings) incorporated within their shopping spaces. Observations were made and relevant photos were taken.

4. RESULTS

4.1 Malls Operating Under Mixed-Mode Ventilation

105 shopping malls were identified operating in Selangor, Kuala Lumpur and Putrajaya with opening year ranging from 1960s to early 2015. Some of the malls are standalone retail buildings (e.g. Aeon and Giant retail outlets) while some are mixed development which includes offices, hotels, entertainments and residential units (e.g. Mont Kiara). Twelve (11.43%) out of 105 identified malls claimed to incorporate passive strategies in their design (i.e. open plan concepts). However, site visitation revealed that only six of these malls actually incorporate 'passive ventilation strategies' within their shopping spaces (i.e. fixed openings). Within all of these 6 malls, the passive ventilation strategies are operating alongside the mechanical ventilation features; hence, these malls are considered as operating under mixed-mode ventilation system. Of the remaining six malls, two followed green building standards, but none of them incorporates any of the passive ventilation features found in the other six malls within their shopping spaces.

4.2 Features Observed in The Malls

Three passive ventilation features (openings, greenery, and water bodies) and four mechanical ventilation features (air-conditioning, energy saving giant fan, ceiling fan, and jet fan blowers) were observed present in these six malls. At least four of these features (passive and mechanical) are found present in each of the malls.

4.3 Descriptions of the Identified Malls

Figure 4.1 shows the external views of six shopping malls identified to incorporate mixed-mode ventilation system, while Table 4.1 gives the general descriptions of and observed ventilation features (passive and mechanical) found in these malls. Table 4.1 shows that the opening dates of these malls are between 2009 and 2013 and most of them are built as mixed developments with an addition of office spaces. Likewise, all of the malls are built as either enclosed (i.e. no parts of the external walls open directly to the outdoor and no parts of the roofs open directly to the sky), open-air concept (i.e. parts of the external walls open directly to the outdoor, and parts of the roofs open directly to the sky) or a combination of both. Three of the six malls (SM01, 02 and 06) are built as a combination of enclosed and open-air concepts with

the height of 3, 3 and 4 storeys, respectively. Two (SM04 and 05) are enclosed and made up of a total of 12 and 4 floors respectively. SM03 is built with an open-air concept and made up of 4 floors. Table 4.1 also shows that at least four of the observed passive and mechanical features are found present in each of the malls.

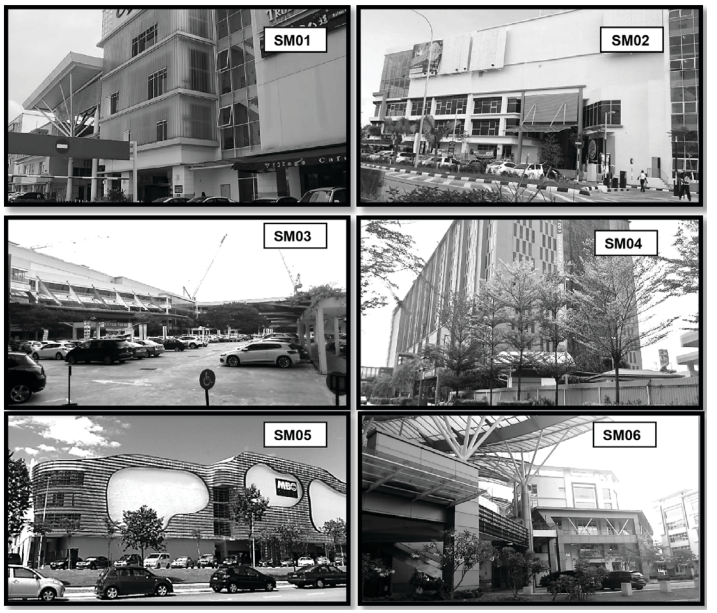


Figure 4.1. Exterior view of six malls that incorporate passive ventilation features
Note: SM represents "Shopping Mall"

Table 4.1. General description of all six (6) malls

Mall's ID	Mall's Description					Passive Features		Mechanical Features				
	Location	Opening Year	Floors	Development type	Concept	Openings	Greenery	Water bodies	AC	Giant fan	Ceiling fan	Jet fan blowers
SM01	Petaling Jaya	2009	3	Retail only	Enclosed and open-air	√	√		√	√	√	
SM02	Bangi	2013	3	Office and retail	Enclosed and open-air	√	√		√	√		
SM03	Petaling Jaya	2011	4	Retail only	Open-air	√	√		√		√	
SM04	Subang Jaya	2013	12	Office and retail	Enclosed	√	√	√	√		√	
SM05	Shah Alam	2011	4	Office and retail	Enclosed	√	√	√	√	√	√	√
SM06	Seri Kembangan	2013	3-4	Office and retail	Enclosed and open-air	√	√	v	√	√		

Table 4.2 Description of how natural and mechanical ventilation is operating in each mall

Malls' ID	Mechanical ventilation		Natural ventilation		Both	Mixed-mode ventilation category
	Central AC	Individually separated AC spaces	Common NV spaces (e.g corridors, courtyard)	Individually separated NV spaces	AC and NV operating in a space	
SM01		√	√			Zoned
SM02	√	√	√			Zoned
SM03		√	√	√		Zoned
SM04	√		√		√	Concurrent
SM05	√	√	√			Zoned
SM06		√	√			Zoned

Note: AC represents Air-condition, NV represents Natural ventilation. The mixed-mode ventilation categories are based on the classification by William Bordass as cited in Brager et. al. [11] and Brager et al. [27] See Table 2.1.

Figure 4.2. Interior view of six malls that incorporate passive ventilation features
Note: SM represents "Shopping Mall"

Figure 4.2 shows the internal view of all the six shopping malls. SM01 and SM02 have similar design characteristics; they are made up of rows of retail lots positioned along a large central common area that is covered and at the same time opened at all ends. These shops are individually air-conditioned whereas the large common area is naturally ventilated. One slight difference is that in SM02, a section of the mall that is connected at one end of the large common area actually operates on central air-conditioning system. In SM02, some retail lots are positioned within the large common area whereas this is not the case in SM01. It is worth noting that some shops (particularly restaurants) in both malls are opened directly into the common area thereby benefiting from the natural ventilation.

In SM03, all retail lots are positioned along a wide corridor that is naturally ventilated. This corridor runs through the whole length of the building and can be found on each floor. Some naturally ventilated restaurants and retail lots can be seen along the corridor. These naturally ventilated spaces were installed with ceiling fans. Other shops are individually air-conditioned. Both SM04 and 05 are enclosed malls, with a large central courtyard and are equipped with central air-conditioning system. The entrances of SM04 are huge open door-ways leading to the central courtyard allowing free exchange of air within the outdoor and the central courtyard. The central courtyard in the two shopping malls is provided with water bodies acting as cooling effect. In SM05, the central courtyard is provided with wide openings at the top for ventilation and day lighting. No opening is provided above the central courtyard of SM04. Instead, openings are provided at the end of the corridors on each floor. In both malls, retail lots can be found in the central courtyard. In SM04, the central courtyard and the corridors that open directly to the courtyard run on both natural ventilation and air-conditioning while office and some retail lots operate on full air-conditioning. In other words, SM04 has a part of its space running on both natural ventilation and air-conditioning at the same time. However in SM05, only the central courtyard and the corridors that open directly to it run fully on natural ventilation while the other spaces run on air-conditioning.

SM06 combines the design features found in the other five malls. It comprises of rows of shops and an additional enclosed mall which is built behind the rows of shops. The rows of shops are built along a large covered open space which is naturally ventilated and connected to the enclosed mall via a covered walkway. Retail lots are positioned within the large covered open space along the connecting row of shops. The rows of shops have been in operation since a few years back but the enclosed mall is yet to be opened to the public.

Table 4.2 describes how the natural and mechanical ventilation systems operate in each mall. The last column in this table indicates the category of mixed-mode ventilation that each mall falls into. This grouping is in line with the classification by William Bordass as cited in Brager et al. [11] and Brager et al. [27] (See Table 2.1). It shows that all of the studied malls have common naturally ventilated spaces and only SM03 has individually separated naturally ventilated spaces. Also, only SM04 has parts of its space (i.e. central courtyard and the corridors that face or open directly to the courtyard) operating on both natural ventilation and air-conditioning at the same time. As such, five malls (SM01, SM02, SM03, SM05 and SM06) are considered as operating under 'zoned' mixed-mode ventilation, whereas the remaining one (SM04) is considered operating under 'concurrent' mixed-mode ventilation. It is however important to note that only a part of SM04 is considered operating under 'concurrent' mixed-mode ventilation and not the whole building.

5. DISCUSSION

This study has revealed the different application modes of mixed-mode ventilation strategy in Malaysia shopping malls by studying malls that incorporates passive ventilation strategies in their design. Malls with passive ventilation features operating alongside mechanical ventilation features in their shopping spaces were grouped under different category of mixed-mode ventilation. Out of 105 malls identified, only six malls were found operating under mixed-mode ventilation. These malls were launched between 2009 and 2013, indicating that mixed-mode ventilation in malls is still a new concept in Malaysia. Some of these malls are similar in their design; they are either built as enclosed, open air concept or a combination of both, and they all have common naturally ventilated spaces (e.g. corridors, open spaces or courtyard). According to Hamlyn et al. [8], this is a common practise of mixed-mode ventilation in malls where naturally ventilated large common spaces are linked with individually air-conditioned retail lots.

Furthermore, three passive design strategies and four mechanical ventilation features were found present in all of the six malls which are: 1) openings, greenery and water bodies; and 2) air-conditioning, energy saving giant fan, ceiling fan, and jet fan blowers. All of these features were found present in SM05 and at least four of these features are present in other malls. It is however interesting to note that all of the passive features are present in SM04 and 05. These two malls are running on central air-conditioning system and are both enclosed with a central courtyard. However, SM04 has its central courtyard operating on both natural ventilation and air-conditioning and this, according to Brager [10] and Emmerich [18], is a cause for concern due to the risk of energy wastage. Only SM03 has individually separated naturally ventilated retail shops (individual retail shops in the rest of the malls are air-

conditioned). However, these shops are provided with ceiling fans to help circulate the air within the spaces. After grouping the malls into different mixed-mode ventilation categories, majority (SM01,02, 03, 05 and 06) fall under 'zoned' category while only one (SM04) falls under 'concurrent' category. However, not the entire SM04 building uses 'concurrent' mixed-mode ventilation but rather a part of the building. The zoned mixed-mode ventilation category is more economical as energy wastage resulting from operating air-conditioning and natural ventilation in the same space at the same time can be avoided.

6. CONCLUSION AND RECOMMENDATION

This study has explored different application modes of mixed-mode ventilation strategy in Malaysia's shopping malls. The study has revealed that zoned mixed-mode ventilation category is the most common mixed-mode ventilation strategy employed in the studied malls. The study has also highlighted three passive (openings, greenery, and water bodies) and four mechanical ventilation features (air-conditioning, energy saving giant fan, ceiling fan, and jet fan blowers) which are operating in the studied malls. The findings provide an insight into the classification of mixed-mode ventilation strategies in Malaysia's retail buildings. However, this study is only based on malls located in Selangor, Kuala Lumpur and Putrajaya; hence, a more comprehensive study is recommended to expand the categories of mixed-mode ventilation strategies identified in this study. Further studies are also recommended to determine the applicability and practicability of various mix-mode ventilation strategies under various classification schemes besides the one used in this study.

This study is part of a research project which aims to investigate the indoor environmental quality (IEQ) performances of shopping malls operating on different ventilation modes under hot-humid climatic condition and the effects of their performance on occupants' perception and overall satisfaction. A better understanding on occupants' expectations and concerns on their IEQ and overall satisfaction will ultimately help in creating malls that are more efficient in resources and also safer and healthier for people and environment, which can be the strongest marketing strategy for any malls.

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