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CAN WE ACHIEVE A BALANCED INDOOR ENVIRONMENTAL QUALITY (IEQ) IN MALAYSIAN HISTORICAL MUSEUM BUILDING?

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Abstract—**Indoor environment (IE) consists of indoor air, thermal, acoustic, visual or lighting, aesthetic, spatial and ergonomical quality. Each factor has its own parameters based on either quantitative or qualitative indicators according to acceptable numbers, ranges or characteristics. A balanced IE conditions in museum buildings refer to the preservation of cultural objects and the human comfort both the visitors and the staffs. The current situations of researches on IE control especially in museum environment are mainly focused in largely isolated ways which try to separate solution for each factor. To date, Malaysia has about 56 historical museum buildings where few studies have been done so far on the quality of their IE. This is something that needs close attention and therefore the aim of this paper is to look the IE issues in a holistic approach. Based on an ongoing research, this paper will discuss on the literatures framework in predicting risks in museum historical buildings due to poor IEQ.**

Keywords-component; IEQ, museum, review, thermal, lighting, indoor air

I. INTRODUCTION

Museums in Malaysia are being challenged with poor general perception from the public as dull repository as well as being queried from financial providers [1] based on museum's performance in giving back profit to the nation. He further mentioned that improvements must be carried out in order to engage more visitors and proof that museums contribute to the economy of the country.

To date, Malaysia has about 56 historical museum buildings and in general they were originally not a purpose built museum buildings. As to demolish the historical buildings are not very good decisions therefore, often the case they will be refurbished, restored, adaptive re-used, conserved and preserved into other type of buildings including museum. In historical buildings, balancing the needs of the building fabric, the occupants and the contents, while meeting desired environmental criteria can be difficult [2] and it is even more crucial in museum building where it needs a strict building control system [3].

For historical museum buildings and the artifacts inside them, the ultimate aim is to making things last longer [4] or sustainable as those are the natural assets not only for today but also for the use of future generation. Both of them cannot be neglected to be exposed to outdoor and indoor environmental changes. All these changes pose unique problems to their IE and therefore there is a need to ensure that these changes will not give risk to the performance of the historical museum buildings as well as to the artifacts and building users. Furthermore, it has become apparent that since the last decade, research on environmental conditions in historic buildings, mainly in museum and archival buildings, is in great demand [5].

Therefore, this paper is aimed to build up a theoretical framework (TF) of IEQ in Malaysian historical museum building. The work described an extensive search and synthesis of literature from a variety of sources. This TF will look into a holistic approach of IEQ and how this can enable the assessment of practical tools for surveyors.

II. BACKGROUND TO THE RESEARCH

Many scientists and researchers in museum environment agree to have a compromised indoor climate and environment [6, 7, 8, 9]. However [10] pointed out that it was not a compromise where two extremes values are averaged into one but rather, a balance in which the different needs of the building, the occupant, and the collection can all be satisfied through a realistic analysis.

Conrad's view to a certain extent is accepted as compromised environment means there will be an agreement in IE level for people and artifacts in such a way of give and take procedures where further he said that it was a popular misconception. Whereas a balanced environment means that people and artifact in museum environment will have a sense of balance, steady, stable and equilibrium design choices in IE for each of them.

But yet, previous researches were still largely focused in isolated ways for each IE factor and further much concentrated to the solution only for the objects and artifacts. Amongst others are; [11] and [12] focused on microclimatic and thermo-hygrometric quality to prevent deterioration of artifacts, [13] and [14] focused on indoor air quality, [15] and [16] on daylighting and its sensitivity to the artifacts and many other examples.

There are also other literatures which investigate total IEQ and their effects but still only to the rate of artifacts' deterioration such as in [17, 18, 5 and 19]. Only in [20], she proposed a simultaneousness index which suggests the common values for both purposes concerning peoples' comfort and the artifacts' preservation. But again, this index is focused in isolated way of one factor in IE which is thermal.

Even though it is noted that these whole debates are concerned either on isolated or total IE, and either only on artifact or both people and object, their works fall within the same conclusion as [21] as a scientific approach. He defined a scientific approach in IE investigation within museum environment as; 1) the level can be measured precisely by scientific measurement, 2) the intensity can be estimated, and 3) the factors are strongly associated with engineering and design of the building, exhibits and storage fittings. Apart of having different methodologies, these literatures also show that pollutant, light level and thermal can be integrated into a single 'museum environment' and they are also classified as scientific agents of deterioration [21] or scientific IE factors.

The research gaps of this study further identified in the context of people's satisfaction on IE in historical museum building concerning museum's visitor and staff. Comparable to the above explanation, previous researches on people satisfaction in museum buildings shows that they are rather more perceptive measurement [22, 23, 24, and 25]. Perceptive measurement is conducted based on people's perceived satisfaction without having scientific approach and measurement and therefore will limit the overall findings [22].

Refer to IE scientific agents, the variables of thermal and light level were investigated by [22] as part of the proposed model on physical environment (Figure 1) but again only based on visitors' perception. This model would have been more interesting and holistic if it is supported with scientific measurement for both variables as suggested as [21].

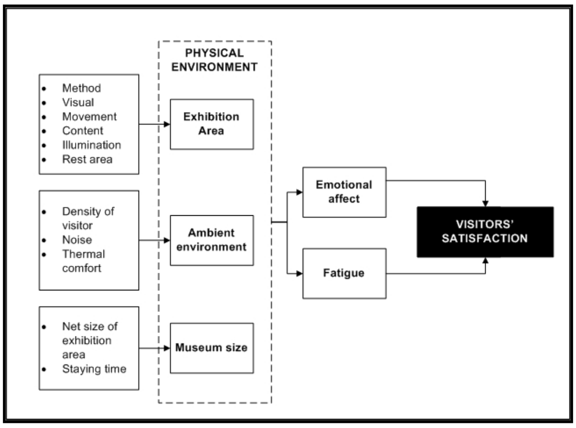

Figure 1: Model of visitors' satisfaction on museum physical environment and the indication of light level and thermal in red boxes.Source: Adopted from [22]

Apart of it, poor IEQ in museum will affect the users on their behavior either temporary for visitor [22] or continuous for staff [26] which indirect or directly due to their health condition. In general, it can be described as temporal behavior (TB) for visitor and sick building syndrome (SBS) for museum staff.

In conclusion, the pollution; relative humidity (RH) and temperature (T) which can be called as thermal; and lighting can be grouped as; 1) the scientific agents which can correlate their effect with artifacts deterioration and people's comfort level, 2) the perceptive agents which can correlate with people's dissatisfaction and health behaviors.

III. REVIEWS ON EFFECT OF IE SCIENTIFIC AND PERCEPTIVE AGENTS TO ARTIFACTS AND PEOPLE IN MUSEUM

The effects of IE scientific agents on artifacts are already reported in huge number of previous researches [e.g. 27, 28, 29 and 30] and also in previous discussion. In contrast, there were limited researches done on the effect of these agents on people in museum environment scientifically. The analyses were mostly relying on their perception and feedback where almost in all literatures said that museum fatigue is known as the effect of poor indoor environment to the visitors [22, 31] regardless due to these agents or others and only based on psychological or behavioral point of view [32]. Therefore, these reviews will look into these 2 groups of agent and their effect to people and artifacts.

A. Thermal

Thermal environment is one of the most important factors contributing to climate-induced damage to the artifacts [33]. T and RH are the most important parameters in the context of artifacts' preservation, so any incorrect value of them - whether too low or too high - will create a risk for the artifacts which further be the agents of deterioration. In a larger scope, the deterioration can be classified as biological, mechanical, physical and chemical damage [27, 29 and 3]. For museum environment, they are usually have to follow strict indoor climate system. In some cases, the climate system in the museum such as air conditioning will run continuously 24-hours. Technical standards are also available internationally such as ASHRAE: Chapter 21, European Standard: Conservation of Cultural Property (prEN15898, prEN15759-1, prEN16095, prEN15999 and prEN16141) and Italian Standard (UNI 10829 and UNI 10969). However, their values are much more suitable for temperate and cold climate and not for Malaysian environment. Therefore, Table 1 below is developed to differentiate the T and RH level between people and artifact in tropical climate.

For people, comfort is largely relying on the air T, mean radiant T, air velocity and RH. Study done by [22] indicated that thermal comfort is one of the variables in ambient museum environment which contribute people's emotional affect and fatigue where results show that it has indirect effect on their satisfaction.

TABLE 1: COMPARISON OF T AND RH RECOMMENDED LEVEL IN MUSEUM ENVIRONMENT

	Temperature °C	Relative Humidity %

Means of vent. system	Comfort level	Environ. control for objects and collections	Comfort level	Environ. control for objects and collections
Ceiling fan /mixed mode	26 - 31[2+]	22 - 28[5*+]	54 - 80[2], 50 – 60[3]/70[2]	55 – 70[5*] 50 - 65[6]
Air cond.	24[2],26[1,3], 23 – 26[4]	22 - 28[5*]	60[1], 40 – 80[2], 50 – 60[3]/70[2], 60 – 70[4]	55 – 70[5*] 50 - 65[6]

Source: [1] [34], [2] [35], [3] [48], [4] [36], [5] [37], [6] [38]

In [20], they managed to suggest a simultaneousness index with the aim of satisfying people and artifacts demand. For people, they referred the parameters of comfort into T (equivalent T) and sensation indices (thermal subjective scale). Figure 2 below shows how the increasing air velocity increased the operative T of people's comfort. The overlapping values of T and RH for both demand represents the zone where the indoor environment of a museum can be controlled.

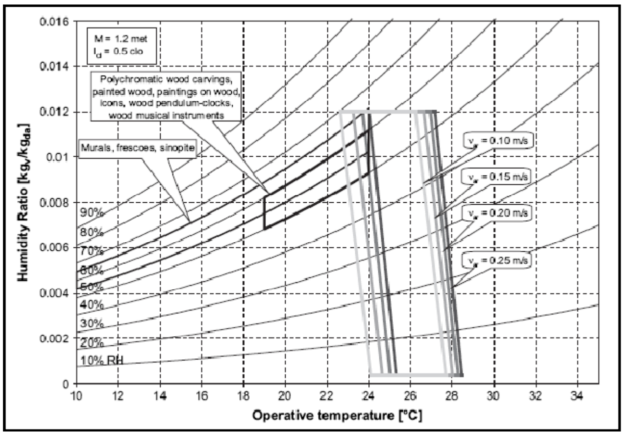

Figure 2: The overlapping values of T and RH for both demands [20].

From this research, it is optimist that balanced environment in terms of thermal can further be developed and improved for Malaysian museum environment.

B. Lighting

Lighting plays a significant role in developing interaction between humans and museum artifacts in one defined space [39]. For people, proper lighting enables them to get close to the artifacts and the surrounding environment and the recommended level is shown in Table 1.

However, peoples' perceptions on museums have been long misinterpreted as mysterious and gloomy atmosphere. Therefore, lighting needs a rigorous improvement especially in exhibition areas as it is believed to be; 1) a visual obstacles and required about 15-20 minutes of dark adaptation [40], 2) a dreary and unwelcoming indoor environment [41], 3) a failure factor in attracting visitors to the museum [1], 4) an improper emotional atmosphere for the visitor [42], 5) a significant effect on emotional affect [22] and many others.

It is important that the visual ambience must not cause fatigue. Symptoms of poor lighting are eyes fatigue, glare, blurred vision, dryness, and itchy. These can be felt within few minutes to few hours depending on the people's sensitivity and health condition and the provision of the light level in the space. Therefore, the magnitude of a functional lighting in a museum must provide good visual ambient [43] based on these requirements [44]; 1) the brightness, 2) the clarity, 3) acceptability of overall color appearance, 4) brightness or colorfulness of individual colors and, 5) naturalness of individual colors.

Lighting needs certain parameters and standards to ensure safety and preserve the artifacts (Table 2). Therefore, special attention needs to be paid to conservation requirements. Poor lighting condition will deteriorate the artifacts such as fading, yellowing, darkening, discoloring, twisting, bending, splintering, tearing, swelling, shriveling, shrinking and dissolving, but in actual fact, exhibits displayed in daylight or under artificial lighting are not normally exposed to more than one of these hazards.

TABLE 2: RECOMMENDED LUX LEVEL FOR PEOPLE AND ARTIFACT

Daylighting		Artificial Lighting	
Comfort level	Environment control for objects and collections	Comfort level	Environment control for objects and collections
100 – 200 lux	• Daylight spectrum ~ 600 – 1000 μW/lm • Daylight through window glass, ~400 μW/lm • Daylight with good UV filter ~75 μW/lm or less • Daily outdoor average: 30,000 lux and recommended indoor level at 50 lux	150 - 300 lux	50 - 150 lux

Source: [45]

C. Indoor air

Based on approximately 153 references,[46] reported that there are about 11 pollutants that will give risk to museums' artifacts with the most common indoor generated gases that pose serious risk are acetic acid (CH_3COOH), formic acid (HCOOH), acetaldehyde (CH3CHO), formaldehyde (HCHO), hydrogen sulfide (H_2S), carbonyl sulfide (COS), and ozone (O_3). Meanwhile, [47] reported approximately 20 pollutants and their possible sensitivity/effect to people. The sources are either indoor or outdoor and their concentrations are found either in macro or micro environment.

To propose a balanced environment in air quality, matrix analysis has been carried out as shown in Figure 3. However, the analysis still need further refinement in order to look in detail on the differences of pollutants concentration and their effect to artifact and people.

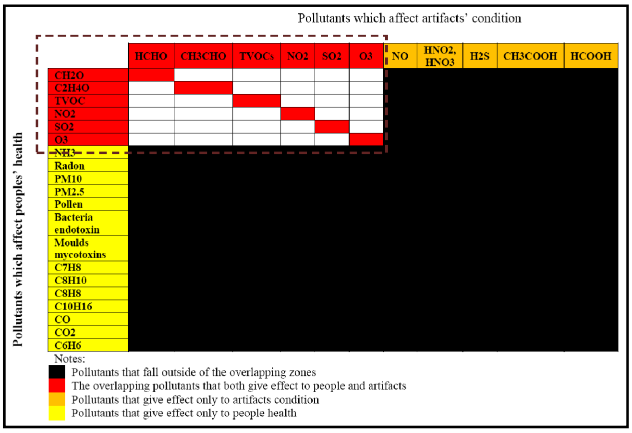

Figure 3: The overlapping zones of gaseous pollutants between peoples' health and artifacts' deterioration.

IV. CONCLUSION

Based on the compilation of these critical reviews and discussion, Figure 4 below proposed the conceptual and theoretical framework in order to achieve a balanced environment for Malaysian museum buildings. This gives a brief overview of the overall situations based on indoor environmental quality, museum environment, scientific and perceptive agents, their risks as well as demands from people and artifacts.

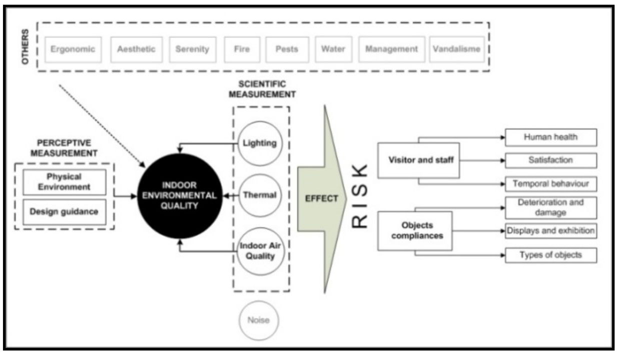

Figure 4: The proposed theoretical framework for a balanced environment in Malaysian museum buildings

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