TEST Engineering & Management

July - August 2020
ISSN: 0193-4120 Page No. 3274 -3280

Empirical Study of GBI on Istana Jahar Adaptive Reuse to Kelantan Royal Customs Museum Focusing on Ventilation System

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Article Info Volume 83
Page Number: 3274 -3280
Publication Issue:
July - August 2020

Article History
***Article Received:** 25 April 2020*
***Revised:** 29 May 2020*
***Accepted:** 20 June 2020*
***Publication:** 10 August 2020*

Abstract:
The conversion of Istana Jahar, a traditional Malay building, gives rise to a conflict between preserving the heritage building or renovating excessively to create a proper museum in which to place valuable artifacts. This article analyses the appropriateness of adapting Istana Jahar, Kelantan, by converting it into Kelantan Royal Customs Museum using recommended Green Building Index (GBI) tools. Istana Jahar was a presidential palace built using traditional Malay architectural technology with two-storey timber construction. It is the only building in Kelantan that has been listed on the National Heritage Register List and has the highest national heritage recognition. At present, no vernacular building based on traditional Malays architecture has been certified as a green building. This study assessed the suitability of adapting a reused building into a sustainable heritage building. The ventilation system was assessed using a survey administered to 95 participants on air quality comfort in the building. The findings showed that Istana Jahar had not been adequately designated as a museum as artifacts are exposed directly to high temperature inside the building. As a museum, daytime temperature and sunlight need to be considered in Istana Jahar, whereby the interior must be fitted with an air-conditioning system to preserve the artifacts displayed. Thus, Istana Jahar is most appropriate for preservation as a heritage building and is not suitable to adopt as a royal museum without excessive renovation.

Keywords: *Istana Jahar; Ventilation; Gbi Tools; Adaptive Reuse; Heritage Building*

I. INTRODUCTION

Increased awareness of the environmental impacts of human activities has propelled a worldwide movement engaged in promoting the adoption of environmentally sustainable practices. Sustainability has moved from a trend to a goal and is currently a necessity. As society moves forward in the 21st Century, sustainable development will be increasingly seen as a way to protect and enhance our quality of life within ever-decreasing environmental limits [1]. The building sector, with its massive consumption of energy, water, and raw materials, is known to be a source of significant environmental impacts [2]. Therefore, considerable efforts have been made worldwide to promote, regulate, and even enforce green building practices both in the construction of new buildings and the renovation of older buildings. Istana Jahar was selected for this study to assess its suitability to be a Kelantan Royal Customs Museum. Istana Jahar was built during the reign of Sultan Muhammad II (1885) and completed during the reign of Sultan Ahmad (1887). The palace was initially being named Istana Raja Bendahara, as it was meant to be a gift for the Raja Bendahara (the crown prince of Kelantan), Long Kundur, who proceeded to ascend the throne as Sultan Muhammad III. The name ‘Istana Jahar’ was coined during the reign of Sultan Muhammad after a Jahar tree was planted inside the palace compound. For 130 years, this palace has undergone several significant architectural changes, as shown in Table 1 [3].

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Table 1: Chronology of renovations in Istana Jahar

Year	Construction/Renovation
1887-1889	The construction of the original structure: a single-story timber building was bearing the traditional architecture of Kelantan-Patani.
1900-1905	Renovation into a double-story timber building.
1905-1920	The additional portion of Istana Jahar was constructed using a double-story masonry structure with a semi-octagonal porch.
1965	A series of renovations before being converted into the Kelantan State Museum.
1990	Another series of renovations to facilitate its conversion to a Royal Tradition and Customs Museum.

II. LITERATURE REVIEW

Researchers and practitioners worldwide, each deriving specific indicators and a reduction in environmental effects have used the term ‘green building’ interchangeably. Currently, the term ‘green building’ has been widely accepted as a vernacular term that means environmentally friendly or sustainable, although various definitions have been suggested. According to Paul and Ziegler [4], definitions may range from a building that is “not as bad” as the average building in terms of its impact on the environment to one that is “notably better” than the average building or even a regenerative process where there are improvement and restoration of the site and its surrounding environment. Some of the definitions proposed by scholars are as follows:-

i) (Green buildings) minimize construction impacts, use fewer resources, and safe operation aimed at ensuring minimization of waste and recycling [5]

ii) (Green) buildings must not only be aesthetically pleasing, but they must also be environmentally responsive [6]

iii) (Green buildings employ) sustainable design, which integrates consideration of resources and energy efficiency, healthy buildings and materials, ecologically and socially sensitive land use, and an aesthetic that inspires, affirms, and enables [7]

iv) (Green buildings are) architecturally compatible with the environment, reduce negative impacts, monitor the efficiency of energy use, make the best use of renewable energy sources, and ensure the efficient use and reuse of materials and resources concerning the site, the climatic conditions, and the convenience of users [8]

One of the most detailed and comprehensive definitions of a green building is provided by Yeang and Spector [6] and shown in Table 2.

Table 2: Four Strands of Eco-Infrastructure

No	Colour Code	Strand
1	Green	Ecological Eco-Infrastructure: Nature’s Utilities, Biodiversity Balancing, Ecological Connectivity
2	Grey	Engineering Eco-Infrastructure: Renewable Energy Systems, Eco-Technology, Carbon Neutral System
3	Blue	Water Eco-Infrastructure: Sustainable Drainage, “Closing the Loop,” Rainwater Harvesting, Water Efficient Fixtures.,
4	Red	Human Eco-Infrastructure: Enclosures, Hardscapes, Use of Materials, Products, Lifestyle, Regulatory System.

Besides, Keeler and Burke [9] argue that a green building must solve more than just one environmental challenge, and thus the approach taken should be holistic. To achieve this, it must be designed to conserve the efficiency of energy consumed by powering mechanical systems for heating and cooling, lighting, and plug loads. Because building construction emits an enormous amount of carbon dioxide (CO2), planning for the reduction of carbon emissions is an immense challenge and will soon become a non-negotiable social and political mandate.

However, due to the loosely defined characteristics of a green building, green building rating systems (a set of assessments and ratings with standardized requirements) are required. These will transform the design goals into specific performance objectives and provide a framework to assess the overall design

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[1]. Some of the most prominent rating systems are presented in Table 3.

Table 3: Comparisons of Green Building Rating Systems

Rating System	Country	Climates
Leadership in Energy and Environmental Design (LEED)	USA	Temperate, tropical, arctic, arid, & semiarid
Building Research Establishment Environmental Assessment Method (BREEAM)	United Kingdom	Variable climate changing from day to day. The overall climate is temperate maritime
Comprehensive Assessment System for Building Environmental Efficiency (CASBEE)	Japan	Temperate, subarctic, & subtropical

The alarming increase in environmental issues about development activities means it is now crucial to adopt sustainable approaches in the Malaysian building industry [10]. However, the adoption of foreign standards might prove impractical, as social and cultural differences will not facilitate a purpose and practice that addresses local needs. More importantly, internationally renowned standards are specialized for a temperate climate, rendering the rating systems irrelevant for tropical regions.

To address these issues, Pertubuhan Arkitek Malaysia (PAM) and Association of Consulting Engineers Malaysia (ACEM) devised a rating system with the following objectives: 1) defining a green building by establishing a common language and standard of measurement; 2) promoting integrated, whole-building design; 3) recognizing and rewarding environmental leadership; 4) transforming the built environment to reduce environmental impacts, and 5) ensuring new buildings remain relevant in the future and that existing building are properly refurbished and upgraded [11]. This resulted in the development of the Green Building Index (GBI), a standard developed specifically for the tropical weather in Malaysia, its environmental and developmental context, and its cultural and social needs [1]. Apart from Singapore's GREEN MARK, GBI is currently the only rating tool specialized for tropical zones [12].

III. MATERIAL AND Methodology

This analysis uses Green Building Index Tools consisting of evaluation focusing on the ventilation system.The findings will indicate the suitability of Istana Jahar for use as a Kelantan Royal Customs Museum. The final assessment was based on the following evaluations. Table 4 and Table 5 show the features of vernacular architecture that are still in use and have been rendered by more recent renovations and retrofitting.

Table 4: The building features of Istana Jahar: Ground Floor

No.	Feature	Location	
		Facade	Internal
1	Door	1	-
2	Window	4	-
3	Opening	-	-
4	Ventilation Panels	-	-

Table 5: The building features of Istana Jahar:1st Floor

No.	Feature	Location	
		Facade	Internal
1	Door	1	10
2	Window	6	12
3	Opening	-	-
4	Ventilation Panels	-	-

The building was examined through measures of temperature and relative humidity, site mapping, a questionnaire, and a solar study. Temperature and relative humidity were used to measure the suitability of ventilation. Higher relative humidity often indicates low ventilation. For these readings, each of the two floors was divided into several rooms consisting of physical divisions and practical divisions. Site mapping measured building openings using a Bosch GLM 50 laser rangefinder. The accuracy of the data was one of the main variables in the simulation of airflow. Comfort was measured using questionnaires distributed to 95 visitors. This study also determined the effect of sunlight on the lighting and internal temperature of the palace, although it focused more on the effect of orientation.

IV. RESULTS AND FINDINGS

The data obtained using GBI tools were then analyzed. The first evaluation was of ventilation in Istana Jahar as a museum that contains artifacts and allows visitors access. The measurement focused on the existing mechanical ventilation system installed in the museum, comprising an air-conditioning system and fans. The survey was conducted to assess the comfort levels of visitors. The second evaluation assessed whether wind flow allowed natural ventilation through the museum, both inside and outside. The results indicated that natural ventilation was suitable for preserving the artifacts stored in the building. A CFD simulation was applied to measure the wind flow. The third evaluation involved measuring visitors' satisfaction with the lighting appliances in the museum through a survey distributed to the same sample of 95 visitors. The final evaluation comprised a solar study that assessed the suitability of the temperature and humidity inside the museum that contains the artifacts. It explored the effect of solar orientation using the simulation of a solar path by Autodesk Revit.

The floors were divided into rooms, each representing either a physical room (enclosed space) or a functional space (near to features likely to affect ventilation). Overall, 14 place marks were placed in each room on the Ground Floor and the First Floor. Probes were then positioned 1.5 meters from floor level to simulate the usage of an anemometer and measure air movement inside the palace. The results of the simulations carried out on both floors for the three significant wind distributions were then compared to the wind speed and human body perception table devised by Weihong Guo et al. [13] (shown in Table 6) to determine whether the ventilation inside the palace is physically comfortable.

Table 6: Wind speed and physical perceptions [13]

Wind speed range	Physical perception
<1.0m/s	Breezeless
1.0-5.0m/s	Comfortable
5.0-10m/s	Uncomfortable with movements affected
10.0-15.0m/s	Uncomfortable with movement greatly affected
15.0-20.0m/s	Intolerable
>20.0m/s	Dangerous

Ventilation is an essential aspect in determining whether a building is comfortable. In this study, respondents gave their views regarding air quality and ventilation in the Istana Jahar building and the use of air conditioning. If ventilation is unable to regulate the temperature inside the building, the use of air conditioning or a fan can help the flow of air inside the building.

Table 7: Survey Results

Survey on the perception of ventilation in this building		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No Answer	1	1.1	1.1	1.1
	Very Uncomfortable	1	1.1	1.1	2.1
	Uncomfortable	6	6.3	6.3	8.4
	Slightly Uncomfortable	12	12.6	12.6	21.1
	Moderate	36	37.9	37.9	58.9
	Slightly Comfortable	12	12.6	12.6	71.6
	Comfortable	20	21.1	21.1	92.6
	Very Comfortable	7	7.4	7.4	100.0
	Total	95	100.0	100.0	

The results showed that 39 of the 95 respondents felt that indoor air quality was moderate, and 25 felt that it was good. This is because, aside from air conditioning, fans were also installed inside the building. However, 12 people felt that air quality was not good. This may be because the airflow is restricted in specific spaces, especially in an enclosed environment. As well as air quality, respondents also gave their views on ventilation (the flow of air) within the building. As shown in Table 7, 36 people stated that the ventilation in this building was moderate, and a further 20 felt that it was comfortable. However, six people felt that the flow of air in the Istana Jahar was uncomfortable. A closed window that caused heat vapors to accumulate and less heat to flow in the building may have caused this. In terms of more detailed data, 62.1 % or 59 respondents felt that the air conditioning and fan installed in the building were insufficient compared to 37.9 % or 36 respondents who thought it was adequate. Ventilation in Istana Jahar is certainly not systematic and not following a green building. Therefore, to promote smooth airflow, 91.6% or 87 respondents supported the addition of air conditioning and a ceiling fan compared to just 8.4 % or eight people who did not. The addition of air conditioning and a fan inside Istana Jahar improves natural ventilation, given that the environment within the building is hot.

The CFD simulation of ventilation was performed using Autodesk Flow Design on a 3D building

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information model of Istana Jahar. This was developed on Autodesk Revit 2015 based on measured drawings, a site survey, and measurements recorded in-situ. Ventilation for each floor was simulated based on the characteristics of wind flow from South-Southwest, East-Northeast, and East, which were the three most prominent directions. To assess the effects of spaces on ventilation, two settings were simulated; Setting X for the layout currently employed in Istana Jahar and Setting Y for an amended layout, with more open doors and windows to theoretically allow better ventilation. The readings from both Setting X and Setting Y were then compared to determine the variation in wind flow speed. The opening of new doors and windows in Setting Y should provide a spatial advantage that will increase airflow. However, the goal of this experiment was not to improve wind speed but to assess whether the airflow in each room is perceived as comfortable to the human body, as outlined by Weihong Guo et al. [13]. Figure 1 shows the results of the CFD Simulation of Ground Floor for wind flow from the South-Southwest. Table 8 presents comparisons between Setting X and Setting Y for wind flow from the South-Southwest.

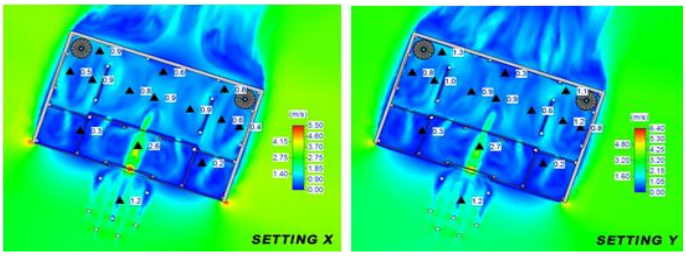

Figure 1: CFD Simulation of the Ground Floor for wind flow from the South-Southwest

Table 8: Comparison of probe readings between Setting X and Setting Y for wind flow from the South-Southwest

Probe	Setting X	Perception	Setting Y	Perception
1	1.2	Comfortable	1.2	Comfortable
2	0.3	Breezeless	0.3	Breezeless
3	2.6	Comfortable	2.7	Comfortable
4	0.2	Breezeless	0.2	Breezeless
5	0.5	Breezeless	0.8	Breezeless
6	0.9	Breezeless	1.0	Comfortable
7	0.8	Breezeless	0.9	Breezeless
8	0.9	Breezeless	0.9	Breezeless
9	0.9	Breezeless	0.6	Breezeless
10	0.6	Breezeless	1.2	Comfortable
11	0.4	Breezeless	0.8	Breezeless
12	0.9	Breezeless	1.3	Comfortable
13	0.6	Breezeless	0.3	Breezeless
14	0.8	Breezeless	1.1	Comfortable

Figure 2 shows the result of CFD Simulation of the Ground Floor for wind flow from the East-Northeast. Table 9 presents the comparison between Setting X and Setting Y for wind flow from the East-Northeast.

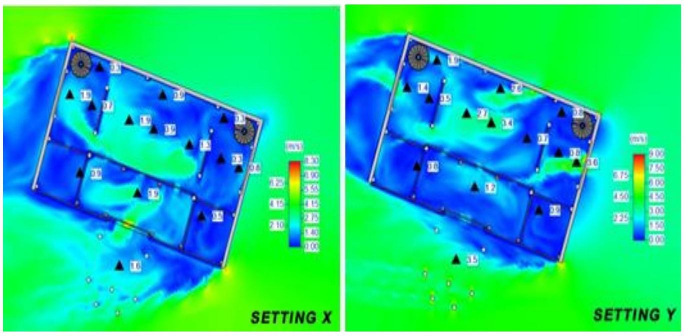

Figure 2: CFD Simulation of the Ground Floor for wind flow from the East-Northeast

Table 9: Comparison of probe readings between Setting X and Setting Y for wind flow from the East-Northeast

Probe	Setting X	Perception	Setting Y	Perception
1	1.6	Comfortable	3.5	Comfortable
2	0.9	Breezeless	0.8	Breezeless
3	1.9	Comfortable	1.2	Comfortable
4	0.5	Breezeless	0.9	Breezeless
5	1.9	Comfortable	1.4	Comfortable
6	0.7	Breezeless	0.5	Breezeless
7	1.9	Comfortable	2.7	Comfortable
8	0.9	Breezeless	3.4	Comfortable
9	1.3	Comfortable	0.7	Breezeless
10	0.3	Breezeless	0.8	Breezeless
11	0.8	Breezeless	3.6	Comfortable
12	0.3	Breezeless	1.9	Comfortable
13	0.9	Breezeless	2.6	Comfortable
14	0.3	Breezeless	0.8	Breezeless

Figure 3 shows the results of CFD Simulation of the Ground Floor for wind flow from the East. Table 10 presents the comparison between Setting X and Setting Y for wind flow from the East.

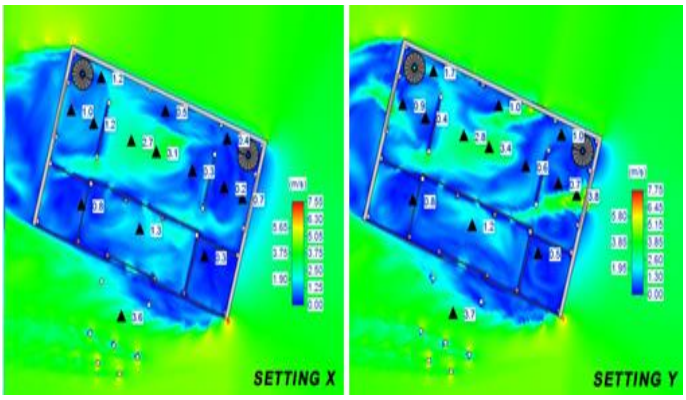

Figure 3: CFD Simulation of the Ground Floor for wind flow from the East

Table 10: Comparison of probe readings between Setting X and Setting Y for wind flow from the East

Probe	Setting X	Perception	Setting Y	Perception
1	3.6	Comfortable	3.7	Comfortable
2	0.8	Breezeless	0.8	Breezeless
3	1.3	Comfortable	1.2	Comfortable
4	0.3	Breezeless	0.5	Breezeless
5	1.0	Comfortable	0.9	Breezeless
6	1.2	Comfortable	0.4	Breezeless
7	2.7	Comfortable	2.8	Comfortable
8	3.1	Comfortable	3.4	Comfortable
9	0.3	Comfortable	0.6	Breezeless
10	0.2	Breezeless	0.7	Breezeless
11	0.7	Breezeless	3.8	Comfortable
12	1.2	Comfortable	1.7	Comfortable
13	0.5	Breezeless	1.0	Comfortable
14	0.4	Breezeless	1.0	Comfortable

Figure 4 shows the result of the CFD Simulation of the Ground Floor for wind flow from the South-Southwest. Table 11 presents the comparison between Setting X and Setting Y for wind flow from the South-Southwest.

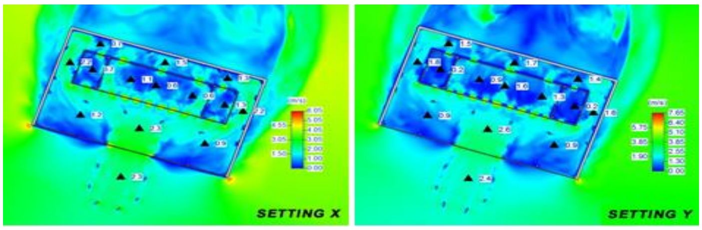

Figure 4: CFD Simulation of the First Floor for wind flow from the South-Southwest

Table 11: Comparison of probe readings between Setting X and Setting Y for wind flow from the South-Southwest

Probe	Setting X	Perception	Setting Y	Perception
1	2.3	Comfortable	2.4	Comfortable
2	1.2	Comfortable	0.9	Breezeless
3	2.3	Comfortable	2.6	Comfortable
4	0.9	Breezeless	0.9	Breezeless
5	2.2	Comfortable	1.8	Comfortable
6	0.7	Breezeless	0.2	Breezeless
7	1.1	Comfortable	0.9	Breezeless
8	0.6	Breezeless	1.6	Comfortable
9	0.6	Breezeless	1.3	Comfortable
10	1.3	Comfortable	0.2	Breezeless
11	2.2	Comfortable	1.6	Comfortable
12	0.7	Breezeless	1.5	Comfortable
13	1.5	Comfortable	1.7	Comfortable
14	1.3	Comfortable	1.4	Comfortable

V. CONCLUSION

GBI assessments on non-green retrofitted heritage buildings that are either in use, adaptably reused, or abandoned can be used as guidelines for improvements to enhance the sustainability of the building, but not as a definite indicator of sustainability. According to the assessment, the majority of criteria that were scored conformed to the features of vernacular architecture, notably ventilation and passive thermal control. These features have great potential to be exploited and enhanced to improve the sustainability of Malaysian heritage buildings. Further research, simulation, or experimentation emphasizing these traits should be conducted to develop a green approach to the adaptive reuse of heritage buildings. The use of such an approach would be environmentally responsible and ensure a resource-efficient life cycle for buildings. This research outlined methodologies in which Building Information Modeling and simulation were utilized to qualitatively and quantitatively analyze the vernacular features of Malaysian heritage buildings. This facilitates the planning of optimal scenarios in which environmental factors can be addressed to enable adaptive reuse towards a green building. The research also highlights the natural features of traditional Malay architecture that are often overshadowed and rendered irrelevant in favor of subsequent renovations, yet are more effective in terms of the sustainable heritage building. Istana Jahar can be adapted into a royal museum in conditions where the mechanical aspect of the cooling system is emphasized, such as the full utilization of a fan and air-conditioning system. The museum must sustain a cold temperature inside the building to preserve the artifacts and provide a comfortable level of humidity for visitors.

VI. Acknowledgments

The authors acknowledge Ministry of Education Malaysia and also thanks to Research, Innovation and Commercialization Center (RMIC), Universiti Malaysia Kelantan (UMK) for supporting this research project under the RAGS grant RAGS/1/2014/STWN08/UMK//1.

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