CHEMICAL ENGINEERING TRANSACTIONS
VOL. 56, 2017
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Jiří Jaromír Klemeš, Peng Yen Liew, Wai Shin Ho, Jeng Shiun Lim

**ISBN** 978-88-95608-47-1; **ISSN** 2283-9216
DOI: 10.3303/CET1756052

# Investigation of Green Assessment Criteria and Sub-criteria for Public Hospital Building Development in Malaysia

Shaza Rina Sahamir*[,a], Rozana Zakaria[a], Gamal Alqaifi[a], Nur Izieadiana Abidin[a], Raja Rafidah Raja Muhd Rooshdi[b]

[a]Faculty of Civil Engineering, Universiti Teknologi Malaysia, UTM, 81310 Johor Bahru, Johor, Malaysia
[b]Faculty of Architecture, Planning and Surveying, Universiti Teknologi Mara, UiTM, 40450 Shah Alam, Selangor, Malaysia
rinashaza@gmail.com

Malaysia as a developing country has extreme motives towards sustainable development as a lifestyles practice, thus the need to prepare for the change is required. The implementations of sustainability have become important initiatives discussed and undertaken by both private and public sector dealing with residential and non-residential buildings including hospital buildings. A hospital, healthcare facility, has been upgraded from essential to very essential in the context of Sustainable City. Buildings are known as human habitat and shelter. Peoples' health and the environment condition are highly influenced by the way the buildings have been designed, constructed and operated. Compared to other building types, the 24 hours' scenario use of healthcare buildings have a particular large impact on the environment. The problems created by rampant urbanisation are among the most important challenges recently. Thus, the development of green hospital is important in order to create a healthy lifestyle that viable economically, environmentally and socially. The investigation of green assessment main criteria and sub criteria for public hospital building development in Malaysia is the primary aim for this research. Healthcare buildings' essential criteria of existing green rating systems worldwide and the difference between each criterion compared to Malaysian green rating system all are compiled. Guideline and existing tools are thoroughly reviewed, analysed and divided according to similar categories covers all aspect of building design, construction and operation. The data then will be analysed using content analysis in order to identify the various sub criteria to hospital buildings development. The results from the analysis demonstrate a set of assessment criteria for green public hospital building corresponding to Malaysia's scale.

## 1. Introduction

Green assessment system basically refers to the processes that are environmentally responsible and resource-efficient throughout a building's life-cycle; from inception to the demolition stage. The ultimate goal for the green assessment system is to generate sustainable building practice that expands and complements the classical building design concerns of economy, society and environment. Although it has been discussed widely as an initiative to offer many benefits to the buildings recently, yet the issues on effectiveness are still in on-going debate from past to present. This is proven in the study conducted by Newsham et al. (2009), who has reported that Leadership in Energy and Environmental Design (LEED) - certified buildings, used more energy compared to non-LEED counterparts. It has been followed by Scofield (2013), mentioned that LEED-certified buildings did not show a significant reduction either on the energy consumption or greenhouse gas emission as compared to non-certified LEED buildings. In addition, in the Malaysian context, Huat and Akasah (2011), found that a few accredited green buildings did not perform as per stated design specifications after the post-occupancy assessment. As things stand, there is an initiative taken by Mustapha et al. (2015), who have conducted a study on the improvement of assessment system by using a new tool to assess the greenness and still at the same time the coverage was in the context of using the existing green elements which is similar with existing green assessment systems. A new Green Index has been developed as a quantitative green performance indicator as a result for their study.

Please cite this article as: Sahamir S.R., Zakaria R., Alqaifi G., Abidin N.I.A., Rooshdi R.R.R.M., 2017, Investigation of green assessment criteria and sub-criteria for public hospital building development in malaysia, Chemical Engineering Transactions, 56, 307-312 DOI:10.3303/CET1756052

## 2. Hospital sustainability

Hospital industry has known as a relatively complex development. It is sensibly known as complex buildings with many unique requirements from the initial business viewpoints until the types of facilities provided. Healthcare services are water and energy intensive, consume a great deal of hazardous and non-hazardous materials and are responsible for producing polluting emissions. Built environment accounts for 40 % of all carbon dioxide ($CO_2$) emission in the Netherlands, thus, sustainable building has become an important issue. Hospitals alone count for 4 % of the built environment, hence there is a lot to gain (Kras, 2011). A recent study revealed that sustainable initiatives such as recycling and reducing common wasteful practices can save hospitals a substantial amount of money. In fact, the industry as a whole could save $ 5.4 billion in 5 y and up to $15 billion in 10 y if it adopts sustainable practices (Kaplan et al., 2012). Therefore, it is necessary that hospitals feel the urgency to undertake actions in determining the environmental impact of a hospital building development. The healthcare buildings should aim to make no contribution to climate change through effective design of buildings and land management to support local biodiversity.

### 2.1 Hospital sustainability in Malaysia

Sahamir and Zakaria (2014) stated that there is slightly small in number of hospital buildings in Malaysia, particularly the ones that being awarded by Green Building Index (GBI) rating tools. The study has reported only 2 numbers of hospital building were documented as green building for the certification level by GBI in 2014. However, according to recent data, there is an increasing number for hospital buildings receiving certification under the GBI rating tools. Thus, it demonstrates the positive result in term of the development of green hospital building in Malaysia. Besides, there are rating systems specifically created for hospital building by GBI, namely; 1) GBI Non-Residential New Construction (NRNC) for hospital tool V1.0, and 2) GBI Non-Residential Existing Building (NREB) for Hospital tool V1.0. Both contents have no differences in term of points, rating score as well as main criteria from the previous rating version used for GBI NRNC and NREB (Sahamir and Zakaria, 2014).

### 2.2 Green assessment system for hospital buildings

The rating system provides an effective framework for assessing building environmental performance and integrating sustainable development into building and construction processes; as it can be used as a design tool by setting sustainable design priorities and goals, developing appropriate sustainable design strategies; and determining performance measures to guide the sustainable design and decision making processes (Ando et al., 2005). There are hundreds of building assessment schemes worldwide focusing on different areas of sustainable development and are designed for different types of projects. However, only few systems are widely acknowledged and really set a recognisable standard for hospital building assessment. The following three (3) systems were chosen to be reviewed in this paper as they are influential and technically advanced rating tools available for healthcare-specific building: 1. Building Research Establishment Environmental Assessment Method (BREEAM), 2. Leadership in Energy and Environmental Design (LEED) and 3. GREEN STAR. The differences between those three rating systems are shown in Table 1.

## 3. Methodology

This paper has developed a research focusing on green hospital building development. The comparison for different assessment systems is essential for the study in providing further direction of the research. This paper approach was qualitative in nature, using holistic account to fulfil the research aims and objectives. This involves reporting multiple perspectives, identifying many factors involved in a situation and generally sketching the larger picture that emerges. During the process of research, the author may collect and analyse public documents (e.g. newspaper, minute of meetings, official reports and etc.) or private documents (Creswell, 2009). Therefore, this paper has identified some relevant documents in order to obtain rich data for analysis purposes. The different types of green assessment systems were used and analysed. It provides comprehensive criteria and sub-criteria for the regions; provide a whole specific type of building evaluation rather than an evaluation of the general building. Identification of green criteria and sub-criteria for hospital building is imperative to study to look on the pattern of sensitivity of each rating systems for hospital building.

## 4. Result

The study has identified several important criteria related to Green Hospital Building Development (GHBD). Thus, the data has been analysed into 2 different aspects, namely; 1) main criteria and 2) sub-criteria.

*Table 1: Recognisable green assessment for hospital buildings (Sahamir and Zakaria, 2014).*

| Country/Title | Type | Versions/Year | Elements and points | Ratings and level of certification |
|---|---|---|---|---|
| UK<br>BREEAM<br>(new builds, extensions & major refurbishments) | Environmental Assessment | Healthcare 2008<br>2008 | Management (12), Health and Wellbeing (15), Energy (19), Transport (8), Water (6), Materials (12.5), Waste (7.5), Land Use & Ecology (10), Pollution (10), Innovation (10).<br>Total points = 110 | Unclassified <30<br>Pass ⩾30<br>Good ⩾45<br>V Good ⩾55<br>Excellent ⩾70<br>Outstanding ⩾85 |
| US<br>LEED<br>(new construction & major renovations) | Environmental Assessment | Healthcare v2009<br>2009 | Sustainable Sites (18), Water Efficiency (9), Energy and Atmosphere (39), Materials and Resources (16), Indoor Environmental Quality (18), Innovation In Design (6), Regional Priority Credits (4).<br>Total points = 110 | Certified 40-49<br>Silver 50-59<br>Gold 60-79<br>Platinum 80 and above |
| AUSTRALIA<br>Green Star<br>(building at the design phase as well as post construction phase 'As-Built') | Environmental Assessment | Healthcare v1<br>2009 | Management (17), Indoor Environment Quality (32), Energy (29), Transport (12), Water (14), Materials (35), Land use &Ecology (8), Emissions (20), Innovation (5).<br>Total points = 172 | Best Practice (4 star) 45-59<br>Australian Excellence (5 star) 60-74<br>World Leadership (6 star) 75-100 |

**4.1 Main criteria for green hospital assessment system**

Table 2 shows there are 10 main criteria that need to be considered for the development of green hospital building. The matrix table has been used in order to investigate the detail differences between each assessment system. Figure 1 has summarised each preferred criterion that will be used against selected factors, namely; 1) economic, 2) environment and 3) social. These factors are significant elements to be measured in green assessment issues. Thus, he summary is significant to examine in order to determine which criteria belong to the stated factors for the upcoming study.

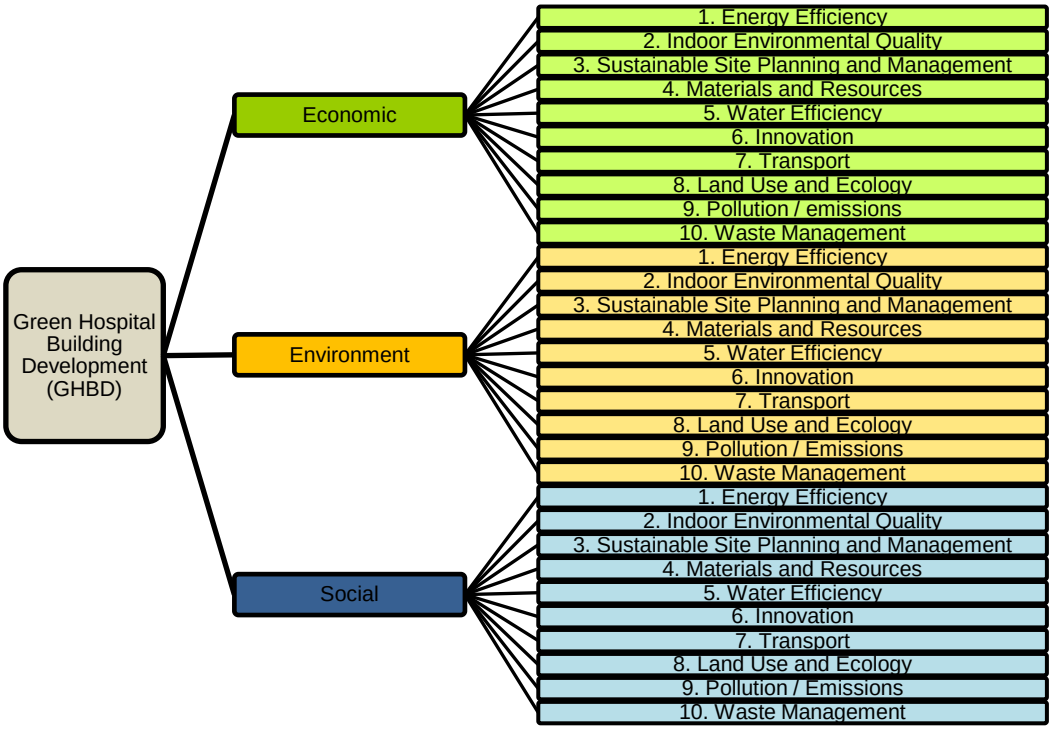


*Figure 1: Summary of main factor against main criteria*

### 4.2 Sub criteria for hospital green assessment system

The tabulation methods have been used in order to gather, separate and coding the sub-criteria according to the main criteria of hospital building development. Table 3 were used to show the example of tabulation method specifically for energy efficiency (stated as main criteria – C1 in Table 4). The tabulation is a vital proses in analysing the detail sub-criteria from each existing green assessment systems. Hence, the sub-criteria that have been extracted from the green assessment systems into the main criteria table is shown in Table 4, 5 and 6.

*Table 2: Comparison of major elements consisted in Green rating system worldwide.*

| NO | GBI | BREEAM | LEED | GREEN STAR |
|---|---|---|---|---|
| 1 | Energy efficiency | Energy | Energy and atmosphere | Energy |
| 2 | Indoor environmental quality | Health and wellbeing | Indoor environment quality | Indoor environment quality |
| 3 | Sustainable site planning & management | Management | Sustainable sites | Management |
| 4 | Materials & resources | Materials | Materials & resources | Materials |
| 5 | Water efficiency | Water | Water efficiency | Water |
| 6 | Innovation | Innovation | Innovation in design | Innovation |
| 7 | - | Transport | - | Transport |
| 8 | - | Land use and ecology | - | Land use and ecology |
| 9 | - | Pollution | - | Emissions |
| 10 | - | Waste | - | - |

*Table 3: The tabulation of green assessment sub-criteria for hospital buildings in term of energy efficiency*

| Green assessment index | GBI NREB | GBI NRNC | BREEAM | LEED | GREEN STAR |
|---|---|---|---|---|---|
| Main criteria | Energy efficiency | Energy efficiency | Energy | Energy and atmosphere | Energy |
| Sub-Criteria | Minimum EE performance | Minimum EE performance | Low or zero carbon technologies | Optimise energy performance | Peak energy demand reduction |
| | Lighting zone | Lighting zone | - | - | Lighting zoning |
| | Electrical sub -metering | Electrical sub - metering | Energy sub-metering | - | Energy sub-metering |
| | Renewable energy | Renewable energy | - | On-site renewable-energy | |
| | Advanced or improved EE performance - BEI | Advanced EE performance - BEI | Energy efficient building systems | Green power | - |
| | Enhanced or Re-commissioning | Enhanced commissioning | - | Enhance commissioning | - |
| | On-going post occupancy commissioning | Post Occupancy Commissioning | - | - | - |
| | EE monitoring & improvement | EE Verification | - | - | - |
| | Sustainable maintenance | Sustainable maintenance | - | - | - |
| | - | - | $CO_2$ emissions | - | Greenhouse gas emissions |
| | - | - | - | Enhance refrigerant management | - |
| | - | - | - | Measurement and verification | - |
| | - | - | - | Community contaminant prevention – airborne releases | - |
| | - | - | - | - | Car park ventilation |
| | - | - | - | - | Efficient external lighting |

*Table 4: The tabulation of green assessment sub-criteria C1, C2 and C3.*

| C1: Energy Efficiency (EE) | C2: Indoor Environmental Quality (EQ) | C3: Sustainable site planning and management |
|---|---|---|
| 1) Minimum Energy Efficiency (EE) performance | 1) Minimum Indoor Air Quality (IAQ) performance | 1) Green Index rated design & construction |
| 2) Lighting Zoning | 2) Environmental Tobacco Smoke (ETS) Control | 2) Building exterior management |
| 3) Electrical sub-metering | 3) Carbon Dioxide Monitoring and Control | 3) Integrated pest management, erosion control & landscape management |
| 4) Renewable energy | 4) Volatile organic compounds (VOC) monitoring | 4) Greenery & roof |
| 5) Advanced or improved EE performance | 5) Indoor Air Pollutants | 5) Building user manual |
| 6) Enhanced, commissioning or Re-commissioning | 6) Indoor chemical and pollutant source control | 6) Commissioning clauses |
| 7) Post occupancy commissioning / On-going post occupancy commissioning | 7) Mould Prevention | 7) Construction site impacts |
| 8) EE monitoring & improvement | 8) Thermal comfort: design & controllability of systems | 8) Security |
| 9) Sustainable maintenance | 9) Air Change Effectiveness | 9) Site selection |
| 10) Greenhouse gas emissions | 10) Daylighting | 10) Stormwater design: quantity and quality control |
| 11) Enhance refrigerant management | 11) Daylight glare control | 11) Development density and community connectivity |
| 12) Measurement and verification | 12) Electric lighting levels | 12) Brownfield redevelopment |
| 13) Community contaminant prevention – airborne releases | 13) Controllability of systems: lighting | 13) Site development – protect or restore habitat |
| 14) Car park ventilation | 14) Internal and external lighting levels | 14) Site development – maximize open space |
| 15) Efficient external lighting | 15) High frequency ballasts | 15) Connection to the natural world - places of respite |
| 16) Sub-metering of high energy load and tenancy areas | 16) External views | 16) Connection to the natural world – direct exterior access for patients |
| 17) Provision of Energy Efficiency Equipment | 17) Internal noise levels / Acoustics environment | 17) Building tuning |
| 18) CHP community energy | 18) IAQ before/during occupancy | 18) Independent commissioning agent |
| | 19) Occupancy / Post occupancy comfort survey: verification | 19) Environmental management |
| | 20) Hazardous material removal or encapsulation | 20) Waste management |
| | 21) Low-emitting materials | 21) Building management systems |
| | 22) Formaldehyde minimization (*Formaldehyde is one of the most toxic chemicals that can invade the human body. It is a known carcinogen and tissue irritant.) | 22) Maintainability |
| | 23) Individual thermal comfort control | 23) Construction indoor air quality plan |
| | 24) Exhaust riser | 24) Sustainable procurement guide |
| | 25) Air distribution system | 25) Earthwork - construction activity pollution control |
| | 26) Outdoor pollutant control | 26) Workers' site amenities |
| | 27) Places of respite | 27) Green vehicle priority |
| | 28) Thermal Zoning | 28) Considerate constructors |
| | 29) Potential for natural ventilation | 29) Consultation |
| | | 30) Shared facilities |
| | | 31) Good corporate citizen |

*Table 6: The tabulation of green assessment sub-criteria C7, C8, C9 and C10.*

| C7: Transport | C8: Land use and ecology | C9: Pollution | C10: Waste |
|---|---|---|---|
| 1) Public transport network connectivity | 1) Site selection | 1) Refrigerant Ozone Depletion Potential (ODP) | 1) Construction waste |
| 2) Commuting mass – transport | 2) Protection of ecological features | 2) Refrigerant Global Warming Potential (GWP) | 2) Recycled aggregates |
| 3) Pedestrian and cyclist facilities | 3) Mitigation / enhancement of ecological value | 3) Refrigerant use and leakage | 3) Recycling facilities |
| 4) Access to amenities | 4) Topsoil | 4) Insulant ODP | |
| 5) Travel plans and information | 5) Re-use of land | 5) Flood risk | |
| 6) Provision of car parking | 6) Reclaimed contaminated land | 6) Stormwater | |
| 7) Fuel-efficient transport | 7) Long term impact on biodiversity | 7) Watercourse pollution | |
| 8) Transport design and planning | | 8) Discharge to sewer | |
| 9) Travel information point | | 9) External light and noise pollution | |
| 10) Deliveries and Manoeuvring | | 10) Legionella | |
| | | 11) Trade Waste Pollution | |
| | | 12) NOx (mono-nitrogen oxides) emissions | |
| | | 13) Noise attenuation | |

*Table 5: The tabulation of green assessment sub-criteria C4, C5 and C6.*

| C4: Materials and resources | C5: Water | C6: Innovation |
|---|---|---|
| 1) Materials reuse and selection | 1) Rainwater harvesting | 1) Innovation & environmental initiatives |
| 2) Recycled content materials | 2) Water recycling | 2) Accredited facilitator / professional |
| 3) Sustainable timber | 3) Water efficient – irrigation / landscaping | 3) Exemplary performance levels |
| 4) Sustainable purchasing policy | 4) Water efficient fittings | 4) New technologies and building processes |
| 5) Storage, collection & disposal of recyclables | 5) Metering and leak detection system | 5) Integrated project planning and design |
| 6) Refrigerants & clean agents | 6) Water consumption | 6) Innovation in design |
| 7) PBT source reduction | 7) Water use reduction | 7) Exceeding green index benchmarks |
| 8) Construction waste management | 8) Minimize potable water use for medical equipment cooling | |
| 9) Recycling waste storage | 9) Heat rejection water | |
| 10) Furniture and medical furnishings | 10) Fire system water | |
| 11) Resource use – design for flexibility | 11) Sanitary supply shut off | |
| 12) Design for disassembly | | |
| 13) PVC minimization | | |
| 14) Concrete, steel, PVC, timber | | |
| 15) Flooring, joinery, ceilings, walls, partitions | | |
| 16) Regional materials | | |
| 17) Materials specification (major building elements) | | |
| 18) Hard landscaping and Boundary protection | | |
| 19) Reuse of building structure | | |
| 20) Insulation | | |
| 21) Responsible sourcing of materials | | |
| 22) Designing for robustness | | |

## 5. Conclusions

As a conclusion, there are 151 numbers of sub-criteria that have been identified in this study (Table 4, 5 and 6). Each of the sub-criterion has been divided into preferred main criteria (C1 – C10) in order to designate the association issues between them. The identification of sub-criteria is an imperative process as it will be used for further study in developing the comprehensive assessment rating system.

### References

Ando S., Arima T., Bogaki K., Hasegawa H., Hoyano A., Ikaga T., 2005, Architecture for a sustainable future. Architectural Institute of Japan, Tokyo, Japan.

Creswell J.W., 2009, Research design qualitative, quantitative, and mixed methods approaches, 3rd ed., Sage, Los Angeles, US.

Huat N.B., Akasah Z.A., 2011, Building performance analysis model using Post Occupancy Evaluation for energy-efficient building in Malaysia: A review, NPC 2011. DOI:10.1109/NatPC.2011.6136351.

Kaplan S., Sadler B., Little K., Franz C., Orris P., 2012, Can Sustainable Hospitals Help Bend the Health Care Cost Curve?, The Commonwealth Fund 29, 1-14.

Kras I., 2011, Sustainable hospital building. Faculty of Architecture, Urbanism and Building Science, Technical University of Delft, Delft, Netherlands.

Mustapha M.A., Manan Z.A., Wan Alwi S.R., 2015, A new green index as an overall quantitative green performance indicator of a facility, Chemical Engineering Transactions, 45, 445-450.

Newsham G.R., Mancini S., Birt B.J., 2009, Do LEED-certified buildings save energy? Yes, but…, Energy and Buildings, 41, 897–905.

Scofield J.H., 2013, Efficacy of LEED-certification in reducing energy consumption and greenhouse gas emission for large New York City office buildings, Energy and Buildings, 67, 517–524.

Sahamir S.R., Zakaria R., 2014, Green Assessment Criteria for Public Hospital Building Development in Malaysia, Procedia Environmental Sciences, 20, 106–115.