Integrating Sustainable Building Design Criteria to the Green Building Index (GBI) and MyCREST in Malaysia: Insights from a Systematic Review and Meta-Analysis

Azirah Adnan[1,2]*, Saipol Bari Abd Karim[1] and Muhammad Hadi Mustafa[1]

[1]Faculty of Built Environment, Universiti Malaya, 50603 Kuala Lumpur, Malaysia.

[2]Politeknik Sultan Azlan Shah, Behrang, Perak, Malaysia.

*Corresponding author: azirahadnan@gmail.com

Abstract

Sustainable building design is pivotal in mitigating environmental impacts and promoting energy efficiency. To support designers in achieving these goals, sustainable rating systems have been established globally according to the climate and suitability of each country including Malaysia. However, the proliferation of sustainable rating systems has led to a fragmented landscape of diverse standards. This poses challenges and confusion for stakeholders particularly designers in designing sustainable buildings which meet the sustainable rating systems requirement. Therefore, by utilizing a systematic review and meta-analysis approaches, this study attempts to align the sustainable building design criteria with the sustainable requirements in Malaysia's rating systems namely Green Building Index (GBI) and Malaysian Carbon Reduction and Environmental Sustainability Tool (MyCREST). By adopting the Preferred Reporting Items for Systematic Reviews (PRISMA) framework, a rigorous search strategy was applied across the Web of Science, Scopus, and ScienceDirect databases, as well as sustainable guidelines, to identify the sustainable building design criteria which then systematically aligned with the primary sustainable criteria required in the rating systems. Finally, a meta-analysis approach was performed to synthesize the quantitative data and provide a consolidated view of the most critical and frequently cited sustainable building design criteria according to the primary sustainable criteria classification. This review offers a comprehensive alignment of sustainable building design criteria with Malaysia's leading rating systems and serving as a fundamental reference for designers in integrating the sustainable practices into building design. It is hoped that this review will alleviate the confusion among designers, while also highlighting areas for improvement within the rating tools themselves to promote greater clarity, consistency, and integration of sustainability criteria in the country.

1.0 INTRODUCTION

Sustainable building development has become a crucial priority in response to global environmental challenges. As a result, there is a growing global movement towards adopting sustainable building practices, with the industry increasingly acknowledging the importance of sustainability through the creation of various policies and sustainable rating systems.

Up to now, various sustainable rating systems have been developed worldwide to align with different countries' local standards, regulations, and climate conditions. For instance, in the United Kingdom, the Building Research Establishment Environmental Assessment Method (BREEAM) was the first of its kind, established in 1990. In the United States, the Leadership in Energy and Environmental Design (LEED) was launched in 1994. Japan introduced the Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) in 2001, while Australia established GREEN STAR in 2003. Italy followed with the Institute for Transparency of Contracts and Environmental Compatibility (ITACA) in 2009, and Singapore implemented the Green Mark in 2005 (Doan et al., 2017). Nevertheless, the effectiveness of these global rating systems often rely on their adaptability to local climatic, cultural, and regulatory contexts. For instance, while LEED emphasizes energy efficiency through advanced HVAC systems, its prescriptive approach may not fully align with the needs of tropical climates, where passive cooling strategies are more impactful (Khogali, 2016). Similarly, BREEAM's comprehensive assessment of lifecycle impacts might require adaptation to accommodate Malaysia's specific construction practices and resource constraints. Hence, to adapt with the local climates, Malaysia has also developed several rating tools to assess and certify sustainability within the construction industry, such as the Green Building Index (GBI), Green Performance Assessment System (GreenPASS), Green Real Estate (GreenRE), Malaysian Carbon Reduction and Environmental Sustainability Tool (MyCREST), Malaysia Green Highway Index (MyGHI), PH JKR, and others (CIDB, 2017).

However, a significant concern arises from the existence of numerous green rating tools within the construction industry, leading to confusion among designers and complicating the design process. The presence of multiple tools often results in inconsistencies, overlapping criteria, and varying methodologies, making it challenging for designers to navigate and compare assessments effectively. This complexity can create ambiguity and hinder efforts to promote sustainability, as designers may struggle to determine which tool is most relevant and reliable for their specific project needs (Assefa et al., 2022). This issue is also evident in Malaysia, where more than ten sustainable rating tools have been developed since the introduction of the Green Building Index (GBI) in 2009. Furthermore, the proliferation of these tools can increase the burden on organizations seeking certification, as they may need to comply with multiple and potentially conflicting requirements (CIDB, 2017). Based on these circumstances, a key research question has emerged: How can sustainable building design criteria be systematically aligned with Malaysia's key green rating systems to address the fragmented standards and reduce confusion among designers?

In response to this issue, the objective of this study is to identify, align, and thematically categorize sustainable building design criteria by extracting them from relevant literatures and aligning them with the requirements of two predominant rating systems in Malaysia. Up to now, there are eleven green rating systems developed in Malaysia, and each has different set of criteria and assessment methods. This study focuses on one primary rating system commonly used in private projects and one rating system typically employed in government projects. For private projects, the GBI rating system which developed by the Malaysian Institute of Architect (PAM) and Association of Consulting Engineer Malaysia (ACEM) is selected as it is the leading and most widely utilized rating tool in Malaysia (Razman et al.,2023), and this rating system has achieved maturity level in Malaysia (CIDB, 2017), and most of the certified building by GBI is private project. For government projects, MyCREST, which is developed by CIDB, is selected as this rating system is made as mandatory for government new project worth RM50 million and above.

This study focuses specifically on non-residential buildings, as both the selected rating systems which are the Non-Residential New Construction (NRNC) under the GBI and for MyCREST which are generally applicable to most building types but place primary emphasis on non-residential and public buildings, especially those funded by the government or public agencies (CIDB, 2017). By focusing on non-residential building, this study targets a building typology with significant environmental impact, as performance evaluation conducted by Tan et al. (2023) which showed that Malaysian government office buildings

consumed approximately 65% of total energy usage, highlighting the substantial energy demand of non-residential buildings in Malaysia and reinforcing their status as a critical focus area for sustainability efforts. Additionally, new construction projects offer the greatest opportunity to integrate sustainability principles from the early design stage, enabling holistic planning and optimized decision-making (Mavi et al., 2021). Additionally, by focusing on non-residential new construction, this study targets a building typology with significant environmental impact, as performance evaluation conducted by Tan et al. (2023) which showed that Malaysian government office buildings consumed approximately 65% of total energy usage, highlighting the substantial energy demand of non-residential buildings in Malaysia and reinforcing their status as a critical focus area for sustainability efforts.

The importance of this study lies in its ability to streamline and enhance sustainable building practices in Malaysia by identifying and aligning sustainable building design criteria with the country's predominant rating systems. By establishing a clear connection between design criteria and these key rating systems, the study aims to facilitate a more coherent and effective approach to sustainable construction. This alignment not only aids architects, engineers, and developers in making informed design decisions but also helps ensure that projects meet the highest standards of sustainability, contributing to Malaysia's broader environmental goals.

2.0 METHODOLOGY

2.1 Prisma Framework

The methodology adopted in this study involves a rigorous process of identifying and aligning sustainable building design criteria with the Malaysia's predominant rating systems. The study employs a Systematic Literature Review (SLR) using the PRISMA 2020 framework to ensure a transparent and replicable selection process of relevant literature. The systematic literature search was conducted in August 2024 using the Web of Science (WoS), Scopus, and ScienceDirect databases. The review included studies published from 2020 to August 2024, focusing on the relevant sustainable building design criteria. WoS and Scopus databases are the two primary and most comprehensive sources of publication metadata and impact indicators, and they are essential tools for a range of tasks, including journal and literature selection as well as research evaluation at various levels (Pranckutė, 2021). ScienceDirect is also selected as a widely used database that offers access to extensive databases, as demonstrated in numerous literature reviews (Charoenthammachoke et al., 2020).

In addition, as highlighted by Kim et al. (2020), the development of sustainable rating systems represents a significant advancement in promoting building efficiency and environmental sustainability. Hence, this study reviewed two organizational publications to extract the sustainable building design criteria outlined in Malaysia's green building rating systems. For this study, the Green Building Index (GBI), developed by the Malaysian Institute of Architects (PAM), and MyCREST, developed by the Construction Industry Development Board (CIDB), were reviewed, as the sustainable building criteria outlined in these systems are highly relevant and valuable for consideration. Furthermore,
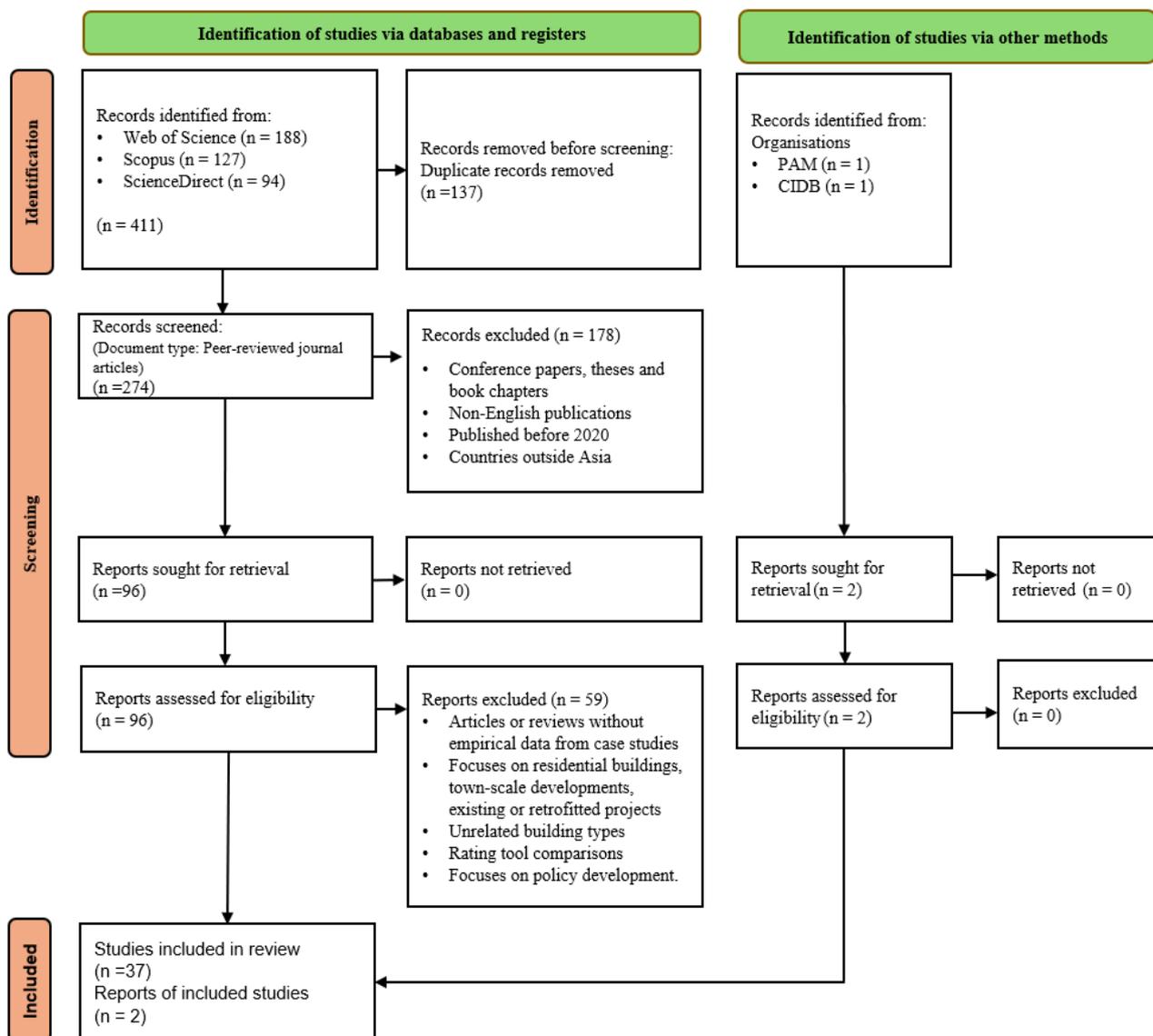
To identify the design criteria for sustainable building, previous literature and sustainable guidelines were reviewed by using the SLR. The process begins with the identification phase where 411 publications were identified by using the search string: ("Sustainable Building Design" OR "Green Building Design") AND ("Criteria" OR "Indicators" OR "Strategy" OR "Requirements" OR "Principles" OR "Factors") AND ("Asia"). This search string was formulated to ensure relevance to the regional context of Malaysia while capturing broader trends in sustainable building practices. The selection process included:

a. **Identification:** A total of 411 publications were initially retrieved from the databases.

b. **Screening:** After removing 137 duplicates, the remaining articles were assessed based on predefined inclusion and exclusion criteria (Table 1).

c. **Eligibility:** Articles that did not focus on sustainable building criteria or were not peer-reviewed were excluded.

d. **Inclusion:** Ultimately, 39 publications met the criteria for detailed review and analysis.

Table 1. Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Document type	Peer-reviewed journal articles, and organisational publication (GBI and MyCREST)	Conference papers, theses and book chapters
Language	English publication	Non-English publications
Publication date	2020 to August 2024	Studies published before 2020
Geographic scope	Studies conducted in Asia (relevant climatic contexts)	Studies from non-Asian (dissimilar climatic contexts)
Content relevance	Articles presenting simulation-based case studies, comprehensive reviews of such studies, and case studies focused on non-residential and new construction projects.	Articles or reviews without empirical data from case studies, or those focusing on residential buildings, town-scale developments, existing or retrofitted projects, unrelated building types, rating tool comparisons, or policy development.

The PRISMA flow diagram illustrating these steps is provided in Figure 1. This systematic approach ensures that the findings are rooted in a comprehensive and methodologically rigorous literature base.

**Figure 1.** PRISMA 2020 flow diagram adopted in this study

2.2 Thematic Analysis Using NVivo

Following the systematic review, thematic analysis was conducted to identify and classify sustainable building design criteria into relevant themes. NVivo software was employed for this process due to its robust capabilities in qualitative data analysis. NVivo allows for efficient coding of text data, enabling researchers to identify patterns, themes, and relationships within large datasets (Sorensen, 2008). Its visualization tools, such as cluster analysis and word frequency queries, further enhance the ability to synthesize complex information. The decision to use NVivo was driven by several factors as claimed by (Bakla, 2021):

a. **Flexibility in Data Management:** NVivo's interface supports diverse data types, including textual documents and PDFs, making it suitable for handling varied literature sources.

b. **Advanced Analytical Features:** The software provides powerful tools for identifying co-occurrences and relationships between coded data, facilitating the categorization of criteria into thematic clusters.

c. **Reproducibility:** NVivo ensures that the coding process is systematic and transparent, allowing for replication and validation of the findings.

During the thematic analysis, sustainable design criteria were first coded individually based on their explicit and implicit meanings. The coding process was conducted by the researcher as a single coder using a thematic analysis approach. To ensure consistency and dependability, a structured coding protocol was developed based on the research objectives and aligned with the phases of thematic analysis as outlined by Braun and Clarke (2006). An initial round of trial coding was conducted on a subset of the data to refine the coding framework. Throughout the process, iterative reflection, constant comparison, and memo-writing techniques were employed to ensure coding consistency and to capture the rationale behind theme development (Nowell et al., 2017; Saldaña, 2016). This approach helped ensure a clear and dependable analytical process, even though the coding was conducted by a single researcher. Subsequently, an inductive approach was used to identify the Design Factors for the analysis. The Design Factors in this study were derived directly from the data by analysing recurring patterns and similarities among the sustainable building design criteria, rather than relying on a pre-established framework. This bottom-up process enabled the categorization of criteria in a manner that corresponds with the building design process and mirrors practical priorities within Malaysia's green building landscape. Additionally, inductive reasoning is also well-suited to exploratory research aimed at producing context-specific findings (Thomas, 2006), particularly when prior research is limited or fragmented (Elo & Kyngäs, 2008).

As illustrated in Figure 2, the coding process identified the citations from previous literature and sustainable guidelines which then summarize into relevant design criteria categories. Then, the design criteria were grouped into 7 relevant main themes that were then coded as the Design Factors.
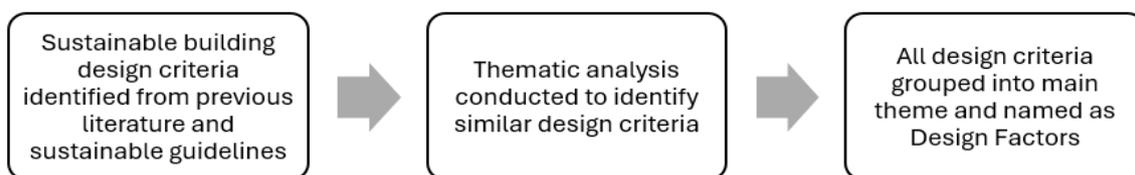
Figure 2. Design Factors identification process

2.3 Primary Sustainable Criteria

As different rating system uses different terminologies to describe the same criteria, Haapio and Viitaniemi (2008) claimed that the complexity of frameworks and their different structures may even make them impossible to compare. Similarly, as GBI and MyCREST are structured differently and have distinct sustainability requirements and credit criteria, the sustainable criteria aligning is challenging. Hence, a comparative analysis was performed to identify any overlaps, gaps, and key differences between the criteria outlined in GBI and MyCREST. This step involved mapping the criteria from both rating systems against

each other to establish a Primary Sustainable Criteria that represents the main sustainability theme. The comparative analysis has resulted in six primary criteria namely Energy Efficiency, Indoor Environmental Quality, Project Planning and Management, Material and Resource, Water Efficiency and Innovation. Table 2 lists the six proposed primary sustainable criteria descriptions, and Table 3 shows the mapping of the primary sustainable criteria with GBI and MyCREST.

Table 2. Description of the proposed primary sustainable criteria

Primary Sustainable Criteria	Description
Energy Efficiency	Focuses on reducing energy consumption and utilizing renewable energy sources to lower the building's carbon footprint.
Indoor Environmental Quality	Ensures occupant comfort and health through optimal air quality, lighting, thermal comfort, and acoustic performance.
Project Planning & Management	Encourages sustainable practices in project development, including efficient resource allocation and lifecycle management.
Material & Resource	Promotes the use of sustainable, recyled, or low-impact materials to reduce waste and environmental harm.
Water Efficiency	Aims to conserve water through efficient systems, rainwater harvesting, and wastewater reuse.
Innovation	Rewards creative and unique solutions that go beyond standard sustainability practices, and advancing environmental performance.

Table 3. Mapping of primary sustainable criteria from GBI and MyCREST

	GBI Criteria		MyCREST Criteria	Primary Sustainable Criteria
1	Energy Efficiency (EE)	3	Energy Performance Impacts (EP)	Energy Efficiency
2	Indoor Environmental Quality (EQ)	4	Occupant and Health (OH)	Indoor Environmental Quality
		10	Elective Points for Healthcare Buildings (EH)	
3	Sustainable Site Planning & Management (SM)	2	Infrastructure And Sequestration (IS)	Project Planning & Management
		7	Social and Cultural Sustainability (SC)	
		1	Pre-Design (PD)	
4	Material & Resource (MR)	5	Lowering Embodied Carbon (EC)	Material & Resource
		8	Demolition and Disposal Factors (DP)	
5	Water Efficiency (WE)	6	Water Efficiency Factors (WE)	Water Efficiency
6	Innovation (IN)	9	Sustainable Low Carbon Initiatives (IN)	Innovation

Finally, Microsoft Excel was utilized for the meta-analysis, which synthesized the quantitative data and provided a consolidated overview of the most critical and frequently cited sustainable building design criteria based on the primary sustainable criteria. The overall process of methodology adopted in this study is illustrated in Figure 3, and Table 4 presents the comprehensive data involved in the analysis, along with the aligned sustainable criteria.
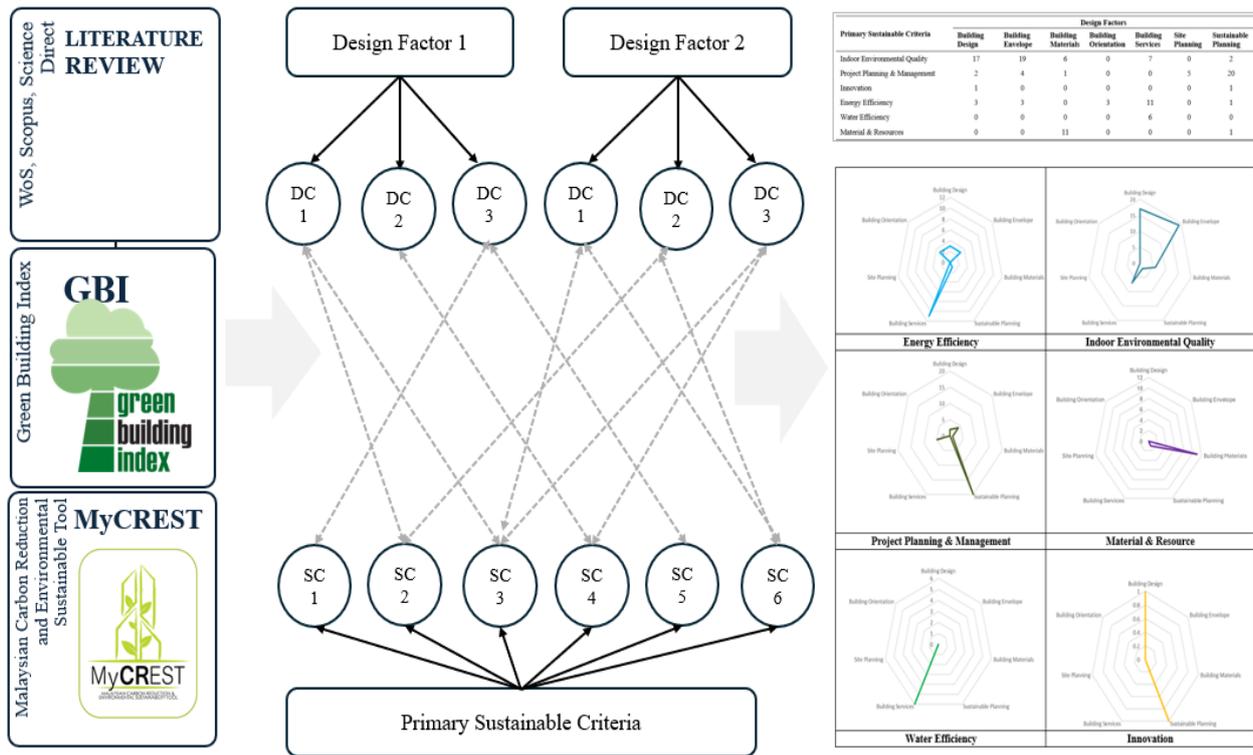
Figure 3. Infographic of the methodology adopted in this study.

Table 4: Alignment of Sustainable Building Design Criteria with Primary Sustainable Criteria

DESIGN FACTORS	DESIGN CRITERIA	REFERENCES	PRIMARY SUSTAINABLE CRITERIA
BUILDING ORIENTATION	Optimizing building orientation enhances daylighting effectiveness.	Guo & Bart (2020), Khahro et al. (2021), Nasrollahi & Shokry (2020)	Energy Efficiency
	Optimize building orientation to increase air change rate and improve resident's comfort	Zoure & Genovese (2022), MyCREST	Energy Efficiency
	Optimize building direction to the right orientation to reduce solar heat gain	Sun et al. (2021), Xu & Yuan (2022), Singh et al. (2022), Cui (2024), MyCREST	Energy Efficiency
BUILDING DESIGN	Walls for natural ventilation temperature must be higher than the dew point at the space	MyCREST	Indoor Environmental Quality
	Utilize BIM technology for designing	MyCREST	Project Planning & Management
	Use acoustical ceiling, furniture with sound-absorbing surfaces and insulate partition cavities.	MyCREST	Indoor Environmental Quality
	Provide high ratio of open space to development footprint to maximize open space	GBI	Indoor Environmental Quality
	Provide design strategies to	MyCREST	Indoor Environmental

minimise air leakage for the air-conditioned areas		Quality
Produce innovation and environmental design initiative	GBI, MyCREST	Innovation
Integrate the design with Culture and Heritage	MyCREST	Project Planning & Management
Enforce smoking restriction area	GBI, MyCREST	Indoor Environmental Quality
Design natural ventilation such as an "open system" to increase the wind-induced ventilation	MyCREST	Indoor Environmental Quality
Design for cross ventilation to provides ventilation to optimize thermal comfort	MyCREST	Indoor Environmental Quality
Design Clerestories or Vented Skylights to exhaust hot air	MyCREST	Indoor Environmental Quality
Use ventilated hollowcore slab systems (VHCS) to optimize thermal comfort and energy efficiency	Abed et al. (2024)	Energy Efficiency
Use underfloor air distribution system to reduces the energy use	Khahro et al. (2021)	Indoor Environmental Quality
Optimize mould prevention design using mechanical or natural ventilation techniques	GBI, MyCREST	Indoor Environmental Quality
Combine passive cooling and nighttime ventilation can improve thermal comfort	Guo et al. (2020)	Indoor Environmental Quality
Optimize window-to-wall ratio (WWR) and its orientation to enhance thermal comfort	Rana et al. (2020) Singh et al. (2022)	Indoor Environmental Quality
Optimize Window to wall ratio (WWR) to enhance the energy-efficiency of a building	Guo & Bart (2020), Nasrollahi & Shokry (2020)	Energy Efficiency
Narrow building geometry encourages the natural cross ventilation	Zoure & Genovese (2022)	Indoor Environmental Quality
Effective use of biomimicry design leads to optimum building thermal comfort.	Elsakksa et al. (2022)	Indoor Environmental Quality
Appropriate Window-to-floor ratio (WFR) can reduce energy consumption	Odiyur Vathanam et al. (2021), Xu & Yuan (2022)	Energy Efficiency
Appropriate window-to-floor ratio (WFR) to enhances daylight harvesting.	Odiyur Vathanam et al. (2021),	Indoor Environmental Quality
Appropriate building geometry is crucial for maximizing energy efficiency in design	Mohsenzadeh et al. (2021)	Indoor Environmental Quality
Avoid of cold air diffuser being near or directed to wall surfaces	MyCREST	Indoor Environmental Quality

BUILDING ENVELOPE	Provide high louvres or transoms to optimize building ventilation	MyCREST	Indoor Environmental Quality
	Reduce the building envelope area exposed to the solar heat	Xu & Yuan (2022)	Indoor Environmental Quality
	USE Double skin façade (DSF) to improve building thermal performance	Lim & Ismail (2023).	Indoor Environmental Quality
	Use wooden insulation frame for window to reduce the heat gain	Khahro et al. (2021)	Indoor Environmental Quality
	Use white reflective coating to reduce the heat gain	Ho et al. (2023), MyCREST	Indoor Environmental Quality
	Use thermal insulation walls to reduce cooling energy demand	Bughio et al. (2021), Ng et al. (2022)	Energy Efficiency
	Use solar wall to optimize energy-saving potential	Ghamari & Sundaram (2024)	Energy Efficiency
	Use roof material with a low roof U-value to avoid higher heat transfer	MyCREST	Project Planning & Management
	Use reflective materials to avoid excessive heat gain	Nasrollahi & Shokry (2020), Cui (2024), MyCREST	Indoor Environmental Quality
	Use photovoltaic integrated shading devices (PVSD) to optimize daylighting condition	Oh et al. (2023)	Indoor Environmental Quality
	Use operable window to optimize building ventilation	GBI, MyCREST	Indoor Environmental Quality
	Use horizontal and vertical louvers to optimize natural cross-ventilation	Rahimi & Hassanzadeh (2024)	Indoor Environmental Quality
	Use hollow foamed concrete roofing tile to reduce the heat gain	Ho et al. (2023)	Indoor Environmental Quality
	Use high efficiency glazing to provide good daylight harvesting and reduce heat gain	Odiyur Vathanam et al. (2021), Singh et al. (2022), Altuhaf et al. (2023), MyCREST	Indoor Environmental Quality
	Use high efficiency materials for walls and window	Lohwanitchai & Jareemit (2021), Singh et al. (2022), Bughio et al. (2021), Shen, & Sun (2023)	Indoor Environmental Quality
	Use green roof to reduce heat island effect	Cui (2024), Rahman et al. (2023), GBI	Project Planning & Management
	Use green envelopes to decrease indoor air temperature	Pragati et al. (2023)	Indoor Environmental Quality
	Use green envelope to reduce energy consumption	Pragati et al. (2023)	Energy Efficiency
	Provide shading system for wall to prevent excessive heating and minimize energy consumption	Huo et al. (2020), Samadi et al. (2020), Singh et al. (2022), Nazari et al. (2023), Cui (2024), Oh et al. (2023), GBI, MyCREST	Project Planning & Management

	Provide roof shading system to reduce solar radiation and indoor temperature	Zoure & Genovese (2022), MyCREST	Project Planning & Management
	Provide roof light and atrium space to optimize daylight	MyCREST	Indoor Environmental Quality
	Provide long distance outdoor views to optimize external view of occupants	GBI, MyCREST	Indoor Environmental Quality
	Optimize window design such as geometry and size to maximize daylight distribution.	Odiyur Vathanam et al. (2021), Nasrollahi & Shokry (2020), Arsad et al. (2023), MyCREST	Indoor Environmental Quality
	Minimize wall area expose to the air to reduce heat gain	Xu & Yuan (2022)	Indoor Environmental Quality
	Combining solar wall with water spraying system can lower the indoor temperatures	Ghamari & Sundaram (2024)	Indoor Environmental Quality
	Combine solar wall with insulation and shading curtains to optimize indoor temperature	Ghamari & Sundaram (2024)	Indoor Environmental Quality
BUILDING MATERIALS	Use zero Ozone Depleting Potential (ODP) products non-CFC and non-HCFC refrigerants agents	GBI	Indoor Environmental Quality
	Use sustainable Timber Sources	GBI, MyCREST	Material & Resource
	Use non-synthetic (natural) refrigerants agents with zero ODP	GBI	Indoor Environmental Quality
	Use materials that can be recycled	Ng et al. (2022), GBI, MyCREST	Material & Resource
	Use IBS components	MyCREST	Project Planning & Management
	Use green products listed in the JKR or SIRIM Standard	MyCREST	Material & Resource
	Use local building material to reduce the environmental impacts resulting from transportation	Bughio et al. (2021), Xu et al. (2024), GBI, MyCREST	Material & Resource
	Reuse building materials to reduce demand for virgin materials and reduce creation of waste.	GBI, MyCREST	Material & Resource
	Reduce the Release of Persistent Bio-Accumulative and Toxic Chemicals (PBTs) associated with the Life Cycle of Building Materials	MyCREST	Indoor Environmental Quality
	Provide the Calculation of Embodied Carbon for	MyCREST	Material & Resource

	Construction Components of Assembly Materials		
	Provide Materials Life Cycle Analysis to verify the environmental emissions	MyCREST	Material & Resource
	Provide dedicated area and storage for collection of non-hazardous materials	GBI, MyCREST	Material & Resource
	Use nanomaterials to reduces carbon emissions	Konbr & Mamdouh (2022)	Material & Resource
	Use Aerated Concrete Block (ACB) to minimize heat transfer	Jannat et al. (2020)	Material & Resource
	Optimize wall material thickness to increase thermal performance and decreased cooling load.	Jannat et al. (2020)	Material & Resource
	Use materials free from urea formaldehyde to optimize indoor air quality	GBI	Indoor Environmental Quality
	Use low VOC materials to optimize indoor air quality	GBI, MyCREST	Indoor Environmental Quality
	Use high-efficiency internal wall material	Shen, & Sun (2023)	Indoor Environmental Quality
BUILDING SERVICES	Use of sub-meters to monitor and manage major water usage	GBI	Water Efficiency
	Use an acceptable multi-zonal analysis tool to calculate the air change and predict comfort in buildings.	MyCREST	Indoor Environmental Quality
	Provide fan-assisted cooling strategies to reduce internal heat gain	Knudsen et al. (2023), Gokarakonda et al. (2023), Guo et al. (2023), MyCREST	Energy Efficiency
	Link all water sub-meters to EMS to facilitate early detection of water leakage	GBI, MyCREST	Water Efficiency
	Install Indoor Monitoring System with CO_2 Sensor	MyCREST	Indoor Environmental Quality
	Implement Environmental Management System	MyCREST	Indoor Environmental Quality
	Encourage water recycling to reduce potable water consumption	GBI, MyCREST	Water Efficiency
	Encourage the system design	GBI, MyCREST	Water Efficiency

|			
	to reduce potable water supply consumption		
	Encourage reduction in potable water consumption by using efficient devices	GBI, MyCREST	Water Efficiency
	Encourage rainwater harvesting to reduce potable water usage	GBI, MyCREST	Water Efficiency
	Use occupancy sensors to reduce energy consumption	Odiyur Vathanam et al. (2021), GBI, MyCREST	Energy Efficiency
	Use high energy-efficiency lighting and equipment	Lohwanitchai & Jareemit (2021), MyCREST	Energy Efficiency
	Use high frequency ballasts in fluorescent lighting	GBI	Indoor Environmental Quality
	Use high energy-efficiency cooling system	Lohwanitchai & Jareemit (2021), MyCREST	Energy Efficiency
	Use daylight sensors to reduce energy use	Khahro et al. (2021), MyCREST	Energy Efficiency
	Record and document the electricity bills during the entire construction period.	MyCREST	Energy Efficiency
	Provide Thermal Comfort System to optimize thermal comfort	GBI	Indoor Environmental Quality
	Provide sub-metering for all energy uses	GBI, MyCREST	Energy Efficiency
	Provide individual switched lighting zones	GBI, MyCREST	Energy Efficiency
	Provide Energy Management Control System	GBI, MyCREST	Energy Efficiency
	Provide carbon dioxide monitor	GBI, MyCREST	Indoor Environmental Quality
	Provide Air Flushing System to optimize indoor air quality	GBI	Indoor Environmental Quality
	Use windcatcher to optimize indoor temperatures	Nejat et al. (2024)	Energy Efficiency
	Optimize the uses of renewable energy	GBI, MyCREST	Energy Efficiency

SITE PLANNING	Plant new vegetation on 20% of the site area	MyCREST	Project Planning & Management
	Locate the building close to existing infrastructure to preserve natural resources and reduce CO2 impact by transportation sector.	GBI, MyCREST	Project Planning & Management
	Integrate Shaded Trees Within 5 Meters from the Building Parameter	MyCREST	Project Planning & Management
	Encourage using rehabilitating site to reduce pressure on undeveloped land	GBI, MyCREST	Project Planning & Management
	Avoid using forbidden land area for building development	GBI	Project Planning & Management
SUSTAINABLE PLANNING	Use staging and spill prevention to restrict the spilling of contaminated materials on site	MyCREST	Project Planning & Management
	Provide Quality Assessment System for Building Construction Work (QLASSIC) assessment to ensure workmanship quality	GBI, MyCREST	Project Planning & Management
	Provide Preferred parking for carpools vehicles.	GBI, MyCREST	Project Planning & Management
	Provide parking space for fuel-efficient vehicle to encourage green vehicle usage	GBI	Project Planning & Management
	Provide a Sustainable Facilitator from project team	GBI, MyCREST	Innovation
	Provide greenery strategies and conservation of trees	MyCREST	Project Planning & Management
	Provide emission reporting for construction machinery and transportation within the site.	MyCREST	Project Planning & Management
	Provide Commissioning Engineer to review the installed system	GBI	Energy Efficiency
	Provide at least the minimum level of sanitation or safety facilities for construction workers	MyCREST	Project Planning & Management
	Involve Facility Management input during the development of the project design	MyCREST	Project Planning & Management
	Incorporate sustainable assessment budget in the total construction cost	MyCREST	Project Planning & Management
	Incorporate sustainable building and carbon reduction objectives in a project's brief	MyCREST	Project Planning & Management

Implement IAQ management plan for construction and preoccupancy phase	MyCREST	Indoor Environmental Quality
Implement a Site Amenities Plan for all construction workers to minimize pollution	GBI	Project Planning & Management
Establish oil interceptors at all drains from parking areas and central plant areas	MyCREST	Project Planning & Management
Establish a construction waste management plan	GBI, MyCREST	Material & Resource
Ensure proper timing for the construction activity to minimise site disturbance	MyCREST	Project Planning & Management
Document the existing environmental features and greenery	MyCREST	Project Planning & Management
Develop an Erosion and Sedimentation Control (ESC) Plan for all construction activities	GBI, MyCREST	Project Planning & Management
Develop a storm water management plan	GBI, MyCREST	Project Planning & Management
Conduct at least one full day of the eco-charrette workshop with the project team	MyCREST	Project Planning & Management
Conduct assessment of environmental impact	MyCREST	Project Planning & Management
Choose contractor with good track records in the adoption of green during construction.	MyCREST	Project Planning & Management
Assess the health and safety conditions on the construction site using SHASSIC score	MyCREST	Project Planning & Management
Appoint Safety, Health, and Environment Officer	MyCREST	Indoor Environmental Quality

3.0 RESULT AND DISCUSSIONS

3.1 Publications Trends
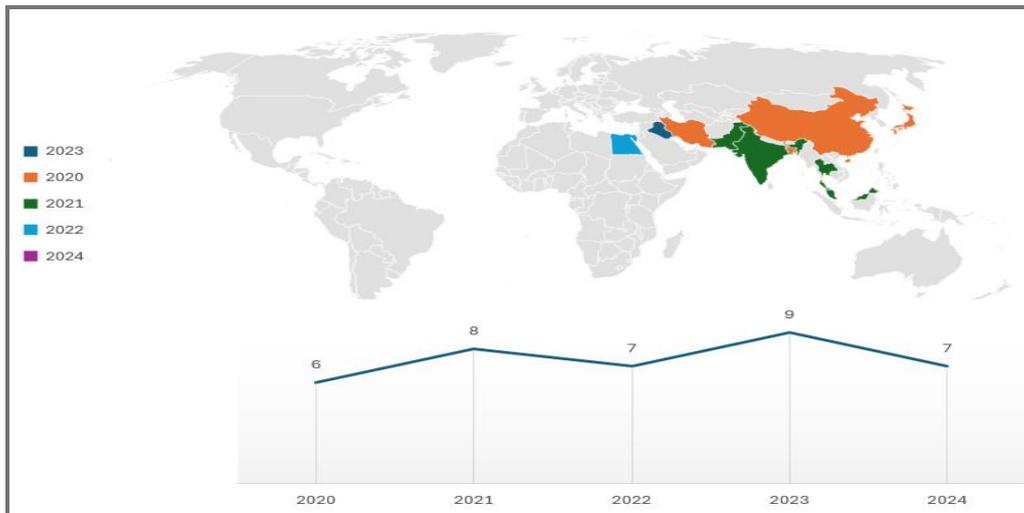
Figure 4. Regional and Temporal Trends in Sustainable Building Research (2020–2024)

Figure 4 illustrates the geographic and temporal distribution of peer-reviewed publications related to sustainable building across selected Asian countries from 2020 to 2024. The map uses a color-coded scheme where each country is shaded according to the year of publication of the relevant study. For instance, countries shaded in orange represent publications from 2020, green for 2021, blue for 2022, and purple for 2024. This coloring highlights the dominant or most recent year of research activity for each country in the dataset.

The data reveals a steady increase in research output, with a notable peak in 2023 (9 publications). Countries such as China, Iran, Japan and Bangladesh (shaded in orange) emerged as early contributors in 2020, while other Southeast Asian countries showed consistent engagement from 2021 onwards. The presence of multiple countries shaded in recent years (2023 and 2024) suggests growing momentum in sustainable building research across the region. This upward trend reflects an increasing academic focus on sustainable building research, especially in rapidly urbanizing countries with hot and humid climates

3.2 Design Factors of Sustainable Building Design Criteria

The thematic analysis process as illustrated in Figure 2 has resulted in 7 Design Factors for sustainable building design namely Building Orientation, Building Design, Building Envelope, Building Materials, Building Services, Site Planning and Sustainable Planning. Table 5 shows the lists of the Design Factors, the corresponding Design Criteria, and the number of citations each Design Factor has received.

Table 5. Design Factors identified from the thematic analysis

Design Factors	Design Criteria	Number of Citation
Building Orientation	3	10
Building Design	23	29
Building Envelope	26	51
Building Materials	18	27
Building Services	24	42
Site Planning	5	7
Sustainable Planning	25	31

The result shows that the Building Envelope design factor has the highest number of citations (51) and 26 design criteria. This suggests that it is a critical component of sustainable building design, likely due to its impact on energy efficiency, thermal comfort, and weather protection, as demonstrated in several studies highlighting the role of building envelopes and passive design strategies in enhancing environmental performance (Kitsopoulou et al., 2024; Verma & Rakshit, 2023). Building Services ranks second in terms of citations (42) with 24 design criteria, indicating its significant role in sustainability as it includes systems such as HVAC, electrical, and plumbing, which are essential for the operational efficiency of sustainable buildings. Sustainable Planning follows closely with 31 citations and 25 design criteria, emphasizing the importance of holistic, long-term planning in sustainable design, while Building Design and Building Materials have 29 and 27 citations respectively, reflecting the importance of these factors in influencing a building's environmental footprint and resource use. Building Orientation and Site Planning are less cited, with 10 and 7 citations respectively, despite their fundamental role in passive design strategies that optimize the use of natural resources like sunlight and wind.

The distribution of citations suggests that Building Envelope and Building Services are currently the most researched and emphasized factors in sustainable building design. This could be due to their direct influence on energy consumption and operational efficiency, which are key concerns in reducing the carbon footprint of buildings. On the other hand, Site Planning and Building Orientation, though fundamental to passive design strategies, appear to receive less attention. This might indicate a gap in the literature or a need for greater focus on these areas, as they play a crucial role in reducing the need for mechanical systems and maximizing natural resources.

Overall, the analysis suggests that while technical systems like the building envelope and services are prioritized, there is room to explore and emphasize the importance of planning and orientation in sustainable building practices.

3.3 Alignment of Design Factors and Primary Sustainable Criteria in Sustainable Rating System

This analysis will provide insight into how the key physical and planning elements contribute to the sustainability design criteria outlined in the sustainable rating systems as detailed in Table 4. Table 6 provides a summary of the alignment between the Design Factors identified from 37 publications and two sustainability guidelines, and the Primary Sustainable Criteria derived from the mapping of GBI and MyCREST. Complementing this, Figure 5 presents the same information in a visual format using radar charts, allowing for a clearer comparison of how each Design Factor contributes to the respective Primary Sustainable Criteria.

Table 6. Summary of Design Factors and Primary Sustainable Criteria Alignment

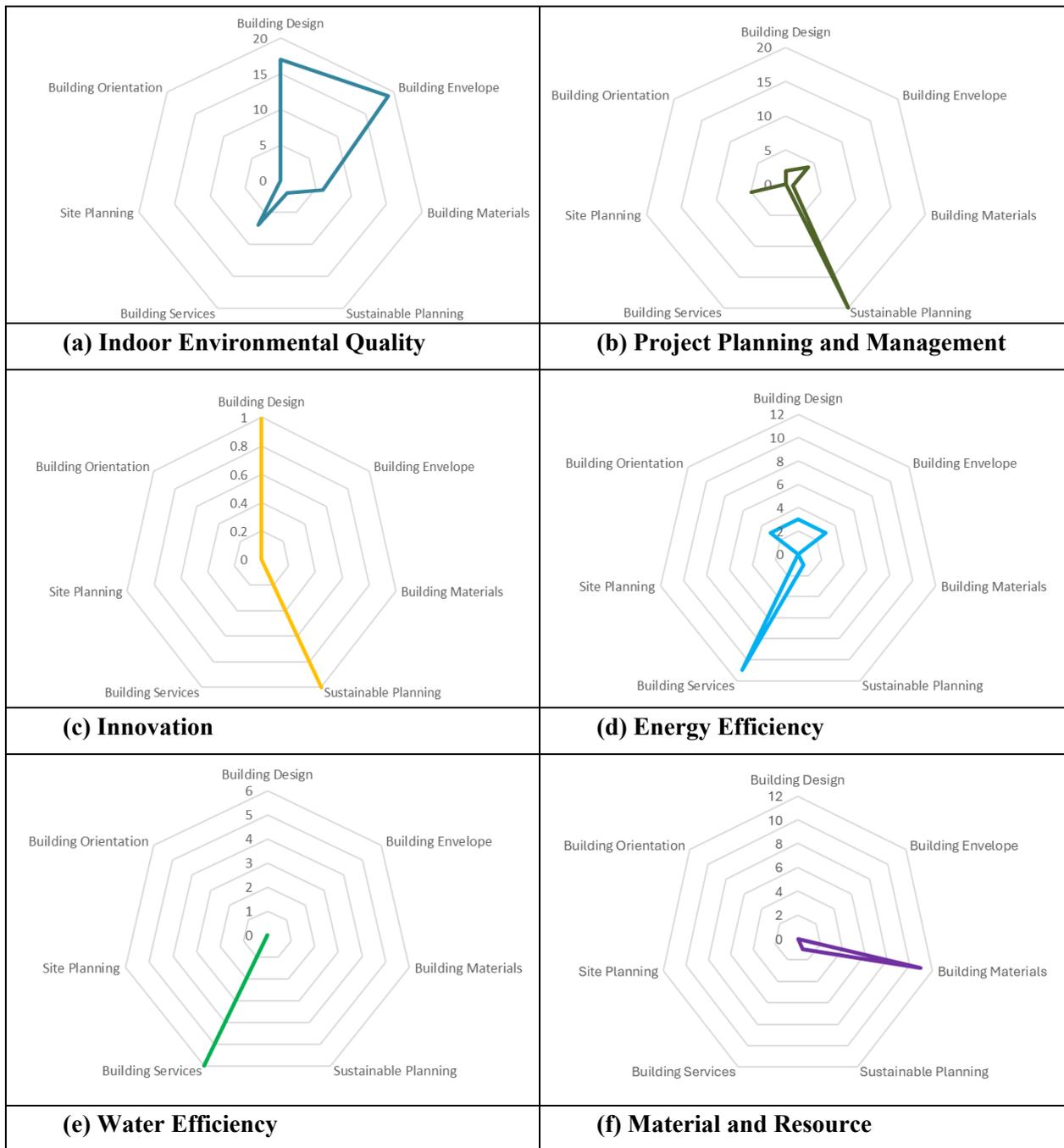| Primary Sustainable Criteria	Design Factors						
	Building Design	Building Envelope	Building Materials	Building Orientation	Building Services	Site Planning	Sustainable Planning
Indoor Environmental Quality	17	19	6	0	7	0	2
Project Planning and Management	2	4	1	0	0	5	20
Innovation	1	0	0	0	0	0	1
Energy Efficiency	3	3	0	3	11	0	1
Water Efficiency	0	0	0	0	6	0	0
Material and Resources	0	0	11	0	0	0	1

Figure 5. Comparison of Design Factor for each Primary Sustainable Criterion.

3.3.1 Indoor Environmental Quality

As shown in Table 6 and Figure 5a, Indoor Environmental Quality indicates a balance focus from previos literatures and sustainable rating systems across several Design Factors with particular emphasis on the Building Envelope and Building Design. The focus on Building Envelope (19) and Building Design (17) indicate that building envelope and design are crucial for controlling air quality, lighting, visual, acoustic and thermal comfort, and they play important roles in maintaining the indoor environmental quality of a building.

According to Ahmad et al. (2021), the building envelope regulates heat transfer between the interior and exterior, which directly influences thermal comfort by reducing unwanted heat gain or loss. Moreover, it controls air infiltration and supports natural or mechanical ventilation strategies, thereby impacting indoor air quality by limiting the entry of outdoor pollutants and ensuring adequate fresh air circulation (GBI, 2009; CIDB, 2020).

This is supported by the findings from previous literature, where Xu and Yuan (2022) and Bano and Sehgal (2020) found that by reducing the wall area exposed to the solar heat, it can improve the building's thermal comfort. Similarly, Odiyur Vathanam et al. (2021), Singh et al. (2022), Altuhaf et al. (2023), and Lazar and Raveendran (2024) found that building's thermal comfort can be optimized by using high efficiency glazing for the building envelope. Guo et al. (2020) also demonstrated that integrating passive cooling techniques with nighttime ventilation strategies improves thermal comfort conditions. In a different approach, Rahman et al. (2022) concluded that green roofs exhibit significantly lower surface temperatures compared to conventional flat roofs.

As for the allignment with the requirement in the both GBI and MyCREST, these sustainable rating systems have emphasize the indoor environmental quality as a crucial factor for occupant health and well-being which includes ventilation, thermal comfort, and indoor air quality. This finding has reflected this alignment, where strong focus on Indoor Environmental Quality aligns well with both GBI and MyCREST. Therefore, necessary attention is needed in designing the building envelope and building system design since they will affect the ventilation, lighting, and thermal comfort in achieving higher sustainability ratings.

In addition to that, attention to building services, such as ventilation systems, is also critical in this context, as the Building Services factor (7) contributes to the operation and management of HVAC systems, which are essential for maintaining indoor air quality. HVAC systems play a direct role in controlling temperature, humidity, and the dilution of indoor pollutants, thereby significantly influencing both air quality and occupant comfort (Yang et al., 2020). This finding highlights the understanding that not only the design and envelope but also the performance of mechanical systems contributes to indoor environmental quality.

Taken together, the design team should prioritize Building Design, Building Envelope, and Building Services to optimize Indoor Environmental Quality for a building. These elements play a critical role in ensuring occupant health and comfort, which are fundamental to achieving sustainability goals. By focusing on these areas, designers can better allign with the stringent requirements set by green building rating systems such as GBI and MyCREST, thereby enhancing both environmental performance and the well-being of building occupants.

3.3.2 Project Planning and Management

As shown in Table 6 and Figure 5b, Project Planning and Management places strong emphasis on Sustainable Planning (20), primarily based on the criteria extracted from the sustainable rating systems as detailed in Table 4. This indicates a high level of attention to construction management, transportation planning, and long-term strategic site planning within the GBI and MyCREST frameworks. However, this emphasis was not strongly reflected in the reviewed literature, where Sustainable Planning was less frequently addressed. This discrepancy suggests that while Sustainable Planning is structurally prioritised in the rating systems, it may be underexplored or underreported in academic research, highlighting a potential gap that future studies could address.

The findings of this review indicate that the dominant aspects under the Sustainable Planning criterion are construction-phase environmental management, integration of sustainability objectives during early project planning, and the health, safety, and welfare of construction workers. Construction-phase environmental management emerged most frequently, with practices such as erosion and sediment control, emission reporting, site spill prevention and stormwater planning being commonly addressed. These measures are essential for minimising environmental impact and maintaining compliance throughout the construction process. In addition, several sources emphasised the early integration of sustainability such as including sustainability goals in the project brief, allocating dedicated sustainability budgets, and involving facility management and sustainability facilitators at the design stage. Worker welfare was also a recurring priority, highlighted through criteria like sanitation facilities, SHASSIC scoring, and the appointment of Safety, Health, and Environment (SHE) officers reflecting the focus on social sustainability within green construction practices.

Sustainable planning is also widely recognised in the literature as a foundational element for achieving long-term environmental performance and social responsibility in the built environment. Effective sustainable project planning not only mitigates environmental degradation but also ensures that sustainability objectives are embedded early in the project lifecycle and ensure success in construction project (Yu et al.,

2018). Recent literature confirms that insufficient planning during pre-construction contributes to inefficiencies, elevated carbon emissions in the construction phase, and missed opportunities for sustainable innovation (Wang et al., 2023). Overall, these findings reinforce the significance of sustainable planning in achieving measurable green building outcomes.This also supported by previous research, where Stanitsas et al. (2021) explored the integration of sustainability indicators into construction project management practices, and they emphasized the need for significant efforts to incorporate sustainability considerations into every project. Therefore, its importance underscores the need for designers to focus on this area to align with the sustainability standards set by these rating systems. By emphasizing these areas, designers can better understand how to incorporate long-term sustainability considerations into their projects, reducing environmental impact and improving project execution in line with the national sustainable rating system.

As for the allignment with the requirement in the both GBI and MyCREST, many of the sustainable planning criteria identified in this review are already well-represented in MyCREST, particularly under the Pre-Design (PD) , Infrastructure and Sequestration (IS), Occupant and Health (OH) and Social and Cultural Sustainability (SC). However, these aspects are less explicitly addressed in the GBI Non-Residential New Construction (NRNC) tool, particularly within the Sustainable Site Planning & Management (SM) section. This reveals a potential opportunity for GBI to enhance its framework by integrating practices such as emission tracking, formal IAQ control plans, early stakeholder involvement, and sustainable procurement processes.

3.3.3 Innovation

Innovation presents an area where current sustainable design practices could benefit from greater engagement with advanced technologies, novel materials, and creative design processes. While both GBI and MyCREST provide additional credits for the integration of innovative strategies that enhance sustainability, the findings of this review (Table 6 and Figure 5c) reveal that innovation is consistently underrepresented across most Design Factors and Primary Sustainable Criteria. No innovation-related criteria were identified in the 37 reviewed publications, and only two criterias emerged from sustainble guidelines which alligned under Buiding Design (1) and Sustainable Planning (1) factor, indicating a limited focus on innovation within current research as detailed in Table 4. This outcome may be partly attributed to the fact that both GBI and MyCREST include only minimal references to innovation design process rather than materials and technologies innovation where GBI focuses on the appointment of a GBI Facilitator and the inclusion of innovative or environmental design initiatives, while MyCREST refers to the appointment of a MyCREST Facilitator and the introduction of technological advancements to improve building performance. Since only the criteria from GBI and MyCREST were identified in the alignment process, this limited emphasis on innovation within both frameworks may have contributed to the absence of materials and technologies innovation-related alignment across the Primary Sustainable Criteria.

Although technologies innovation-related practices such as BIM, advanced materials, and improved processes are widely discussed in the broader sustainability literature, they were not identified as standalone innovation criteria in the alignment process. This may be due to redundancy in how innovation is categorised within both the literature and sustainability frameworks. For example, technological innovations like BIM are recognised in MyCREST, but appear under Pre-Design (PD) rather than within the Innovation (IN1 and IN2) categories. Similarly, material innovations (e.g., recycled, low-carbon materials or bio-based products) are often categorised under the Material and Resource (MR) category in GBI, and Lowering Embodied Carbon (EC) category in MyCREST. For example, Konbr and Mamdouh (2022) utilised nanomaterials to reduce emissions, Lee et al. (2021) applied lower-density concrete to regulate indoor temperature, and Fereidoni et al. (2023) demonstrated how fibre cement panels can improve energy efficiency. However, these findings were categorised under the Materials and Resources criterion, as they align more closely with the objectives and scope of that category. As a result, innovation may be underrepresented not due to its absence, but because it is embedded within other primary criteria. This overlap suggests a need for greater clarity in how innovation is defined, labelled, and scored in both green building rating frameworks.

Despite the observed redundancy in how innovation is categorised within rating systems, practitioners should adopt a combination of technological, material, and process-oriented strategies to enhance innovation in sustainable building design. Doing so not only improves project outcomes but also positions projects for higher recognition within green building rating frameworks. One of the most impactful technological tools is

Building Information Modelling (BIM), which supports early-stage sustainability analysis, clash detection, energy modelling, and real-time collaboration across disciplines. By integrating BIM with green building rating systems, design teams can better align their proposals with sustainability criteria and identify opportunities for performance optimisation. Ur Rehman et al. (2022) found that the integration of BIM and green rating systems enables designers to simulate and predict building performance more accurately, leading to better sustainability outcomes. In addition to digital tools, practitioners are also encouraged to adopt advanced materials such as low-carbon concrete, bio-based insulation, and recycled content products, which enhance environmental performance while introducing material innovation. Although innovation currently carries low scoring weight in both GBI and MyCREST, its proven impact on sustainable outcomes suggests that rating bodies should consider expanding and elevating the role of innovation in future revisions of their frameworks.

3.3.4 Energy Efficiency

For Energy Efficiency (Figure 5d), it can be seen that this criteria is mostly driven by Building Services design factor (11) suggesting that HVAC systems, lighting, and other operational aspects are considered essential in achieving energy efficiency. This criterion is derived from a balanced focus from both the reviewed literature and the sustainable rating systems, where many studies have explored the impact of building services on energy performance. For example, Lohwanitchai and Jareemit (2021) explore the use of high energy-efficiency lighting and equipment, Odiyur Vathanam et al. (2021) explore the use of occupancy sensors, and Khahro et al. (2021) explore the use of daylight sensors in attempt to reduce the energy consumption and optimize the energy efficiency of a building, and all of them have succeeded and proven that the building services element can enhance the Energy Efficiency criteria. In contrast, Chohan et al. (2024) investigates the use of renewable energy which is windcatcher to reduce the energy consumption and the result was positive. Same goes with the requirement in the both GBI and MyCREST where the Energy Efficiency become the core criterion for both rating system. They emphasized the Energy Efficiency criteria through promoting the lighting zoning, sub-metering, sensor and monitoring systems and renewable energy. Therefore, this result indicates that the designers should prioritize the Building Services elements in fulfilling the energy efficiency requirements to obtain more credit in sustainable rating system.

However, Energy Efficiency is only partially aligned with the goals outlined in GBI and MyCREST. While the emphasis on Building Services aligns well with the need to reduce operational energy use, there is a notable gap in passive design measures, such as optimising building orientation, incorporating external shading devices into building envelopes, and facilitating natural ventilation. These strategies are critical because they reduce energy demand at the source, thereby lowering reliance on mechanical systems. Passive approaches are also widely recognised as fundamental to sustainable building design, particularly in hot and humid climates like Malaysia, where controlling solar heat gain and enhancing natural airflow are key to maintaining indoor thermal comfort (Kolani et al., 2023). Strengthening the integration of these passive elements would improve alignment with both the Energy Efficiency (EE) criterion in GBI and the Energy Performance Impact (EP) category in MyCREST. While both frameworks acknowledge energy efficiency, their implementation guidance tends to favour active solutions such as HVAC optimisation and lighting controls over passive architectural strategies. This imbalance may lead to over-reliance on energy-intensive technologies and missed opportunities for performance improvements through design innovation.

Therefore, designers may adopt a dual approach that combines passive energy-saving strategies with active building services systems, ensuring energy reduction is addressed both at the source and through system efficiency. This integrated, performance-based strategy not only aligns more effectively with green building rating requirements but also supports long-term sustainability goals, enhances occupant comfort, and contributes to lower operational costs and reduced environmental impact over the building's lifecycle.

3.3.5 Water Efficiency

As illustrated in Figure 5e, Water Efficiency criterion is solely driven by the Building Services design factor (6), suggesting that strategies such as high-efficiency water fixtures, sub-metering, water recycling, and rainwater harvesting optimisation are critical to achieving water efficiency. However, unlike Energy Efficiency, this criterion was derived exclusively from the sustainable rating systems, with no related criteria identified in the reviewed literature, as highlighted in the SLR. This indicates that Water Efficiency has received limited academic attention, leaving it largely underexplored in current research.

In terms of alignment with GBI and MyCREST, both sustainable rating systems emphasise Water Efficiency as a key component of sustainable building design. GBI addresses Water Efficiency through its Water Efficiency (WE) category, which promotes the reduction of potable water use and encourages the installation of water-efficient fixtures, along with the reuse of rainwater and greywater. Points are awarded for strategies such as low-flow fixtures, rainwater harvesting systems, and water-efficient landscaping. Similarly, MyCREST places significant emphasis on water conservation in its Water Efficiency Factors (WE) category, promoting the use of technologies that reduce water consumption and improve sustainability throughout the building's lifecycle. Additionally, MyCREST advances further by integrating carbon reduction strategies related to water use, linking water efficiency to broader environmental performance goals.

However, despite this emphasis within both frameworks, the dataset reveals that Water Efficiency is not thoroughly addressed across many design factors, indicating a gap in integrated water-focused design strategies. Although both GBI and MyCREST include Water Efficiency as a standalone category, the low scoring weight (10% for GBI and 7% for MyCREST) and its limited integration across design-related criteria may reflect a structural shortcoming within the rating frameworks themselves, potentially contributing to its underrepresentation in actual design considerations. This finding is further supported by a review conducted by Yadegaridehkordi et al. (2020), which found that Water Efficiency was perceived as one of the least important criteria in green building assessment in Malaysia. In contrast, Shad et al. (2017) developed an assessment tool for green buildings in Iran and identified Water Efficiency as the most important factor in their local sustainable building context. However, they also observed that many countries tend to overlook this criterion as a critical component in building assessment procedures.

This underrepresentation may stem from a combination of factors, including the low weighting of Water Efficiency in both GBI and MyCREST, its limited integration across various design factors, and a general lack of emphasis in academic literature. In light of this, it is important for designers to reconsider the role of water efficiency, to ensure that related strategies extend beyond building services to include aspects such as site planning, material selection, and overall design orientation. A more holistic approach would not only enhance alignment with the requirements of GBI and MyCREST, but also can contribute to long-term environmental performance, water conservation, and higher sustainability ratings.

3.3.6 Material and Resource

Similar to Water Efficiency, the Material and Resource is solely driven by the Building Materials design factor (11), and as illustrated in Figure 5f, this criterion is also underutilised across key Design Factors. While this criterion reflects a balanced focus from both the reviewed literature and the sustainable rating systems, its application appears narrowly concentrated. Despite its foundational role in sustainability, Material Selection plays a minimal role in the current analysis. For example, numerous researchers have highlighted the benefits of sustainable material choices. For instance, Bughio et al. (2021) and Xu et al. (2024) argued that locally sourced materials can significantly reduce environmental impacts associated with transportation, and this criteria also highlighted in GBI and MyCREST rating systems. Jannat et al. (2020) suggest to optimize wall material thickness to increase thermal performance and decreased cooling load, and Konbr and Mamdouh (2022) claimed that use nanomaterials can reduces the carbon emissions. In terms of alignment with sustainable rating systems , GBI promotes strategies such as reuse and recycling, the use of sustainable resources, and the selection of certified green products through the Material and Resource (MR) category. Similarly, MyCREST promotes the use of low-impact materials under its Lowering Embodied Carbon (EC) category, encouraging decisions that minimise environmental burdens across the building's lifecycle.

However, despite this emphasis within both frameworks and previous literatures, the dataset reveals that Water Efficiency is not thoroughly addressed across many design factors, indicating a gap in integrated water-focused design strategies. The underrepresentation of Material and Resource considerations across design factors may be attributed to a combination of overlapping challenges. First, there may be a lack of research focus on material sustainability, as sustainability literature and green building priorities have historically emphasised operational energy performance such as HVAC and lighting efficiency over embodied energy and material impacts. Second, there are clear challenges in implementation, particularly in assessing the full environmental impact of materials. Life cycle assessment (LCA), embodied carbon

calculations, and supply chain transparency require detailed data and specialised tools that may not be readily accessible or prioritised during typical design workflows. Finally, there appear to be shortcomings in how the rating systems emphasise material sustainability, with relevant criteria fragmented across categories such as recyclability, local sourcing, or low-carbon materials, rather than being framed as part of an integrated, holistic strategy. This fragmentation within the frameworks may reduce the visibility and perceived importance of material-related sustainability. As a result, Material and Resource sustainability remains underrepresented in broader building design integration.

Therefore, to strengthen material sustainability in building design, it is important that designers move beyond a narrow focus on operational energy performance and place greater emphasis on the environmental impacts of materials. This involves exceeding the minimum requirements of green building rating systems by prioritising material choices that offer lower embodied carbon, local availability, and long-term environmental benefits. Meaningful collaboration with suppliers and consultants during the specification stage can improve access to reliable data and support more informed decision-making. Furthermore, designers should advocate for greater alignment across rating system categories by recognising that material strategies are closely linked to other sustainability domains, including energy use, waste management, and indoor environmental quality. An integrated approach of this kind can enhance both the design outcome and its alignment with broader sustainability goals.

4.0 CONCLUSIONS

This study has provided a comprehensive analysis of the alignment between sustainable design criteria with Malaysia's two leading green building rating systems: The Green Building Index (GBI) and the Malaysian Carbon Reduction and Environmental Sustainability Tool (MyCREST). By closely examining the sustainable Design Factors obtained from previous literatures and the sustainable guidelines, the results reveal strong alignment in Indoor Environmental Quality and Project Planning & Management, while also identifying areas for improvement in Energy Efficiency, Material and Resource, Water Efficiency and Innovation.

The findings also address the key challenge faced by designers which is the confusion caused by the variety of sustainable rating systems available in Malaysia. This study contributes to alleviating that confusion by offering a clear framework for aligning sustainable design practices with the most relevant criteria from GBI and MyCREST, thus providing clarity on which areas should be prioritized to achieve optimal sustainability performance across both systems.

As evidenced by the results of this study, several conclusions can be drawn:

a. Indoor Environmental Quality demonstrates strong alignment, particularly through the Design Factors of Building Design, Building Envelope, and Building Services. These factors are well-supported in both GBI and MyCREST requirements for maintaining occupant health and comfort, serving as a crucial guideline for designers seeking to meet sustainability goals in this category.

b. Project Planning & Management also shows robust alignment with the Design Factors, particularly in Sustainable Planning and Site Planning. By emphasizing these factors, designers can better understand how to incorporate long-term sustainability considerations into their projects, reducing environmental impact and improving project execution in line with national standards.

c. For Energy Efficiency, while aligned in terms of Building Services, it shows a gap in passive strategies such as Building Envelope and Building Design. This suggests that designers should integrate passive approaches to improve alignment and better satisfy the requirements of both GBI's Energy Efficiency and MyCREST's Energy and Carbon Impact categories.

d. Material and Resource, Water Efficiency and Innovation are currently underrepresented across most Design Factors, despite being recognised in both rating systems. This may reflect challenges in implementation, limited research focus, and the way these criteria are categorised in rating frameworks. Designers are therefore encouraged to use of eco-friendly and locally sourced materials to minimize environmental impact, incorporate high-efficiency water systems, sub-metering, and rainwater harvesting strategies, and embrace innovative technologies (e.g., BIM and low-carbon

products) as integrated and not isolated elements of sustainable design to improve sustainability performance and fulfilling the requirements of both GBI and MyCREST sustainable rating system.

In conclusion, by offering clear alignment strategies with Malaysia's key green building frameworks, this study provides a practical reference for designers to navigate the diverse landscape of sustainable rating options. It empowers designers to make informed, performance-driven decisions that meet sustainability targets while improving clarity, consistency, and effectiveness in the green building design process in Malaysia.

Additionally, this study also identifies a need for improvements within the structure of both GBI and MyCREST. The findings suggest that innovation-related strategies are often embedded within other categories, which may limit their recognition and contribution to project scoring. To enhance clarity and encourage more innovative practices, the Innovation category should be expanded and better defined. Additionally, while sustainable planning is well integrated in MyCREST, it appears to be less emphasised in GBI. Strengthening this aspect would improve GBI's ability to guide projects toward more comprehensive and effective sustainability outcomes.

While this study has successfully aligned sustainable building design criteria with GBI and MyCREST, further research is recommended in the following areas:

- *Expansion to other Rating Systems:* Future studies could explore the integration of more rating system in Malaysia to provide a more comprehensive framework for sustainable building development.
- *Focus on Lifecycle Assessment:* While this study primarily focused on the design phase, future research could extend the framework to include a comprehensive lifecycle assessment, covering construction, operation, and decommissioning phases to ensure sustainability is maintained throughout the building's lifecycle.

By addressing these areas, future studies can further refine and enhance the integration of sustainability criteria into the design and development of green buildings.

This study offers a novel contribution by systematically identifying and thematically grouping sustainable building design criteria using an inductive approach, resulting in a set of context-specific Design Factors aligned with Malaysia's green building rating systems. By adopting a bottom-up perspective grounded in actual criteria from both GBI and MyCREST, the study addresses the current fragmentation across frameworks and provides greater clarity for practitioners. The findings establish a structured foundation to support more informed and integrated decision-making in sustainable building design particularly during the early design stages where multiple criteria intersect.

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