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Future-Ready Construction and Facility Management:
Driving Research and Innovation for a Smart Built Environment

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COOLING URBAN HEAT: A HEAT-SMART FRAMEWORK FOR SUSTAINABLE CONSTRUCTION PERMITS

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Abstract
The increasing temperature and Heat Island (UHI) impacts in cities are the result of climate change and rapid urbanization, aggravating urban heat problems. Metropolitan regions in Malaysia have experienced temperature rises of up to 6.75˚C, resulting in increased health risks and surging energy demands for cooling. Current building and planning frameworks only address sustainability in a general sense, but lack the mechanism to assess building-specific heat performance before construction that can provide thermal comfort in new development areas. This study proposes a framework focused on heat management by identifying critical Building Heat Indicators (BHI) for integration into construction permit approvals as a standard requirement, to promote climate-responsive and future-ready building design. A qualitative method was employed, involving expert interviews to gather insights on key heat contributors and mitigation strategies. Thematic analysis revealed a core set of BHIs that encompass microclimatic elements (e.g., temperature, wind speed, humidity, heat index, building characteristics (e.g., height, material used, shape, occupant behavior), and urban attributes (e.g., green cover, building arrangement, surrounding surface materials. All experts strongly endorsed that these indicators are critical for assessing and managing building heat. The findings have shown that integrating these indicators can reduce UHI impacts at the building level.

Keywords: Urban Heat Island (UHI), Building Heat Indicators, Thermal Comfort, Construction Permit, Sustainability

1. INTRODUCTION

The phenomenon of climate change has heightened global initiatives toward sustainable urban development, particularly in mitigating Urban Heat Islands (UHIs). These localized increases in temperature within cities caused by heat-absorbing infrastructure, reduced green spaces, and anthropogenic activities (Khamchiangta & Dhakal, 2019; Yushaimi et al., 2021). According to Ramayah (2021), in Malaysia, urban areas such as Kuala Lumpur and Penang have experienced alarming temperature increases of up to 6.75°C in recent decades, which increases health risks, energy demands, and urban resilience crises. Notwithstanding initiatives such as the Green Building Index (GBI), energy consumption is still on the rise, having increased by 35% (2015–2019), underscoring inefficiencies in addressing the heat dynamics specific to buildings (Energy Commission, 2022). The existing frameworks, such as LEED, BREEAM, and CASBEE, lack localized tools to assess thermal performance at the building level, while a lack of cohesive collaboration among stakeholders and insufficient resources worsens the problem (Aktar et al., 2022; Oh et al., 2018). This

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research aims to address existing gaps by identifying critical Building Heat Indicators (BHIs) such as microclimate elements, building characteristics, and urban attributes to integrate into construction permit approvals. This approach aims to optimize outdoor thermal comfort, reduce energy consumption, and promote climate-resilient urban development by integrating policy and design.

2. LITERATURE REVIEW

Building heat has a profound influence on indoor thermal comfort, energy efficiency, and overall structural performance (Kuczyński & Staszczuk, 2020; Zhao et al., 2021). Heat transfer in edifices occurs via conduction, convection, and radiation. Conduction, the movement of heat through solid materials such as building envelopes, depends on material thermal conductivity and thickness (Dutta, 2023). For instance, concrete walls possess high thermal mass, absorbing heat during the day and releasing heat slowly at night, thereby stabilising indoor temperatures but exacerbating nighttime heat retention in urban areas (He, 2019). Convection, driven by air movement, vertically redistributes heat or warm air ascends while cooler air descends, creating temperature stratification in multi-story buildings and influencing HVAC efficiency (Sharma & Sengar, 2019). Radiation, particularly solar gain through windows and roofs, contributes significantly to external heat influx, with unshaded glazing, which may elevate cooling demands by up to 25% in tropical climates (Harkouss et al., 2018). These mechanisms collectively dictate a building's thermal behavior and cooling demand.

Heat gain from internal and external further compounds thermal challenges. Occupants and equipment within the building produce substantial heat internally; for instance, human metabolism and electronic devices (e.g., computers, lighting) contribute 10–20 W/m² of heat in the office environment, requiring adaptive cooling adjustments (Salerno et al., 2021). On the other hand, external heat gains originate from urban surfaces, solar exposure, and infrastructure. For example, dark asphalt pavements can increase ambient temperatures by 5–7°C, hence intensifying UHI effects (Yang et al., 2020). Effective heat management strategies, including high-performance insulation and reflective coatings on the building exterior, reduce conductive and radiative heat transfer by 30–40%, enhancing energy efficiency (Amaral et al., 2020). Harkouss et al. (2018) recommended using natural ventilation and shading devices to promote airflow and reduce solar heat gain. These findings highlighted the need for proactive design strategies to regulate heat accumulation, ensure occupant comfort, and reduce reliance on air conditioning.

Identifying building heat indicators (BHIs) is critical for evaluating and improving thermal performance within buildings and their surrounding environment. These indicators encompass meteorological, architectural, and urban elements. Air temperature and relative humidity (RH) collectively influence thermal comfort levels. RH in Malaysia's humid tropics is around 70–90%, where evaporative cooling is limited, resulting in increased reliance on mechanical systems to regulate temperature (Allah et al., 2023). The heat index reflects the combined impact of temperature and humidity that contribute to heat stress risks, with values above 40°C posing health hazards (Ghalhari et al., 2019). Additionally, wind speed with sufficient airflow rates above 1 m/s can augment convective cooling, while stagnant air exacerbates thermal

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discomfort (Mohammed et al., 2020).

The characteristics of buildings become a second category of BHIs that substantially influence thermal performance. According to Nugroho et al. (2022), height and morphology significantly alter microclimatic conditions. Moreover, tall buildings with aspect ratios (height-to-width) exceeding 3:1 can reduce street-level daytime temperatures by 2–3°C through strategic shading. Besides that, their vertical mass often disrupts natural wind flow, compromising ventilation efficiency. Furthermore, material properties influence heat dynamics, such as reflective roofing materials, particularly white coatings that lower surface temperatures by 10–15°C. However, thermal mass materials such as brick or concrete stabilize indoor climates by moderating temperature fluctuations, reducing peak heating and cooling loads, and creates thermal comfort (Pasztory, 2021). Building use and occupancy patterns also play a pivotal role. For instance, densely populated commercial buildings often require higher overall heating capacity and adaptable heating systems to accommodate fluctuating demand throughout the day (Petersen et al., 2018). These factors underscore the importance of integrating building-scale indications into design and regulations to mitigate heat retention and energy consumption.

As cities develop and urbanize there will be certain changes such as land use, building density, surface properties, heat emissions, and modifications to the natural environment. This urban attribute is another element that influences building heat and the surroundings. Green infrastructure, such as urban parks, water surface, vegetated roofs, reduces ambient temperatures by 3–5°C through evapotranspiration and shading, counteracting the heat-absorbing properties of impermeable surfaces like asphalt and concrete, which contribute up to 60% of UHI intensity in densely built areas (Wong et al., 2011; Uddin et al., 2022). In contrast, anthropogenic heat emissions from vehicular traffic, industrial operations, and mechanical systems add 10–50 W/m^2 of waste heat to urban environments, exacerbating localized temperature spikes (Yushaimi et al., 2021). High-traffic corridors in cities like Kuala Lumpur typically retains elevated nighttime temperatures due to prolonged heat release from pavements and engines. Addressing these challenges requires holistic urban planning prioritizing permeable surfaces, green networks, and low-emission zones to disrupt heat accumulation cycles and enhance thermal equity.

Holistic approaches integrating BHIs into urban planning are vital. For example, Singapore's Green Mark Scheme clearly mandates reflective materials and green coverage ratios, reducing energy use by 25% in certified buildings (Sharifi, 2019). Similarly, Urban Building Energy Modeling (UBEM) tools simulate microclimate interactions, enabling data-driven permit approvals (Hong et al., 2020). However, gaps persist in Malaysia's policy framework, where voluntary guidelines and fragmented enforcement limit adoption (Aktar et al., 2022). The synthesis of BHIs—spanning building design, material science, and urban ecology—provides a foundation for climate-responsive regulations. Future frameworks must prioritize localized metrics, stakeholder collaboration, and advanced modeling tools to mitigate UHI impacts effectively.

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3. METHODOLOGY

This study employed a qualitative exploratory design, utilizing semi-structured interviews with seven purposively selected experts based on their direct expertise. Four out of seven participants represent local authorities, comprising industry experts involved in policymaking for construction permits and construction regulation. The selection criteria were based on their job designation, relevant experience, and background pertinent to this study. Additionally, three academicians from different universities who specialised in urban climate, building technology, and thermal comfort research were invited to participate in the interview. The number of participants was determined by thematic saturation, where data collection was complegted no new themes emerged from subsequent interviews, indicating that the data is comprehensive and sufficient for the research topic (Hennink et al., 2020; Saunders et al., 2018).

Interviews, conducted face-to-face and online (30–60 minutes each), followed a protocol covering demographics, conceptual definitions of building heat, rationale for BHIs, and indicator validation. Data were transcribed and analyzed thematically using NVivo Pro 14, involving open, axial, and selective coding to identify key themes (e.g., material reflectivity, microclimate factors), with inter-coder reliability achieving 85% agreement (Cohen's $\kappa = 0.78$). The validity and reliability of the findings in this study were established through two principal qualitative validation techniques, member checking and literature triangulation. Member checking entitled the distribution of interview transcripts and identified selected theme outcomes to certify accuracy and confirm that the analysis authentically represents their perspectives and experiences (Birt et al. 2016, Lincoln & Guba, 1985). All participants validated and agreed with the identified themes, thereby strengthening the viability of this study. Moreover, literature triangulations were employed, wherein the selected themes and building heat indicators were systematically cross-referenced with recent scholarly works (Liang et al., 2021; Santanouris, 2021), revealing strong alignment with prior research and reinforcing the reliability of the discovered building heat indicators.

4. FINDING AND DISCUSSION

The expert interviews revealed a set of key BHI categories into three main categories: Building Characteristics, Urban Attributes, and Microclimate. Eight indicators received unanimous support as essential for evaluating building heat which include building height, envelopes material reflectivity, equipment utilized, building function, occupant density, percentage of green space, percentage of hardscape area, and ambient air temperature. These indicators correspond with current studies highlighting that reflecting materials can significantly generate cooler microclimates, reduce surface temperature, and building height and shape influence local heat dispersion. Additionally, experts proposed new indicators such as roof type, proximity to water bodies, road and pavement materials, and heat index, further enhancing the comprehensive scope of heat assessment. Yang et al. (2020) assert that the installation of reflective or green roofs can reduce surface temperatures by up to 10°C, thus lowering the overall heat load on the building and improving thermal comfort. Moreover, by adding proximity to water bodies in the assessment can be considered

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cooling effects of natural features within urban environments. Nouri et al. (2021) agreed that buildings near water bodies experience lower ambient temperatures, contributing to reduced cooling demands and enhanced thermal comfort. In contrast, building orientation, radiant temperature and sky view factors were considered impractical for regulatory application as this might pose a problem to the developers throughout the permit approval process. This evaluation needs to be carefully analysed to ensure the set of criteria can be effectively implemented in the construction permit approval process.

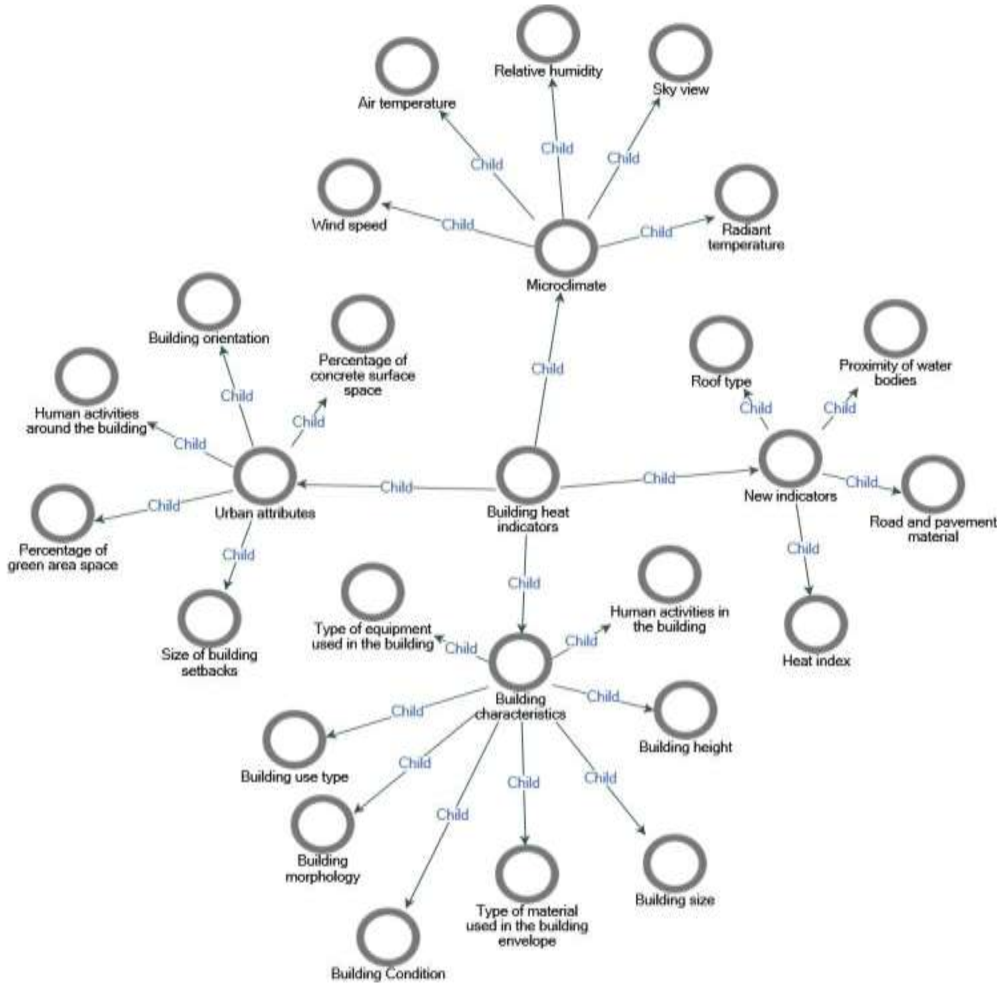

Figure 1. Nvivo 14 outcome of Building Heat Indicators (BHI)

5. CONCLUSION

Efficient building heat evaluation is crucial to tackle urban heat issues exacerbated by climate change. Current sustainability projects in nations such as Malaysia face limitations due to inadequate stakeholder engagement and governance frameworks. This study identified critical BHI including building height, façade materials, air temperature and newly proposed factors such as roof type, proximity to water bodies, road and pavement materials, and heat index. While incorporating these BHIs into construction permits is beneficial, it must be carefully implemented to prevent burdening developers. Future research should broaden its geographical scope, conduct comparative analyses, and empirically validate the proposed framework through pilot studies to ensure its practicality and effectiveness.

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