UNRAVELING THE LIFE CYCLE CARBON EMISSIONS OF GREEN OFFICE BUILDING WITH HOTSPOT-ORIENTED REGRESSION

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Buildings contribute to 38% of global energy-related CO_2 emissions, and the trend to develop green buildings with low or net-zero status has gained traction. A regression model focused on hotspots (i.e., high carbon emissions) has been developed for green-certified office buildings, utilizing Life Cycle Assessment (LCA) and Multiple Linear Regression (MLR) methods. We collected on-site data and adopted material-specific parameters contributing to the most embodied carbon (EC) and operational carbon (OC) to enhance the prediction accuracy of regression models from a life cycle perspective.

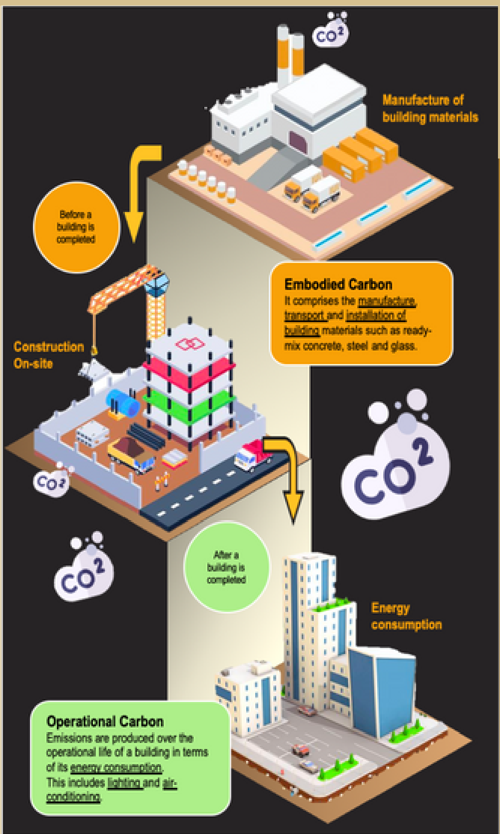
Based on the data collected and assumptions made, findings reveal that OC emissions constitute a significant portion of a building's 86-97% carbon footprint, with electricity usage as a dominant factor. Embodied carbon, accounting for 3-14% of total life cycle carbon emissions, is mainly influenced by cement and steel usage, emphasizing the importance of sustainable building materials in the green building rating system. The MLR analysis identifies key parameters for EC to offer insights into their impact on carbon emissions. Hotspot-oriented regression equations demonstrate more accurate predictions than basic building parameters (e.g., GFA and number of storeys) for embodied and operational carbon. Material-based regression equations for EC exhibit the lowest margin of error, with a 23.7-42.1% variance between the actual and predicted values, compared to GFA and the number of storeys, which provide lower carbon emissions and incur higher errors in predicting carbon emissions for green buildings. The study underscores the underestimation of carbon emissions when applying basic parameters due to material quality and quantity variations during construction. Considering diverse building designs and lifespans, material-based regression equations are essential for accurate predictions. Basic parameters also fall short in representing energy efficiency factors, such as air-conditioning, water systems, lighting, office space occupancy, and the number of users, impacting utility consumption. The regression equations for both EC and OC are shown below for reference.

$$\sqrt{EC} = -0.01 + 0.73\sqrt{x_1} + 0.28\sqrt{x_2} \quad Eq\ (1)$$

$$\sqrt{OC} = -0.002 + 0.937\sqrt{x_3} + 0.029\sqrt{x_4} + 0.095\sqrt{x_5} \quad Eq\ (2)$$

Where EC refers to the embodied carbon emission ($kgCO_2e/m^2$); x_1 refers to the cement usage for the building (kg/m^2); x_2 refers to the steel usage for the building (kg/m^2); OC refers to the operational carbon emission ($kgCO_2e/y$); x_3 refers to the annual electricity consumption for the building (kWh/y); x_4 refers to the water consumption and wastewater generation from the building (m^3/y); x_5 refers to the solid waste generation from the building (kg/y). The OC value is divided by the GFA of the building to have a fair comparison among the building projects.

We also developed a five-grade Green Office Building Rating System to allow stakeholders to benchmark their buildings with existing green-certified office buildings in Malaysia. Those achieving a 5-diamond carbon rating are considered the most carbon-friendly. The study enables stakeholders to predict and benchmark the carbon emission of green-certified buildings, contributing to SDGs 11 and 13, which encompasses sustainable cities and development and climate action in reducing carbon emissions.



Developing Hotspot-Oriented Regression Models and Green Office Building Carbon Rating via an Integrated LCA-MLR Framework