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# A framework for Sustainable Materials Selection for High-rise Buildings in Sri Lanka

The construction industry, as a resource-intensive sector, significantly impacts the environment by consuming vast quantities of raw materials, energy, and water, while emitting substantial greenhouse gases and generating landfill waste [1]. Particularly, high-rise buildings are often associated with the consumption of significant amounts of energy and raw materials that result in negative consequences on the environment, economy, and society [2]. Consequently, there is an urgent need for sustainable construction practices, and the efficient use of materials plays a crucial role [3]. Hence this research aims to develop a framework to select sustainable materials for high-rise buildings in Sri Lanka.

Sustainable materials in construction minimise environmental damage, protect raw materials from excessive depletion, and enhance long-term durability and efficiency of buildings [3]. The goal of these materials is to achieve a balance between environment, society, and economy without compromising the structural integrity and performance of the building [4]. The construction industry of Sri Lanka faces several challenges in the adoption of sustainable materials. One of the primary challenges is the lack of tools and data to sufficiently assess alternative materials to achieve sustainability in building [5]. In addressing this challenge, this research developed a framework to select suitable sustainable materials for high-rise buildings.

This research adopted a mixed-method approach. Case study and survey were the research strategies used. Five green-certified high-rise buildings in Sri Lanka were selected as case studies, within which a total of 10 semi-structured interviews distributed equally across the five selected buildings were conducted with project managers, engineers, and architects to gather data regarding the sustainable materials used and their selection criteria. 51 questionnaires were conducted among industry professionals who are associated with green-certified high-rise buildings in Sri Lanka to rank the sustainable materials against each selection criterion. Qualitative content analysis and RII analysis were used to analyse the data collected from interviews and questionnaire, respectively. The analysed data from the case studies and questionnaires served as the primary input for developing the framework. Through the questionnaire survey, the significance of each sustainable material against the selection criteria was assessed and the value of each material in relation to the criteria was reported as a percentage. The overall sustainability rating for each material was calculated by averaging the values of all selection criteria. Subsequently, four experts in the construction industry who have adequate experience in sustainable building materials were consulted to validate the developed framework and their expert views were incorporated in upgrading the framework.

The research identified 23 sustainable materials as suitable for high-rise buildings in Sri Lanka; those are steel, lime, wood, fly ash bricks, stone, eco-friendly tiles, bamboo, straw bales/dura panels, ferro cement, mineral fibre, recycled aggregates, clay bricks, terrazzo, ceramic tiles, porcelain tiles, foam concrete, natural fibre reinforced polymer composites (NFPCs), hempcrete, aluminum panels, bark siding, acetylated wood products, glass, sandwich panels, gypsum panels and low VOC paints. Materials, such as hempcrete, rammed earth, and bark siding were excluded due to limited local availability and insufficient strength to meet the structural requirements of high-rise construction.

Cost-effectiveness, functionality, performance, strength, local availability, waste management, durability, and energy efficiency were identified as the main selection criteria in the framework. Water efficiency and pollution reduction were excluded from the selection criteria as they were considered more relevant to the material production phase rather than the operational phase. Personal preference of client is an unavoidable criterion in the selection of sustainable materials in high-rise buildings. Therefore, the framework is developed to be flexible to accommodate manual comparisons of sustainable materials based on client's own preference.

The framework incorporates the key elements of the high-rise building such as walls, floors, partitions, insulation, wall finishes, floor finishes, ceiling finishes, and doors and windows. These elements represent critical areas where material choices significantly impact the sustainability of high-rise buildings. Respondents emphasised that foundation and frame (columns and beams) are essential to the structural stability of high-rise buildings. Hence, such elements are excluded from the framework, as they demand to use materials that provide strength and stability rather than sustainability.

The framework was created using MS Excel to identify sustainable alternatives for materials used in high-rise buildings of Sri Lanka. The operation of the framework comprised six key steps as outlined below:

• Step 1 – Selection of building elements: The user initially, selects one of the eight key building elements (walls, floors, partitions, insulation, wall finishes, floor finishes, ceiling finishes, or doors and windows) from a dropdown list.

• Step 2 – Display of available sustainable materials: Once the element is selected, the framework displays a list of suitable sustainable materials for that selected building element.

• Step 3 – Input the selection criteria: Then the user selects the criteria based on which the material should be chosen. This could include the selection criteria such as cost-effectiveness, strength, durability, local availability, waste management, or energy efficiency.

• Step 4 – Display of suitable sustainable materials based on criteria: Based on the selection criteria, the framework displays the three most suitable sustainable materials for the chosen building element.

• Step 5 – Review sustainability criteria details: The framework provides additional details (percentage of performance) demonstrating how each of the three selected materials performs against the eight selection criteria.

• Step 6 – Manual comparison of alternatives: The framework allows the user to manually compare two to three alternative sustainable materials, providing an option to further evaluate and choose the best-suited material based on their project-specific needs.

The process of deriving rank of each material is depicted graphically in Figure 1.

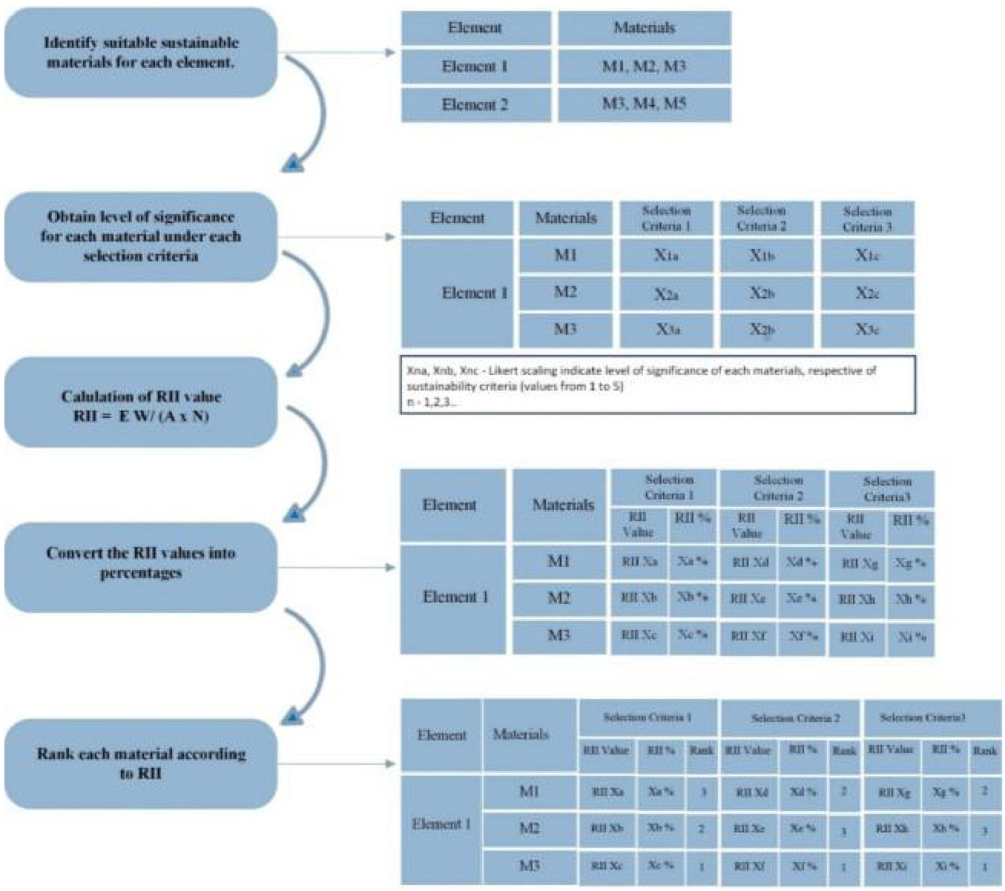


Figure 1: Process of deriving rank of each materials [5]

A sample interface of the developed framework with the selected element and the selection criteria as partition and cost-effectiveness, respectively is shown in Figure 2.

The developed framework serves as a valuable tool for selecting sustainable materials in the construction of high-rise buildings. By enabling professionals to assess materials based on selection criteria, the framework facilitates sustainable decision-making. Additionally, the framework is flexible, enabling users to alter the selection criteria in accordance with their preferred selection criteria. As Sri Lanka continues to develop its built environment, it is crucial to promote sustainable construction practices. However, lack of policies, frameworks, and government incentives has been identified as major barriers in encouraging sustainable construction practices. The developed framework addresses this gap by providing a structured framework for the selection of suitable sustainable materials for the key elements of high-rise buildings, by considering selection criteria. As a result, it helps the adoption of sustainable practices in the construction industry. To enhance the efficiency and reliability of the framework, it is recommended to expand the data collection to include a larger number of respondents from diverse backgrounds within the construction industry.

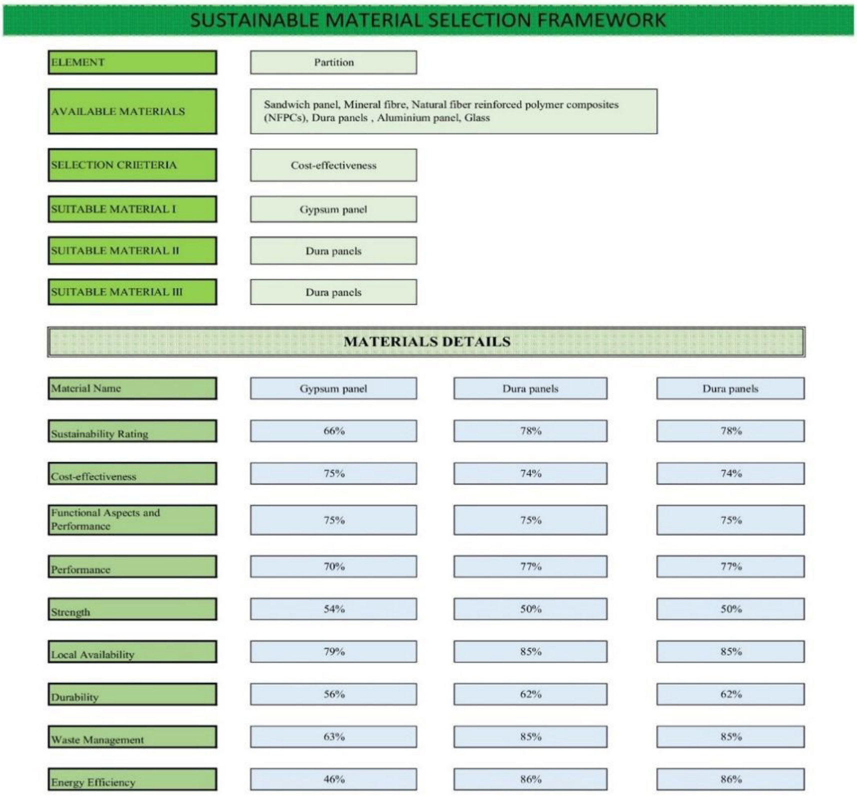


Figure 2: Process of deriving rank of each materials (Sachchithananthan and Thayaparan, 2024)

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