Table 1: Relationship between the trapezoidal fuzzy numbers (TFN) and degree of importance (linguistics variables) on a five-linguistic-term scale

|  |  |
| --- | --- |
| **Degree of importance** | **Trapezoidal fuzzy numbers** |
| **Label** | **Linguistic terms** |
| VH | Very High  | (0.774, 0.834, 0.860, 0.876) |
| H | High  | (0.649, 0.704, 0.744, 0.816) |
| M | Medium  | (0.556, 0.589, 0.631, 0.676) |
| L | Low  | (0.411, 0.471, 0.500, 0.574) |
| VL | Very Low  | (0.252, 0.282, 0.324, 0.416) |

Table 2: Average values of the degree of significance and tolerance zones of each criterion (SA) using TFN

| **Sustainability Criteria (Attributes)** | **Average ‘degree of significance’ value for each criterion ()** | **Min. Tolerance Value** | **Max. Tolerance Value** | **Tolerance Zone**() | **RON values ()** | **Average ‘degree of significance’ value****(*Best Alternative*)** () |
| --- | --- | --- | --- | --- | --- | --- |
| **A-** “**Sustainable Construction Practices”** |  |  |  |  |  |  |
| A1- “Project Site and Design” | (0.660, 0.709, 0.745, 0.789) | M | VH | (0.556, 0.589, 0.860, 0.876) | 0.667 | (0.516, 0.556, 0.574, 0.584) |
| A2- “Societal Engagement”  | (0.597, 0.650, 0.684, 0.736) | L | VH | (0.411, 0.471, 0.860, 0.876) | 0.547 | (0.423, 0.456, 0.471, 0.479) |
| A3- “Safety & Health” | (0.597, 0.650, 0.684, 0.736) | L | VH | (0.411, 0.471, 0.860, 0.876) | 0.650 | (0.503, 0.542, 0.559, 0.570) |
| A4- “Ethics & Equity” | (0.528, 0.576, 0.612, 0.672) | VL | VH | (0.252, 0.282, 0.860, 0.876) | 0.708 | (0.548, 0.591, 0.609, 0.621) |
| A5- “Construction Material & Waste” | (0.660, 0.709, 0.745, 0.789) | M | VH | (0.556, 0.589, 0.860, 0.876) | 0.638 | (0.493, 0.532, 0.549, 0.559) |
| A6- “Project Management” | (0.597, 0.650, 0.684, 0.736) | L | VH | (0.411, 0.471, 0.860, 0.876) | 0.657 | (0.509, 0.548, 0.566, 0.576) |
| **B-** “**Site and Ecology”** |  |  |  |  |  |  |
| B1- “Site Selection” | (0.597, 0.650, 0.684, 0.736) | L | VH | (0.411, 0.471, 0.860, 0.876) | 0.583 | (0.452, 0.486, 0.502, 0.511) |
| B2- “Site Management” | (0.528, 0.576, 0.612, 0.672) | VL | VH | (0.252, 0.282, 0.860, 0.876) | 0.563 | (0.435, 0.469, 0.484, 0.493) |
| B3- “Reduction of Heat Island Effect” | (0.528, 0.576, 0.612, 0.672) | VL | VH | (0.252, 0.282, 0.860, 0.876) | 0.550 | (0.426, 0.459, 0.473, 0.482) |
| **C- “Energy”** |  |  |  |  |  |  |
| C1- “Energy Performance” | (0.528, 0.576, 0.612, 0.672) | VL | VH | (0.252, 0.282, 0.860, 0.876) | 0.540 | (0.418, 0.450, 0.464, 0.473) |
| C2- “Energy Management” | (0.528, 0.576, 0.612, 0.672) | VL | VH | (0.252, 0.282, 0.860, 0.876) | 0.600 | (0.464, 0.500, 0.516, 0.526) |
| C3- “Energy Efficient Systems & Equipment” | (0.528, 0.576, 0.612, 0.672) | VL | VH | (0.252, 0.282, 0.860, 0.876) | 0.571 | (0.442, 0.477, 0.492, 0.501) |
| **D- “Water”** |  |  |  |  |  |  |
| D1- “Water Efficiency” | (0.528, 0.576, 0.612, 0.672) | VL | VH | (0.252, 0.282, 0.860, 0.876) | 0.500 | (0.387, 0.417, 0.430, 0.438) |
| D2- “Water Management” | (0.597, 0.650, 0.684, 0.736) | L | VH | (0.411, 0.471, 0.860, 0.876) | 0.563 | (0.435, 0.469, 0.484, 0.493) |
| D3- “Water Efficient Systems & Equipment” | (0.597, 0.650, 0.684, 0.736) | L | VH | (0.411, 0.471, 0.860, 0.876) | 0.333 | (0.258, 0.278, 0.287, 0.292) |
| **E- “Material and Waste”** |  |  |  |  |  |  |
| E1- “Sustainable Purchasing Practice” | (0.528, 0.576, 0.612, 0.672) | VL | VH | (0.252, 0.282, 0.860, 0.876) | 0.589 | (0.456, 0.491, 0.507, 0.516) |
| E2- “Efficient Use & Selection of Materials” | (0.528, 0.576, 0.612, 0.672) | VL | VH | (0.252, 0.282, 0.860, 0.876) | 0.583 | (0.452, 0.486, 0.502, 0.511) |
| E3- “Waste Management Practice” | (0.528, 0.576, 0.612, 0.672) | VL | VH | (0.252, 0.282, 0.860, 0.876) | 0.560 | (0.434, 0.467, 0.482, 0.491) |
| E4- “Ease of Conversion of Building Functions” | (0.528, 0.576, 0.612, 0.672) | VL | VH | (0.252, 0.282, 0.860, 0.876) | 0.500 | (0.387, 0.417, 0.430, 0.438) |
| **F- “Transportation”** |  |  |  |  |  |  |
| F1- “Alternative Means of Transport” | (0.528, 0.576, 0.612, 0.672) | VL | VH | (0.252, 0.282, 0.860, 0.876) | 0.583 | (0.452, 0.486, 0.502, 0.512) |
| F2- “Community Accessibility” | (0.528, 0.576, 0.612, 0.672) | VL | VH | (0.252, 0.282, 0.860, 0.876) | 0.500 | (0.387, 0.417, 0.430, 0.438) |
| F3- “Transport Management” | (0.528, 0.576, 0.612, 0.672) | VL | VH | (0.252, 0.282, 0.860, 0.876) | 0.625 | (0.484, 0.521, 0.538, 0.548) |
| **G- “Indoor Environmental Quality”** |  |  |  |  |  |  |
| G1- “Visual Comfort” | (0.597, 0.650, 0.684, 0.736) | L | VH | (0.411, 0.471, 0.860, 0.876) | 0.578 | (0.447, 0.482, 0.497, 0.506) |
| G2- “Indoor Air Quality” | (0.597, 0.650, 0.684, 0.736) | L | VH | (0.411, 0.471, 0.860, 0.876) | 0.583 | (0.452, 0.486, 0.502, 0.511) |
| G3- “Thermal Comfort” | (0.597, 0.650, 0.684, 0.736) | L | VH | (0.411, 0.471, 0.860, 0.876) | 0.500 | (0.387, 0.417, 0.430, 0.438) |
| G4- “Acoustic Performance” | (0.559, 0.609, 0.662, 0.700) | VL | VH | (0.252, 0.282, 0.860, 0.876) | 0.500 | (0.387, 0.417, 0.430, 0.438) |
| G5- “Hygiene” | (0.597, 0.650, 0.684, 0.736) | L | VH | (0.411, 0.471, 0.860, 0.876) | 0.578 | (0.447, 0.482, 0.497, 0.506) |
| G6- “Building Amenities” | (0.528, 0.576, 0.612, 0.672) | VL | VH | (0.252, 0.282, 0.860, 0.876) | 0.563 | (0.435, 0.469, 0.484, 0.493) |
| **H- “Building Management”** |  |  |  |  |  |  |
| H1- “Operation & Maintenance” | (0.597, 0.650, 0.684, 0.736) | L | VH | (0.411, 0.471, 0.860, 0.876) | 0.592 | (0.458, 0.493, 0.509, 0.519) |
| H2- “Security” | (0.597, 0.650, 0.684, 0.736) | L | VH | (0.411, 0.471, 0.860, 0.876) | 0.500 | (0.387, 0.417, 0.430, 0.438) |
| H3- “Risk Management” | (0.528, 0.576, 0.612, 0.672) | VL | VH | (0.252, 0.282, 0.860, 0.876) | 0.547 | (0.423, 0.456, 0.471, 0.479) |
| H4- “Green Innovations” | (0.528, 0.576, 0.612, 0.672) | VL | VH | (0.252, 0.282, 0.860, 0.876) | 0.500 | (0.387, 0.417, 0.430, 0.438) |

Table 3: Evaluation result of the GCFI algorithm for the fuzzy valence function, for ∝ = 0

| **Criteria code** | **Individual significance** () | **Value for the ‘BA’** | **Criteria code** | **Individual significance** () | **Value for the ‘BA’** |
| --- | --- | --- | --- | --- | --- |
| [] / () | [] / () |
| **A** |  | [0.327, 0.650] | **F** |  | [0.291, 0.639] |
| A1 | (0.516, 0.584) | (0.320, 0.514) | F1 | (0.452, 0.512) | (0.288, 0.630) |
| A2 | (0.423, 0.479) | (0.273, 0.534) | F2 | (0.387, 0.438) | (0.255, 0.593) |
| A3 | (0.503, 0.570) | (0.313, 0.579) | F3 | (0.484, 0.548) | (0.304, 0.648) |
| A4 | (0.548, 0.621) | (0.336, 0.685) | **G** |  | [0.286, 0.607] |
| A5 | (0.493, 0.559) | (0.308, 0.501) | G1 | (0.447, 0.506) | (0.285, 0.548) |
| A6 | (0.509, 0.576) | (0.316, 0.583) | G2 | (0.452, 0.511) | (0.288, 0.550) |
| **B** |  | [0.284, 0.613] | G3 | (0.387, 0.438) | (0.255, 0.514) |
| B1 | (0.452, 0.511) | (0.288, 0.550) | G4 | (0.387, 0.438) | (0.255, 0.593) |
| B2 | (0.435, 0.493) | (0.279, 0.621) | G5 | (0.447, 0.506) | (0.285, 0.548) |
| B3 | (0.426, 0.482) | (0.275, 0.615) | G6 | (0.435, 0.493) | (0.279, 0.621) |
| **C** |  | [0.287, 0.632] | **H** |  | [0.281, 0.602] |
| C1 | (0.418, 0.473) | (0.271, 0.611) | H1 | (0.458, 0.519) | (0.291, 0.554) |
| C2 | (0.464, 0.526) | (0.294, 0.637) | H2 | (0.387, 0.438) | (0.255, 0.514) |
| C3 | (0.442, 0.501) | (0.283, 0.625) | H3 | (0.423, 0.479) | (0.273, 0.614) |
| **D** |  | [0.260, 0.569] | H4 | (0.387, 0.438) | (0.255, 0.593) |
| D1 | (0.387, 0.438) | (0.255, 0.593) |  |  |  |
| D2 | (0.435, 0.493) | (0.279, 0.541) |  |  |  |
| D3 | (0.258, 0.292) | (0.191, 0.441) |  |  |  |
| **E** |  | [0.285, 0.630] |  |  |  |
| E1 | (0.456, 0.516) | (0.290, 0.632) |  |  |  |
| E2 | (0.452, 0.511) | (0.288, 0.630) |  |  |  |
| E3 | (0.434, 0.491) | (0.279, 0.620) |  |  |  |
| E4 | (0.387, 0.438) | (0.255, 0.593) |  |  |  |

Table 4: Evaluation result of the GCFI algorithm for the fuzzy valence function, for ∝ = 1

| **Criteria code** | **Individual significance**() | **Value for the ‘BA’** | **Criteria code** | **Individual significance**() | **Value for the ‘BA’** |
| --- | --- | --- | --- | --- | --- |
| [] / () | [] / () |
| **A** |  | [0.357, 0.616] | **F** |  | [0.318, 0.617] |
| A1 | (0.556, 0.574) | (0.348, 0.492) | F1 | (0.486, 0.502) | (0.313, 0.610) |
| A2 | (0.456, 0.471) | (0.298, 0.450) | F2 | (0.417, 0.430) | (0.278, 0.574) |
| A3 | (0.542, 0.559) | (0.341, 0.544) | F3 | (0.521, 0.538) | (0.330, 0.628) |
| A4 | (0.591, 0.609) | (0.365, 0.664) | **G** |  | [0.312, 0.583] |
| A5 | (0.532, 0.549) | (0.336, 0.480) | G1 | (0.482, 0.497) | (0.311, 0.513) |
| A6 | (0.548, 0.566) | (0.344, 0.547) | G2 | (0.486, 0.502) | (0.313, 0.515) |
| **B** |  | [0.309, 0.589] | G3 | (0.417, 0.430) | (0.278, 0.480) |
| B1 | (0.486, 0.502) | (0.313, 0.515) | G4 | (0.417, 0.430) | (0.278, 0.574) |
| B2 | (0.469, 0.484) | (0.304, 0.601) | G5 | (0.482, 0.497) | (0.311, 0.513) |
| B3 | (0.459, 0.473) | (0.299, 0.596) | G6 | (0.469, 0.484) | (0.304, 0.601) |
| **C** |  | [0.313, 0.611] | **H** |  | [0.307, 0.577] |
| C1 | (0.450, 0.464) | (0.295, 0.591) | H1 | (0.493, 0.509) | (0.316, 0.519) |
| C2 | (0.500, 0.516) | (0.320, 0.617) | H2 | (0.417, 0.430) | (0.278, 0.480) |
| C3 | (0.477, 0.492) | (0.308, 0.605) | H3 | (0.456, 0.471) | (0.298, 0.594) |
| **D** |  | [0.287, 0.538] | H4 | (0.417, 0.430) | (0.278, 0.574) |
| D1 | (0.417, 0.430) | (0.278, 0.574) |  |  |  |
| D2 | (0.469, 0.484) | (0.304, 0.506) |  |  |  |
| D3 | (0.278, 0.287) | (0.209, 0.408) |  |  |  |
| **E** |  | [0.312, 0.609] |  |  |  |
| E1 | (0.491, 0.507) | (0.315, 0.612) |  |  |  |
| E2 | (0.486, 0.502) | (0.313, 0.610) |  |  |  |
| E3 | (0.467, 0.482) | (0.303, 0.600) |  |  |  |
| E4 | (0.417, 0.430) | (0.278, 0.574) |  |  |  |

Table 5: For , fuzzy measures and values

| **Criteria code** |  | **Fuzzy measures**  |  | **Fuzzy measures**  | **Criteria code** |  | **Fuzzy measures**  |  | **Fuzzy measures**  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **A** | -0.9963 |  | -0.9997 |  | **F** | -0.8157 |  | -0.9536 |  |
| A1 |  | 0.8407 |  | 0.9990 | F1 |  | 0.8289 |  | 0.9132 |
| A2 |  | 1.0000 |  | 0.9942 | F2 |  | 1.0000 |  | 0.6718 |
| A3 |  | 0.9770 |  | 0.9772 | F3 |  | 0.5283 |  | 1.0000 |
| A4 |  | 0.5283 |  | 0.6718 | **G** | -0.9943 |  | -0.9995 |  |
| A5 |  | 0.9945 |  | 1.0000 | G1 |  | 0.9384 |  | 0.9987 |
| A6 |  | 0.9377 |  | 0.9133 | G2 |  | 0.5974 |  | 0.9744 |
| **B** | -0.8511 |  | -0.9638 |  | G3 |  | 0.9928 |  | 1.0000 |
| B1 |  | 0.5974 |  | 1.0000 | G4 |  | 1.0000 |  | 0.9018 |
| B2 |  | 0.8289 |  | 0.6718 | G5 |  | 0.8400 |  | 0.9936 |
| B3 |  | 1.0000 |  | 0.9086 | G6 |  | 0.9738 |  | 0.6718 |
| **C** | -0.8157 |  | -0.9536 |  | **H** | -0.9546 |  | -0.9919 |  |
| C1 |  | 1.0000 |  | 1.0000 | H1 |  | 0.5974 |  | 0.9779 |
| C2 |  | 0.5283 |  | 0.6718 | H2 |  | 0.8244 |  | 1.0000 |
| C3 |  | 0.8289 |  | 0.9132 | H3 |  | 0.9369 |  | 0.6718 |
| **D** | -0.8793 |  | -0.9718 |  | H4 |  | 1.0000 |  | 0.8959 |
| D1 |  | 0.8482 |  | 0.6718 |  |  |  |  |  |
| D2 |  | 0.5974 |  | 0.9272 |  |  |  |  |  |
| D3 |  | 1.0000 |  | 1.0000 |  |  |  |  |  |
| **E** | -0.9342 |  | -0.9871 |  |  |  |  |  |  |
| E1 |  | 0.5283 |  | 0.6718 |  |  |  |  |  |
| E2 |  | 0.7958 |  | 0.8980 |  |  |  |  |  |
| E3 |  | 0.9314 |  | 0.9743 |  |  |  |  |  |
| E4 |  | 1.0000 |  | 1.0000 |  |  |  |  |  |

Table 6: For , fuzzy measures and values

| **Criteria code** |  | **Fuzzy measures**  |  | **Fuzzy measures**  | **Criteria code** |  | **Fuzzy measures**  |  | **Fuzzy measures**  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **A** | -0.9984 |  | -0.9992 |  | **F** | -0.8802 |  | -0.9146 |  |
| A1 |  | 0.8773 |  | 0.9977 | F1 |  | 0.8600 |  | 0.8813 |
| A2 |  | 1.0000 |  | 0.9885 | F2 |  | 1.0000 |  | 0.6119 |
| A3 |  | 0.9862 |  | 0.9618 | F3 |  | 0.5761 |  | 1.0000 |
| A4 |  | 0.5761 |  | 0.6119 | **G** | -0.9974 |  | -0.9987 |  |
| A5 |  | 0.9971 |  | 1.0000 | G1 |  | 0.9588 |  | 0.9971 |
| A6 |  | 0.9579 |  | 0.8776 | G2 |  | 0.6496 |  | 0.9595 |
| **B** | -0.9059 |  | -0.9335 |  | G3 |  | 0.9960 |  | 1.0000 |
| B1 |  | 0.6496 |  | 1.0000 | G4 |  | 1.0000 |  | 0.8693 |
| B2 |  | 0.8866 |  | 0.6119 | G5 |  | 0.8783 |  | 0.9881 |
| B3 |  | 1.0000 |  | 0.8742 | G6 |  | 0.9840 |  | 0.6119 |
| **C** | -0.8802 |  | -0.9146 |  | **H** | -0.9740 |  | -0.9829 |  |
| C1 |  | 1.0000 |  | 1.0000 | H1 |  | 0.6496 |  | 0.9644 |
| C2 |  | 0.5761 |  | 0.6119 | H2 |  | 1.0000 |  | 1.0000 |
| C3 |  | 0.8600 |  | 0.8813 | H3 |  | 0.8612 |  | 0.6119 |
| **D** | -0.9259 |  | -0.9481 |  | H4 |  | 0.6496 |  | 0.8557 |
| D1 |  | 0.8792 |  | 0.6119 |  |  |  |  |  |
| D2 |  | 0.6496 |  | 0.8990 |  |  |  |  |  |
| D3 |  | 1.0000 |  | 1.0000 |  |  |  |  |  |
| **E** | -0.9601 |  | -0.9732 |  |  |  |  |  |  |
| E1 |  | 0.5761 |  | 0.6119 |  |  |  |  |  |
| E2 |  | 0.8335 |  | 0.8594 |  |  |  |  |  |
| E3 |  | 0.9486 |  | 0.9595 |  |  |  |  |  |
| E4 |  | 1.0000 |  | 1.0000 |  |  |  |  |  |

Table 7: Defuzzification and normalization results for the sustainability criteria (SI & SA) using GCFI method

| **Criteria code** | **Fuzzy numbers for the** **‘best alternative’**  | **Defuzzied Value**  | **Normalized weights – for NB**  | **Weights global (*SA*) – for NB** | **Normalized weights – for EB**  | **Weights global (*SA*) – for EB** |
| --- | --- | --- | --- | --- | --- | --- |
| **A** | **(0.327, 0.357, 0.616, 0.650)** | **0.488** | **0.1346** |  | - | - |
| A1 | (0.320, 0.348, 0.492, 0.514) | 0.419 | 0.1591 | 0.0214 | - | - |
| A2 | (0.273, 0.298, 0.450, 0.534) | 0.401 | 0.1526 | 0.0205 | - | - |
| A3 | (0.313, 0.341, 0.544, 0.579) | 0.444 | 0.1690 | 0.0227 | - | - |
| A4 | (0.336, 0.365, 0.664, 0.685) | 0.512 | 0.1948 | 0.0262 | - | - |
| A5 | (0.308, 0.336, 0.480, 0.501) | 0.406 | 0.1545 | 0.0208 | - | - |
| A6 | (0.316, 0.344, 0.547, 0.583) | 0.447 | 0.1701 | 0.0229 | - | - |
| **B** | **(0.284, 0.309, 0.589, 0.613)** | **0.449** | **0.1238** |  | **0.1431** |  |
| B1 | (0.288, 0.313, 0.515, 0.550) | 0.417 | 0.3170 | 0.0392 | 0.3170 | 0.0454 |
| B2 | (0.279, 0.304, 0.601, 0.621) | 0.451 | 0.3435 | 0.0425 | 0.3435 | 0.0491 |
| B3 | (0.275, 0.299, 0.596, 0.615) | 0.446 | 0.3395 | 0.0420 | 0.3395 | 0.0486 |
| **C** | **(0.287, 0.313, 0.611, 0.632)** | **0.461** | **0.1271** |  | **0.1469** |  |
| C1 | (0.271, 0.295, 0.591, 0.611) | 0.442 | 0.3240 | 0.0412 | 0.3240 | 0.0476 |
| C2 | (0.294, 0.320, 0.617, 0.637) | 0.467 | 0.3424 | 0.0435 | 0.3424 | 0.0503 |
| C3 | (0.283, 0.308, 0.605, 0.625) | 0.455 | 0.3336 | 0.0424 | 0.3336 | 0.0490 |
| **D** | **(0.260, 0.287, 0.538, 0.569)** | **0.413** | **0.1141** |  | **0.1318** |  |
| D1 | (0.255, 0.278, 0.574, 0.593) | 0.425 | 0.3713 | 0.0424 | 0.3713 | 0.0489 |
| D2 | (0.279, 0.304, 0.506, 0.541) | 0.408 | 0.3562 | 0.0406 | 0.3562 | 0.0469 |
| D3 | (0.191, 0.209, 0.408, 0.441) | 0.312 | 0.2725 | 0.0311 | 0.2725 | 0.0359 |
| **E** | **(0.285, 0.312, 0.609, 0.630)** | **0.459** | **0.1267** |  | **0.1463** |  |
| E1 | (0.290, 0.315, 0.612, 0.632) | 0.463 | 0.2572 | 0.0326 | 0.2572 | 0.0376 |
| E2 | (0.288, 0.313, 0.610, 0.630) | 0.460 | 0.2558 | 0.0324 | 0.2558 | 0.0374 |
| E3 | (0.279, 0.303, 0.600, 0.620) | 0.450 | 0.2505 | 0.0317 | 0.2505 | 0.0367 |
| E4 | (0.255, 0.278, 0.574, 0.593) | 0.425 | 0.2365 | 0.0299 | 0.2365 | 0.0346 |
| **F** | **(0.291, 0.318, 0.617, 0.639)** | **0.466** | **0.1286** |  | **0.1486** |  |
| F1 | (0.288, 0.313, 0.610, 0.630) | 0.460 | 0.3376 | 0.0434 | 0.3376 | 0.0502 |
| F2 | (0.255, 0.278, 0.574, 0.593) | 0.425 | 0.3120 | 0.0401 | 0.3120 | 0.0464 |
| F3 | (0.304, 0.330, 0.628, 0.648) | 0.477 | 0.3504 | 0.0451 | 0.3504 | 0.0521 |
| **G** | **(0.286, 0.312, 0.583, 0.607)** | **0.447** | **0.1232** |  | **0.1425** |  |
| G1 | (0.285, 0.311, 0.513, 0.548) | 0.414 | 0.1655 | 0.0204 | 0.1655 | 0.0236 |
| G2 | (0.288, 0.313, 0.515, 0.550) | 0.417 | 0.1664 | 0.0205 | 0.1664 | 0.0237 |
| G3 | (0.255, 0.278, 0.480, 0.514) | 0.382 | 0.1525 | 0.0188 | 0.1525 | 0.0217 |
| G4 | (0.255, 0.278, 0.574, 0.593) | 0.425 | 0.1699 | 0.0209 | 0.1699 | 0.0242 |
| G5 | (0.285, 0.311, 0.513, 0.548) | 0.414 | 0.1655 | 0.0204 | 0.1655 | 0.0236 |
| G6 | (0.279, 0.304, 0.601, 0.621) | 0.451 | 0.1803 | 0.0222 | 0.1803 | 0.0257 |
| **H** | **(0.281, 0.307, 0.577, 0.602)** | **0.442** | **0.1219** |  | **0.1409** |  |
| H1 | (0.291, 0.316, 0.519, 0.554) | 0.420 | 0.2512 | 0.0306 | 0.2512 | 0.0354 |
| H2 | (0.255, 0.278, 0.480, 0.514) | 0.382 | 0.2283 | 0.0278 | 0.2283 | 0.0322 |
| H3 | (0.273, 0.298, 0.594, 0.614) | 0.445 | 0.2661 | 0.0324 | 0.2661 | 0.0375 |
| H4 | (0.255, 0.278, 0.574, 0.593) | 0.425 | 0.2544 | 0.0310 | 0.2544 | 0.0358 |

*Note: Sustainability Indicator (SI) levels (bolded values); SA – Sustainability attributes levels; NB – New Buildings; EB – Existing Buildings.*

Table 8: Building Sustainability Evaluation Index (BSEI) – for the two New Buildings Case Studies

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Sustainability Indicators** **(SI)** | **SI Normalized Weight** | **Sustainability Attributes****(SA)** | **SA****Normalized Weight** | **SI****Global Weight** | **CE duplex building** |  | **RA labs building** |
| **Attained Credit Point** **(CP)** | **Maximum Credit Point****(CP)** | **Factor Index****(FI)** | **Maximum Factor Index (FI)max** |  | **Attained Credit Point (CP)** | **Maximum Credit Point (CP)** | **Factor Index (FI)** | **Maximum Factor Index****(FI)max** |
| “Sustainable Construction Practices”(A) | 0.1346 | A1 | 0.1591 | 0.0214 | 15.5 | 17 | 0.3318 | 0.3640 |  | 14 | 17 | 0.2997 | 0.3640 |
| A2 | 0.1526 | 0.0205 | 6 | 8 | 0.1232 | 0.1642 |  | 5 | 8 | 0.1026 | 0.1642 |
| A3 | 0.1690 | 0.0227 | 4 | 7 | 0.0909 | 0.1591 |  | 6.5 | 7 | 0.1478 | 0.1591 |
| A4 | 0.1948 | 0.0262 | 5 | 14 | 0.1310 | 0.3669 |  | 13 | 14 | 0.3407 | 0.3669 |
| A5 | 0.1545 | 0.0208 | 3.5 | 11 | 0.0728 | 0.2286 |  | 5 | 11 | 0.1039 | 0.2286 |
| A6 | 0.1701 | 0.0229 | 3.5 | 12 | 0.0801 | 0.2747 |  | 7 | 12 | 0.1602 | 0.2747 |
| “Site and Ecology”(B) | 0.1238 | B1 | 0.3170 | 0.0392 | 1.5 | 3 | 0.0589 | 0.1178 |  | 2 | 3 | 0.0785 | 0.1178 |
| B2 | 0.3435 | 0.0425 | 4 | 7 | 0.1701 | 0.2977 |  | 4.5 | 7 | 0.1914 | 0.2977 |
| B3 | 0.3395 | 0.0420 | 2.5 | 5 | 0.1051 | 0.2102 |  | 1 | 5 | 0.0420 | 0.2102 |
| “Energy”(C) | 0.1271 | C1 | 0.3240 | 0.0412 | 6.5 | 10 | 0.2677 | 0.4118 |  | 6.5 | 10 | 0.2677 | 0.4118 |
| C2 | 0.3424 | 0.0435 | 9 | 10 | 0.3917 | 0.4352 |  | 10 | 10 | 0.4352 | 0.4352 |
| C3 | 0.3336 | 0.0424 | 4.5 | 12 | 0.1908 | 0.5088 |  | 5.5 | 12 | 0.2332 | 0.5088 |
| “Water”(D) | 0.1141 | D1 | 0.3713 | 0.0424 | 3 | 6 | 0.1271 | 0.2542 |  | 4 | 6 | 0.1694 | 0.2542 |
| D2 | 0.3562 | 0.0406 | 5 | 6 | 0.2031 | 0.2438 |  | 5.5 | 6 | 0.2235 | 0.2438 |
| D3 | 0.2725 | 0.0311 | 2.5 | 6 | 0.0777 | 0.1865 |  | 3 | 6 | 0.0933 | 0.1865 |
| “Material and Waste”(E) | 0.1267 | E1 | 0.2572 | 0.0326 | 5 | 5 | 0.1629 | 0.1629 |  | 3 | 5 | 0.0977 | 0.1629 |
| E2 | 0.2558 | 0.0324 | 3 | 4 | 0.0972 | 0.1296 |  | 1.5 | 4 | 0.0486 | 0.1296 |
| E3 | 0.2505 | 0.0317 | 6.5 | 9 | 0.2062 | 0.2855 |  | 9 | 9 | 0.2855 | 0.2855 |
| E4 | 0.2365 | 0.0299 | 5 | 5 | 0.1497 | 0.1497 |  | 4 | 5 | 0.1198 | 0.1497 |
| “Transportation”(F) | 0.1286 | F1 | 0.3376 | 0.0434 | 5 | 7 | 0.2171 | 0.3039 |  | 3 | 7 | 0.1303 | 0.3039 |
| F2 | 0.3120 | 0.0401 | 7 | 7 | 0.2809 | 0.2809 |  | 4 | 7 | 0.1605 | 0.2809 |
| F3 | 0.3504 | 0.0451 | 2 | 2 | 0.0901 | 0.0901 |  | 1.5 | 2 | 0.0676 | 0.0901 |
| “Indoor Environmental Quality (IEQ)”(G) | 0.1232 | G1 | 0.1655 | 0.0204 | 3 | 8 | 0.0612 | 0.1632 |  | 7 | 8 | 0.1428 | 0.1632 |
| G2 | 0.1664 | 0.0205 | 6.5 | 8 | 0.1334 | 0.1641 |  | 8 | 8 | 0.1641 | 0.1641 |
| G3 | 0.1525 | 0.0188 | 2.5 | 5 | 0.0470 | 0.0940 |  | 4 | 5 | 0.0752 | 0.0940 |
| G4 | 0.1699 | 0.0209 | 2.75 | 4 | 0.0576 | 0.0838 |  | 2.5 | 4 | 0.0524 | 0.0838 |
| G5 | 0.1655 | 0.0204 | 8 | 9 | 0.1632 | 0.1836 |  | 9 | 9 | 0.1836 | 0.1836 |
| G6 | 0.1803 | 0.0222 | 6 | 8 | 0.1334 | 0.1779 |  | 5 | 8 | 0.1112 | 0.1779 |
| “Building Management”(H) | 0.1219 | H1 | 0.2512 | 0.0306 | 6 | 13 | 0.1838 | 0.3982 |  | 10 | 13 | 0.3063 | 0.3982 |
| H2 | 0.2283 | 0.0278 | 1 | 3 | 0.0278 | 0.0835 |  | 3 | 3 | 0.0835 | 0.0835 |
| H3 | 0.2661 | 0.0324 | 3 | 7 | 0.0973 | 0.2271 |  | 4 | 7 | 0.1297 | 0.2271 |
| H4 | 0.2544 | 0.0310 | 1 | 3 | 0.0310 | 0.0930 |  | 2 | 3 | 0.0620 | 0.0930 |
| **Building Sustainability Evaluation Index (BSEI)** |  | **4.5618**  | **7.2944** |  |  |  | **5.1099**  | **7.2944** |
| **Building Sustainability Evaluation Ratio (BSER)** |  | **62.54%** |  |  |  | **70.05%** |

Table 9: Building Sustainability Evaluation Index (BSEI) – for the two Existing Buildings Case Studies

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Sustainability Indicators** **(SI)** | **SI Normalized Weight** | **Sustainability Attributes****(SA)** | **SA****Normalized Weight** | **SI****Global Weight** | **SNN building** |  | **FT building** |
| **Attained Credit Point** **(CP)** | **Maximum Credit Point****(CP)** | **Factor Index****(FI)** | **Maximum Factor Index (FI)max** |  | **Attained Credit Point (CP)** | **Maximum Credit Point (CP)** | **Factor Index (FI)** | **Maximum Factor Index****(FI)max** |
| “Site and Ecology”(B) | 0.1431 | B1 | 0.3170 | 0.0454 | 2 | 3 | 0.0907 | 0.1361 |  | 2 | 3 | 0.0907 | 0.1361 |
| B2 | 0.3435 | 0.0491 | 5.5 | 7 | 0.2703 | 0.3440 |  | 4.5 | 7 | 0.2211 | 0.3440 |
| B3 | 0.3395 | 0.0486 | 1 | 5 | 0.0486 | 0.2429 |  | 2.5 | 5 | 0.1214 | 0.2429 |
| “Energy”(C) | 0.1469 | C1 | 0.3240 | 0.0476 | 6.5 | 10 | 0.3093 | 0.4758 |  | 7.5 | 10 | 0.3569 | 0.4758 |
| C2 | 0.3424 | 0.0503 | 10 | 10 | 0.5028 | 0.5028 |  | 10 | 10 | 0.5028 | 0.5028 |
| C3 | 0.3336 | 0.0490 | 6.5 | 12 | 0.3185 | 0.5880 |  | 5.5 | 12 | 0.2695 | 0.5880 |
| “Water”(D) | 0.1318 | D1 | 0.3713 | 0.0489 | 6 | 6 | 0.2937 | 0.2937 |  | 3.5 | 6 | 0.1713 | 0.2937 |
| D2 | 0.3562 | 0.0469 | 5.5 | 6 | 0.2582 | 0.2817 |  | 5 | 6 | 0.2347 | 0.2817 |
| D3 | 0.2725 | 0.0359 | 5.5 | 6 | 0.1975 | 0.2155 |  | 5 | 6 | 0.1796 | 0.2155 |
| “Material and Waste”(E) | 0.1463 | E1 | 0.2572 | 0.0376 | 4 | 5 | 0.1506 | 0.1882 |  | 5 | 5 | 0.1882 | 0.1882 |
| E2 | 0.2558 | 0.0374 | 2.5 | 4 | 0.0936 | 0.1498 |  | 3 | 4 | 0.1123 | 0.1498 |
| E3 | 0.2505 | 0.0367 | 6.5 | 9 | 0.2383 | 0.3299 |  | 8.5 | 9 | 0.3116 | 0.3299 |
| E4 | 0.2365 | 0.0346 | 5 | 5 | 0.1730 | 0.1730 |  | 5 | 5 | 0.1730 | 0.1730 |
| “Transportation”(F) | 0.1486 | F1 | 0.3376 | 0.0502 | 5 | 7 | 0.2509 | 0.3512 |  | 4 | 7 | 0.2007 | 0.3512 |
| F2 | 0.3120 | 0.0464 | 7 | 7 | 0.3246 | 0.3246 |  | 2.5 | 7 | 0.1159 | 0.3246 |
| F3 | 0.3504 | 0.0521 | 1 | 2 | 0.0521 | 0.1041 |  | 0.75 | 2 | 0.0391 | 0.1041 |
| “Indoor Environmental Quality (IEQ) ”(G) | 0.1425 | G1 | 0.1655 | 0.0236 | 7 | 8 | 0.1650 | 0.1886 |  | 7.5 | 8 | 0.1768 | 0.1886 |
| G2 | 0.1664 | 0.0237 | 6.25 | 8 | 0.1482 | 0.1897 |  | 6.5 | 8 | 0.1541 | 0.1897 |
| G3 | 0.1525 | 0.0217 | 3.5 | 5 | 0.0760 | 0.1086 |  | 3.5 | 5 | 0.0760 | 0.1086 |
| G4 | 0.1699 | 0.0242 | 2.25 | 4 | 0.0545 | 0.0968 |  | 2.75 | 4 | 0.0666 | 0.0968 |
| G5 | 0.1655 | 0.0236 | 7.5 | 9 | 0.1768 | 0.2122 |  | 8 | 9 | 0.1886 | 0.2122 |
| G6 | 0.1803 | 0.0257 | 5 | 8 | 0.1284 | 0.2055 |  | 6 | 8 | 0.1541 | 0.2055 |
| “Building Management”(H) | 0.1409 | H1 | 0.2512 | 0.0354 | 10 | 13 | 0.3539 | 0.4601 |  | 8.5 | 13 | 0.3008 | 0.4601 |
| H2 | 0.2283 | 0.0322 | 3 | 3 | 0.0965 | 0.0965 |  | 1 | 3 | 0.0322 | 0.0965 |
| H3 | 0.2661 | 0.0375 | 4 | 7 | 0.1499 | 0.2624 |  | 4 | 7 | 0.1499 | 0.2624 |
| H4 | 0.2544 | 0.0358 | 2 | 3 | 0.0717 | 0.1075 |  | 2 | 3 | 0.0717 | 0.1075 |
| **Building Sustainability Evaluation Index (BSEI)** |  | **4.9933**  | **6.6288** |  |  |  | **4.6595**  | **6.6288** |
| **Building Sustainability Evaluation Ratio (BSER)** |  | **75.33%** |  |  |  | **70.29%** |

Table 10: Precedence of the BSAM scheme over the existing green building rating systems

|  |  |  |  |
| --- | --- | --- | --- |
| **Items** | **Other GBRS** | **BSAM Scheme** | **Reference *(inclusive of the GBRS documentations)*** |
| Inclusive of the **3 pillars of sustainable development –** *social, economic, and environmental sustainability criteria* | Mainly environmental criteria | All | Illankoon et al. (2017); Olawumi and Chan (2019) |
| Key **social** sustainability criteria - like *education, awareness, stakeholder relation, inclusiveness, employment* | None | In detail | Liu et al. (2013); Shari (2011) |
| Key **economic** sustainability criteria - *like local economy, re-use etc.*  | Little or no focus | In detail | Ali and Al Nsairat (2009); Liu et al. (2013); Wei et al. (2011) |
| **Cultural aspect** - such as *cultural heritage in design* | None except in ***BEAM Plus*** | In detail | Banani et al. (2013); Salehudin et al. (2012); Shari (2011) |
| “**Management**” criterion | Little or no focus | More focus | Illankoon et al. (2017); Olawumi and Chan (2019); Sev (2009) |
| “**Material and waste**” criterion (*at the construction phase*) | None | In detail | Olawumi and Chan (2019) |
| **Weighting methodology** – *robustness and capability of the method to express the interaction among the sustainability criteria* | “Aggregation of points” method – *incapable of expressing interaction* | GCFI method – *see section 2.3* | Mahmoud et al. (2019) |

**Note:** *GBRS – Green Building Rating System; GBRS documentations -* (*see* BCA, 2015; GBCA, 2017; HKGBC, 2019; IBEC, 2008; IGBC, 2014; USGBC, 2017)