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Construction Material selection based on Sustainability Principle: A Research in Surat City-India

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Abstract:

Sustainable construction materials mean the products which possess the environmental, economical and social merits maintaining the ecological impact. In this Research, the selection of construction material is focused based on the principle of sustainability. The sustainability criteria are framed in five dimension as General criteria, Economic criteria, Technical criteria, Environmental criteria and Social Criteria. A questionnaire survey was conducted in Surat city of Gujarat State that comprises of 41 criteria. A total of 144 questionnaires are received from various stakeholders of construction industry. The analysis was carried out for determination of the most effective criteria for the sustainable construction material in Surat city by Relative Importance Index (RII) and Exploratory Factor Analysis (EFA). A correlation matrix is developed to relate the relationship between all these selected 41 criteria, from the data obtained through questionnaire survey. The results show that not only objective criteria but also subjective criteria impose a role in sustainable materials selection. The analysis of the results may assist in framing the specifications for the manufactures to focus these criteria and the developers to adopt these criteria for sustainable development.

Keywords

Sustainability, Construction Material, EFA, RII, Selection Criteria

1. Introduction

The Indian economy has been recorded with a growth rate of between 7 and 8% since 2001. Building construction in India is estimated to grow at a rate of 6.6% per year from 8.0 billion square meters in 2005 to 41.0 billion square meters in 2030 (Sabapathy, Maithel, 2013). The building stock is expected to multiply five times during this period, resulting in a continuous increase in demand for building materials. Construction practice and Building Design with sustainability features is gaining noteworthy lift in the construction industry. Designers and owners are understanding that with sustainable design, buildings can save energy and have a decreased impact on the environment. Each construction is unique and so the framework that can be effectively utilized under umbrella of sustainability for one project may prove to be ineffective for other projects. Hence, the critical issue is the effective selection of building materials with sustainability features. These set of approaches are shaping the construction industry into revolutionary and competiveness and leading to promote the sustainability through standards and policies.

2. Developments of Sustainability assessment criteria

The selection phase of construction materials includes many criteria and functions that all plays a role in final outcomes and concluding decisions. Here, the selection is basically categorized under objective factors and subjective factors. The proposed criteria framework under the research involves both the objective factors and subjective factors. Research concludes that decisions change when not only objective but also subjective factors are considered. Such results may assists construction material manufactures, suppliers and designers to select the right materials by considering not only budget, design and LEED constraints but also information about perceived values (Florez, Lacouture, 2013). The following guidelines has been developed to assist the selection of construction materials sustainability assessment criteria:

2.1. Comprehensiveness

The criteria that have chosen must involve the selection with both objective factor and subjective factors. The criteria must reflect the march from sustainable materials to sustainable buildings.

2.2. Applicability

The criteria must respond to the construction standards, rules and policies. It must be legally and logically fit to adopt in construction practice.

2.3. Transparency

The criteria must reflect the transparency from various materials selection under similar functions so that the stakeholders can compare the various materials and choose most effective one.

2.4. Practicability

The criteria must be practicable in construction industry in assessment of economic, technical, environmental and social consideration. It must not oppose any construction standards and policies.

3. Research Methodology

The research is followed by two different analysis for the same data that is collected by questionnaire survey. .

3.1. Relative Importance Index (RII)

Relative index analysis was selected in this study to rank the criteria according to their relative importance. The following formula is used to determine the relative index (Olomolaiye et al., 1987; Chinyio et al., 1998; Chan and Kumaraswamy, 1997; Adetunji, 2005; Braimah and Ndekugri, 2009):

$$RII = \Sigma W / A*N$$

Where;

W is the weighting as assigned by each respondent on a scale of one to five with one implying the least and five the highest. A is the highest weight (i.e. 5 in our case) and N is the total number of the respondents.

3.2. Exploratory Factor Analysis (EFA)

EFA is a technique within factor analysis by which one can identify the underlying relationships between measured variables. EFA is carried out in 5 Stages:

Descriptive: There are several options under descriptive; this allows you to decide on how the factors are to be extracted and how many factors to retain. This allows you to decide on how the factors are to be extracted and how many factors to retain.

Extraction: This allows you to decide on how the factors are to be extracted and how many factors to retain. By default, the number of factors that are having Eigen value higher than 1 are considered for further analysis.

Rotation: Specifying the nature of relationship between the factors. Factors can be deemed to be correlated (oblique) or uncorrelated (orthogonal).

Score: This option is used for further analysis, or simply to identify groups of subjects having higher scores.

Options: This option helps in sorting the data by size and suppressing the absolute value by the fixed value to be considered.

4. Data Collection

The data is collected is a form of questionnaire survey that comprises of set of criteria that affect the construction sustainable material selection as mentioned above. These Questionnaire is surveyed in Surat city of Gujarat state only since it is the limit area chosen under the research. A total of 200 questionnaire is being circulated among the various stakeholders of construction to whom sustainable material selections come into consideration. Out of 200 questionnaire, 144 questionnaire is replied by the respondents.

Table 1. Contribution of various stakeholders in data collection

Types of Respondent	No. of Questionnaire Filled
Project Manager	08
Consultant	10
Contractor	26
Site Engineer	82
Developer/Owner	08
Material Supplier/Producer	10

5. Data Analysis by RII

The above equation for RII can be explored as follow:

$$RII = \frac{5n5 + 4n4 + 3n3 + 2n2 + 1n1}{A*N}$$

Where;

n5 = the number of respondents who answered "Extremely Important"

n4 = the number of respondents who answered "Important"

n3 = the number of respondents who answered "Neutral"

n2 = the number of respondents who answered "Somewhat Important"

n1 = the number of respondents who answered "Not at all Important"

Table 2. RII results of all criteria

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Criteria	n1	n2	n3	n4	n5	RII
G1 Availability of materials	0	0	0	45	99	0.938
G2 User’s Choice	1	5	54	62	22	0.738
G3 Relationship with the distributor	3	14	62	50	15	0.683
G4 Experience of User	0	4	23	96	21	0.786
G5 Scale of demand	0	7	48	76	13	0.732
G6 Legal/Standard Norms	0	18	50	58	18	0.706
E1 Cost of material	0	0	3	24	117	0.958
E2 Transportation cost	2	2	16	77	47	0.829
E3 Initial-acquisition cost	1	5	17	50	71	0.857
E4 Storage cost	1	2	44	84	13	0.747
E5 Maintenance cost	0	0	56	60	28	0.761
E6 Disposal cost	1	14	60	59	10	0.688
E7 Labour cost and availability	0	6	16	84	38	0.814
E8 Life cycle cost	1	6	22	80	35	0.797
T1 Strength	0	0	3	33	108	0.946
T2 Durability	0	1	2	18	123	0.965
T3 Weight and Dimension	4	8	9	36	87	0.869
T4 Maintainability	1	8	35	80	20	0.753
T5 Reusability	2	10	43	74	15	0.725
T6 Material fixing	4	8	21	75	36	0.782
T7 Heat resistance	5	7	75	45	12	0.672
T8 Fire resistance	7	9	78	33	17	0.661
T9 Water resistance	6	4	58	58	18	0.708
T10 Chemical resistance	6	17	81	29	11	0.631
T11 Sound resistance	4	34	68	30	8	0.606
T12 Coefficient of thermal expansion	6	33	50	40	15	0.635
N1 Potential for recycling and reuse	6	5	16	80	37	0.790
N2 Availability of environmentally sound disposal options	7	4	31	80	22	0.747
N3 Ozone depletion potential	6	27	65	33	13	0.628
N4 Level of toxicity	5	45	48	40	6	0.596
N5 Embodied energy within material	4	32	59	43	6	0.621
N6 Amount of likely wastage in use of material	4	14	49	66	11	0.692
N7 Fuel consumption	10	27	42	49	16	0.647
S1 Health and safety	1	2	7	76	58	0.861
S2Decorative/Creativity/Artistic look of material	0	13	34	67	30	0.758
S3 Maturity of locality	1	8	44	54	37	0.764
S4 Development rate of locality	3	3	41	45	52	0.794
S5 Metaphysical feelings	6	54	48	29	7	0.568

S6 Cultural aspects	3	55	53	22	11	0.576
S7 Customer Emotions	5	56	43	29	11	0.579
S8 User's special demand	1	23	56	52	12	0.671

5. Data Analysis by EFA

Exploratory Factor Analysis is a statistics technique under SPSS Software which is used to uncover various relationship of large set of variables. EFA cover a large statistics data results and in the research the test and results are limited to listed results whose value is directly obtained from EFA tools.

5.1. KMO and Bartlett's Test

The Kaiser-Meyer-Olkin Measure of Sampling (KMO) is an index for comparing the magnitudes of the observed correlation coefficients to the magnitudes of the partial correlation coefficients. The following criteria are used to assess and describe the sampling adequacy (Kaiser, 1974):

- 0.90 = Marvelous
- 0.80 = Meritorious
- 0.60 = Mediocre
- 0.70 = Middling
- 0.50 = Miserable
- Below 0.50 = Unacceptable

The significant value in Bartlett test significant indicates that the correlation matrix is significantly different from an identity matrix, in which correlations between variables are all zero. This value must be less than 0.05.

Table 3. KMO and Bartlett's Test Result

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.787
Bartlett's Test of Sphericity	Approx. Chi-Square	4365.652
	df	820
	Sig.	.000

5.2. Factor Extraction

The Eigen values represent variance. Because the variance that each standardized variable contributes to a principal factor extraction is 1, a factor with an eigenvalues less than 1 is not as important, from a variance perspective, as an observed variable.

In our Data result, out of 41 criteria only 9 criteria is having Eigen value greater than 1, and so only 9 components are considered for further analysis. These 9 components comprises 72.723 of the total variance. Out of 41 criteria, the data is compressed to 9 dominants components that plays a vital role in sustainable materials selection.

5.3. Correlation Matrix

In the correlation matrix; the matrix indicates how each components (here in our case it is the criteria) is correlated to the other components. The value of the matrix ranges from +1(positive one) to -1 (negative one); having unity value for its principal axis. The positive value of the matrix indicates that the two criteria are positively correlates with each other while the negative value indicates that the two criteria are negatively correlates with each other.

The correlation matrix is a square matrix of having row or column of each component. Since we have taken 41 criteria in the research; the correlation matrix generated is of 41 * 41 square matrix. Relatively high correlations indicate that two items are associated and will probably be grouped together by the factor analysis. Items with low correlations (e.g., ≤.20) usually will not have high loadings on the same factor.

From the correlation matrix, one can judge how importantly one criteria is associated with the rest of all the criteria under the same approach. In the entire set of matrix values the positive values are higher moreover very few criteria correlation falls less than (negative) 0.3 value. Hence the interdependency achieved in the data and analysis is remarkable.

Table 4. Value of Total Variance based on Eigen Value

Total Variance Explained							
Component	**Initial Eigenvalues**			**Extraction Sums of Squared Loadings**			**Rotation Sums of Squared Loadings[a]**
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	9.037	22.042	22.042	9.037	22.042	22.042	6.374
2	5.748	14.019	36.062	5.748	14.019	36.062	6.323
3	4.706	11.478	47.540	4.706	11.478	47.540	5.480
4	2.823	6.884	54.424	2.823	6.884	54.424	3.025
5	1.971	4.807	59.231	1.971	4.807	59.231	2.974
6	1.934	4.718	63.949	1.934	4.718	63.949	4.414
7	1.334	3.253	67.202	1.334	3.253	67.202	2.535
8	1.148	2.800	70.002	1.148	2.800	70.002	2.650
9	1.116	2.721	72.723	1.116	2.721	72.723	2.330
10	.966	2.356	75.079				
11	.862	2.102	77.181				
12	.765	1.866	79.047				
13	.716	1.746	80.793				
14	.662	1.615	82.408				
15	.625	1.524	83.931				
16	.613	1.496	85.427				
17	.510	1.244	86.671				
18	.470	1.146	87.817				
19	.444	1.084	88.901				
20	.411	1.003	89.904				
21	.389	.950	90.854				
22	.343	.838	91.691				
23	.321	.783	92.474				
24	.296	.721	93.195				
25	.287	.700	93.894				
26	.270	.658	94.552				
27	.252	.614	95.166				
28	.249	.608	95.774				
29	.215	.524	96.298				
30	.203	.496	96.794				
31	.194	.473	97.266				
32	.180	.439	97.705				
33	.165	.404	98.109				
34	.142	.347	98.456				
35	.126	.307	98.763				
36	.121	.295	99.058				

37	.100	.244	99.302				
38	.094	.229	99.530				
39	.083	.202	99.732				
40	.062	.150	99.883				
41	.048	.117	100.000				
Extraction Method: Principal Component Analysis.							
a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance.							

Table 5(a). Correlation matrix of criteria G1 to E4

	G1	G2	G3	G4	G5	G6	E1	E2	E3	E4
G1	1	0.263	0.218	0.207	0.332	0.048	0.548	0.224	0.277	0.295
G2	0.263	1	0.236	0.407	0.267	0.22	0.127	0.074	-0.196	0.316
G3	0.218	0.236	1	0.162	0.273	0.168	0.026	0.412	0.027	0.342
G4	0.207	0.407	0.162	1	0.36	0.116	0.236	-0.022	0.023	0.444
G5	0.332	0.267	0.273	0.36	1	0.372	0.233	0.141	0.08	0.192
G6	0.048	0.22	0.168	0.116	0.372	1	-0.091	0.28	-0.147	0.061
E1	0.548	0.127	0.026	0.236	0.233	-0.091	1	0.185	0.438	0.208
E2	0.224	0.074	0.412	-0.022	0.141	0.28	0.185	1	0.326	0.331
E3	0.277	-0.196	0.027	0.023	0.08	-0.147	0.438	0.326	1	0.022
E4	0.295	0.316	0.342	0.444	0.192	0.061	0.208	0.331	0.022	1
E5	0.147	0.382	0.104	0.162	0.298	0.454	-0.017	0.147	-0.187	0.347
E6	0.241	0.074	0.158	0.348	0.204	0.028	0.254	0.123	0.279	0.326
E7	0.146	0.061	0.214	-0.019	0.219	0.238	0.21	0.154	0.113	0.094
E8	0.178	0.026	-0.132	0.162	0.165	0.214	0.282	0.117	0.314	-0.02
T1	0.27	0.229	0.053	0.206	0.255	0.075	0.402	0.178	0.201	0.228
T2	0.396	0.098	-0.113	0.077	0.159	-0.049	0.556	0.032	0.442	0.077
T3	0.44	0.075	-0.101	0.155	0.155	-0.059	0.672	0.176	0.529	0.188
T4	0.276	0.273	0.002	0.106	0.156	0.174	0.35	0.115	0.173	0.254
T5	0.278	0.055	0.044	0.003	0.116	0.074	0.408	0.164	0.382	0.176
T6	0.225	-0.095	-0.082	0.001	0.048	0.016	0.417	0.222	0.479	0.164
T7	0.076	-0.008	0.069	-0.134	0.008	0.197	0.088	0.38	0.167	0.133
T8	-0.068	-0.031	0.15	-0.162	-0.032	0.309	-0.079	0.315	0.004	0.085
T9	0.006	0.013	0.11	-0.092	-0.038	0.186	0.021	0.297	0.116	0.146
T10	-0.088	0.039	0.161	-0.043	0.05	0.342	-0.077	0.336	0.062	0.105
T11	-0.081	0.072	0.227	-0.107	0.137	0.345	-0.072	0.351	0.026	0.024
T12	-0.075	-0.044	0.289	-0.024	0.033	0.271	-0.13	0.265	0.039	0.127
N1	0.205	-0.048	0.016	-0.063	-0.014	-0.097	0.4	0.154	0.519	-0.065
N2	0.116	-0.132	0.162	-0.008	-0.106	-0.104	0.201	0.318	0.519	0.045
N3	-0.043	-0.034	0.063	-0.153	-0.053	0.371	-0.124	0.281	-0.031	0.003
N4	-0.062	-0.073	-0.048	-0.117	0.031	0.293	-0.204	0.071	0.102	-0.141
N5	0.012	0.145	0.051	-0.048	-0.021	0.172	-0.015	0.18	-0.057	0.046
N6	0.028	0.216	0.204	0.106	0.084	0.204	0.013	0.323	0.03	0.184
N7	0.091	0.149	0.18	0.013	0.077	0.25	0.155	0.305	0.054	0.133
S1	0.103	0.212	0.031	0.095	0.241	0.311	0.137	0.216	0.206	-0.051
S2	0.079	0.467	0.267	0.111	0.11	0.109	-0.057	0.21	-0.283	0.12
S3	0.181	0.454	0.261	0.278	0.165	-0.011	0.213	0.366	-0.068	0.336
S4	0.153	0.281	0.27	0.234	0.088	-0.225	0.242	0.315	0.154	0.272
S5	0.154	0.438	0.237	0.288	0.217	0.152	0.115	0.323	0.03	0.261
S6	0.152	0.4	0.2	0.214	0.156	0.244	0.103	0.306	-0.095	0.279
S7	0.108	0.625	0.26	0.385	0.26	0.293	-0.017	0.188	-0.335	0.33
S8	0.171	0.602	0.198	0.529	0.274	0.185	0.046	0.171	-0.229	0.437

Table 5(b). Correlation matrix of criteria E5 to T6

	E5	E6	E7	E8	T1	T2	T3	T4	T5	T6
G1	0.147	0.241	0.146	0.178	0.27	0.396	0.44	0.276	0.278	0.225
G2	0.382	0.074	0.061	0.026	0.229	0.098	0.075	0.273	0.055	-0.095
G3	0.104	0.158	0.214	-0.132	0.053	-0.113	-0.101	0.002	0.044	-0.082
G4	0.162	0.348	-0.019	0.162	0.206	0.077	0.155	0.106	0.003	0.001
G5	0.298	0.204	0.219	0.165	0.255	0.159	0.155	0.156	0.116	0.048
G6	0.454	0.028	0.238	0.214	0.075	-0.049	-0.059	0.174	0.074	0.016
E1	-0.017	0.254	0.21	0.282	0.402	0.556	0.672	0.35	0.408	0.417
E2	0.147	0.123	0.154	0.117	0.178	0.032	0.176	0.115	0.164	0.222
E3	-0.187	0.279	0.113	0.314	0.201	0.442	0.529	0.173	0.382	0.479
E4	0.347	0.326	0.094	-0.02	0.228	0.077	0.188	0.254	0.176	0.164
E5	1	0.11	-0.026	0.209	0.277	0.044	-0.031	0.221	0.11	-0.026
E6	0.11	1	0.344	0.422	-0.035	0.171	0.307	0.235	0.353	0.282
E7	-0.026	0.344	1	0.265	0.052	0.2	0.24	0.356	0.311	0.224
E8	0.209	0.422	0.265	1	0.242	0.336	0.372	0.175	0.304	0.207
T1	0.277	-0.035	0.052	0.242	1	0.53	0.416	0.341	0.285	0.191
T2	0.044	0.171	0.2	0.336	0.53	1	0.681	0.445	0.473	0.499
T3	-0.031	0.307	0.24	0.372	0.416	0.681	1	0.623	0.665	0.627
T4	0.221	0.235	0.356	0.175	0.341	0.445	0.623	1	0.667	0.593
T5	0.11	0.353	0.311	0.304	0.285	0.473	0.665	0.667	1	0.635
T6	-0.026	0.282	0.224	0.207	0.191	0.499	0.627	0.593	0.635	1
T7	0.125	0.066	0.287	0.123	0.103	0.234	0.229	0.48	0.411	0.578
T8	0.097	-0.031	0.285	0.015	-0.017	0.059	0.087	0.405	0.325	0.467
T9	0.033	0.058	0.27	0.011	0.065	0.211	0.184	0.43	0.325	0.543
T10	0.121	0.034	0.221	0.113	0.048	-0.037	0.011	0.245	0.255	0.359
T11	0.168	-0.037	0.352	0.08	0.13	0.097	-0.019	0.312	0.217	0.266
T12	0.154	0.24	0.288	0.131	-0.1	-0.024	0.002	0.198	0.152	0.3
N1	-0.214	0.16	0.136	0.233	0.168	0.414	0.539	0.335	0.412	0.49
N2	-0.27	0.284	0.233	0.167	0.011	0.219	0.33	0.193	0.285	0.444
N3	0.263	0.222	0.252	0.185	-0.053	0.07	-0.043	0.21	0.155	0.201
N4	0.203	0.264	0.252	0.269	-0.012	0.071	0.015	0.2	0.233	0.109
N5	0.222	-0.184	0.021	-0.107	0.177	0.078	-0.002	0.166	0.073	0.02
N6	-0.002	0.001	0.2	-0.011	0.177	0.077	0.079	0.189	0.124	0.111
N7	0.117	-0.128	0.257	0.028	0.302	0.233	0.303	0.317	0.224	0.213
S1	0.266	0.125	0.192	0.364	0.163	0.036	0.107	0.005	0.019	-0.022
S2	0.271	-0.291	0.044	-0.175	0.258	-0.124	-0.123	0.142	-0.051	-0.135
S3	0.124	-0.123	-0.044	-0.15	0.361	0.008	0.153	0.196	0.04	0.022
S4	-0.027	-0.094	-0.096	-0.166	0.355	0.115	0.219	0.103	0.147	0.13
S5	0.281	0.001	0.056	0.098	0.413	0.142	0.216	0.266	0.226	0.078
S6	0.391	-0.014	0.131	0.081	0.348	0.08	0.151	0.289	0.157	0.09
S7	0.391	0.04	0.103	-0.01	0.266	-0.054	-0.033	0.206	-0.022	-0.143
S8	0.313	0.027	0.092	0.088	0.356	-0.003	0.105	0.174	0.011	-0.098

Table 5(c). Correlation matrix of criteria T7 to N4

	T7	T8	T9	T10	T11	T12	N1	N2	N3	N4
G1	0.076	-0.068	0.006	-0.088	-0.081	-0.075	0.205	0.116	-0.043	-0.062
G2	-0.008	-0.031	0.013	0.039	0.072	-0.044	-0.048	-0.132	-0.034	-0.073
G3	0.069	0.15	0.11	0.161	0.227	0.289	0.016	0.162	0.063	-0.048
G4	-0.134	-0.162	-0.092	-0.043	-0.107	-0.024	-0.063	-0.008	-0.153	-0.117
G5	0.008	-0.032	-0.038	0.05	0.137	0.033	-0.014	-0.106	-0.053	0.031
G6	0.197	0.309	0.186	0.342	0.345	0.271	-0.097	-0.104	0.371	0.293
E1	0.088	-0.079	0.021	-0.077	-0.072	-0.13	0.4	0.201	-0.124	-0.204
E2	0.38	0.315	0.297	0.336	0.351	0.265	0.154	0.318	0.281	0.071
E3	0.167	0.004	0.116	0.062	0.026	0.039	0.519	0.519	-0.031	0.102

E4	0.133	0.085	0.146	0.105	0.024	0.127	-0.065	0.045	0.003	-0.141
E5	0.125	0.097	0.033	0.121	0.168	0.154	-0.214	-0.27	0.263	0.203
E6	0.066	-0.031	0.058	0.034	-0.037	0.24	0.16	0.284	0.222	0.264
E7	0.287	0.285	0.27	0.221	0.352	0.288	0.136	0.233	0.252	0.252
E8	0.123	0.015	0.011	0.113	0.08	0.131	0.233	0.167	0.185	0.269
T1	0.103	-0.017	0.065	0.048	0.13	-0.1	0.168	0.011	-0.053	-0.012
T2	0.234	0.059	0.211	-0.037	0.097	-0.024	0.414	0.219	0.07	0.071
T3	0.229	0.087	0.184	0.011	-0.019	0.002	0.539	0.33	-0.043	0.015
T4	0.48	0.405	0.43	0.245	0.312	0.198	0.335	0.193	0.21	0.2
T5	0.411	0.325	0.325	0.255	0.217	0.152	0.412	0.285	0.155	0.233
T6	0.578	0.467	0.543	0.359	0.266	0.3	0.49	0.444	0.201	0.109
T7	1	0.856	0.83	0.709	0.635	0.466	0.314	0.393	0.515	0.316
T8	0.856	1	0.809	0.786	0.633	0.576	0.192	0.346	0.566	0.378
T9	0.83	0.809	1	0.725	0.605	0.5	0.32	0.384	0.444	0.283
T10	0.709	0.786	0.725	1	0.732	0.578	0.254	0.343	0.494	0.347
T11	0.635	0.633	0.605	0.732	1	0.523	0.161	0.197	0.438	0.225
T12	0.466	0.576	0.5	0.578	0.523	1	0.224	0.349	0.544	0.439
N1	0.314	0.192	0.32	0.254	0.161	0.224	1	0.717	0.192	0.14
N2	0.393	0.346	0.384	0.343	0.197	0.349	0.717	1	0.316	0.233
N3	0.515	0.566	0.444	0.494	0.438	0.544	0.192	0.316	1	0.644
N4	0.316	0.378	0.283	0.347	0.225	0.439	0.14	0.233	0.644	1
N5	0.304	0.315	0.235	0.39	0.378	0.208	0.231	0.127	0.308	0.35
N6	0.315	0.332	0.295	0.353	0.344	0.282	0.392	0.41	0.296	0.23
N7	0.384	0.394	0.38	0.426	0.433	0.235	0.282	0.255	0.167	0.159
S1	0.097	0.028	0.024	0.29	0.249	0.092	0.259	0.138	0.187	0.254
S2	0.207	0.232	0.144	0.214	0.296	0.009	-0.157	-0.181	0.068	-0.089
S3	0.141	0.082	0.069	0.105	0.198	-0.108	0.022	-0.016	-0.115	-0.289
S4	0.116	0.017	0.09	0.104	0.166	-0.094	0.192	0.134	-0.237	-0.307
S5	0.237	0.188	0.215	0.311	0.434	0.134	0.015	0.023	0.039	0.058
S6	0.244	0.26	0.197	0.346	0.417	0.162	-0.069	-0.075	0.162	0.097
S7	0.053	0.049	0.024	0.128	0.276	0.111	-0.254	-0.208	0.065	-0.031
S8	-0.004	0.047	0.021	0.111	0.168	-0.014	-0.183	-0.135	-0.092	-0.101

Table 5(d). Correlation matrix of criteria N5 to S8

	N5	N6	N7	S1	S2	S3	S4	S5	S6	S7	S8
G1	0.012	0.028	0.091	0.103	0.079	0.181	0.153	0.154	0.152	0.108	0.171
G2	0.145	0.216	0.149	0.212	0.467	0.454	0.281	0.438	0.4	0.625	0.602
G3	0.051	0.204	0.18	0.031	0.267	0.261	0.27	0.237	0.2	0.26	0.198
G4	-0.048	0.106	0.013	0.095	0.111	0.278	0.234	0.288	0.214	0.385	0.529
G5	-0.021	0.084	0.077	0.241	0.11	0.165	0.088	0.217	0.156	0.26	0.274
G6	0.172	0.204	0.25	0.311	0.109	-0.011	-0.225	0.152	0.244	0.293	0.185
E1	-0.015	0.013	0.155	0.137	-0.057	0.213	0.242	0.115	0.103	-0.017	0.046
E2	0.18	0.323	0.305	0.216	0.21	0.366	0.315	0.323	0.306	0.188	0.171
E3	-0.057	0.03	0.054	0.206	-0.283	-0.068	0.154	0.03	-0.095	-0.335	-0.229
E4	0.046	0.184	0.133	-0.051	0.12	0.336	0.272	0.261	0.279	0.33	0.437
E5	0.222	-0.002	0.117	0.266	0.271	0.124	-0.027	0.281	0.391	0.391	0.313
E6	-0.184	0.001	-0.128	0.125	-0.291	-0.123	-0.094	0.001	-0.014	0.04	0.027
E7	0.021	0.2	0.257	0.192	0.044	-0.044	-0.096	0.056	0.131	0.103	0.092
E8	-0.107	-0.011	0.028	0.364	-0.175	-0.15	-0.166	0.098	0.081	-0.01	0.088
T1	0.177	0.177	0.302	0.163	0.258	0.361	0.355	0.413	0.348	0.266	0.356
T2	0.078	0.077	0.233	0.036	-0.124	0.008	0.115	0.142	0.08	-0.054	-0.003
T3	-0.002	0.079	0.303	0.107	-0.123	0.153	0.219	0.216	0.151	-0.033	0.105
T4	0.166	0.189	0.317	0.005	0.142	0.196	0.103	0.266	0.289	0.206	0.174
T5	0.073	0.124	0.224	0.019	-0.051	0.04	0.147	0.226	0.157	-0.022	0.011

T6	0.02	0.111	0.213	-0.022	-0.135	0.022	0.13	0.078	0.09	-0.143	-0.098
T7	0.304	0.315	0.384	0.097	0.207	0.141	0.116	0.237	0.244	0.053	-0.004
T8	0.315	0.332	0.394	0.028	0.232	0.082	0.017	0.188	0.26	0.049	0.047
T9	0.235	0.295	0.38	0.024	0.144	0.069	0.09	0.215	0.197	0.024	0.021
T10	0.39	0.353	0.426	0.29	0.214	0.105	0.104	0.311	0.346	0.128	0.111
T11	0.378	0.344	0.433	0.249	0.296	0.198	0.166	0.434	0.417	0.276	0.168
T12	0.208	0.282	0.235	0.092	0.009	-0.108	-0.094	0.134	0.162	0.111	-0.014
N1	0.231	0.392	0.282	0.259	-0.157	0.022	0.192	0.015	-0.069	-0.254	-0.183
N2	0.127	0.41	0.255	0.138	-0.181	-0.016	0.134	0.023	-0.075	-0.208	-0.135
N3	0.308	0.296	0.167	0.187	0.068	-0.115	-0.237	0.039	0.162	0.065	-0.092
N4	0.35	0.23	0.159	0.254	-0.089	-0.289	-0.307	0.058	0.097	-0.031	-0.101
N5	1	0.584	0.469	0.345	0.333	0.292	0.191	0.356	0.408	0.244	0.231
N6	0.584	1	0.505	0.263	0.189	0.396	0.281	0.338	0.282	0.211	0.335
N7	0.469	0.505	1	0.227	0.263	0.346	0.318	0.469	0.506	0.286	0.328
S1	0.345	0.263	0.227	1	0.152	0.111	0.076	0.222	0.35	0.195	0.19
S2	0.333	0.189	0.263	0.152	1	0.578	0.459	0.56	0.571	0.596	0.536
S3	0.292	0.396	0.346	0.111	0.578	1	0.742	0.619	0.548	0.527	0.603
S4	0.191	0.281	0.318	0.076	0.459	0.742	1	0.535	0.392	0.334	0.454
S5	0.356	0.338	0.469	0.222	0.56	0.619	0.535	1	0.795	0.644	0.687
S6	0.408	0.282	0.506	0.35	0.571	0.548	0.392	0.795	1	0.7	0.661
S7	0.244	0.211	0.286	0.195	0.596	0.527	0.334	0.644	0.7	1	0.736
S8	0.231	0.335	0.328	0.19	0.536	0.603	0.454	0.687	0.661	0.736	1

6. Conclusion

i. The top criteria for sustainable construction material selection are Durability, Cost of the material, Strength and Availability of materials in decreasing order.

ii. The top 10 criteria includes the social criteria, hence the subjective factors also plays a vital role as importantly as objective factors.

iii. The top 10 criteria does not includes any criteria of environmental factors, hence need to focus more on environmental aspects to achieve sustainability.

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