Investigation of Measures for Sustainable Development using Sustainable Construction

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Abstract— **Sustainable construction practices throughout the life cycle of a project refer to minimize the adverse effect on social, environmental and economic development in a country. The present study focused on how sustainable construction practices contribute to the sustainable development of a country. 36 factors related to sustainable constructions were identified under three categories namely environmental development, social development and economic development through a comprehensive literature review. The importance of the identified factors was assessed based on the responses collected through a questionnaire. Respondents include experts in the CS2 to C5 grades construction companies. The relative importance index (RII) was used to translate the collected responses into a quantitative value. Further correlation between factors within three categories and correlation between three categories were determined through a complete SPSS analysis. With those results, it can be identified which factors need to be addressed to improve the sustainable development of a country effectively. So, project teams can get necessary actions to improve such factors to achieve sustainable development through sustainable construction practices. In addition to that factor analysis was conducted to highlight the factors that can be addressed simultaneously.**

Keywords—construction industry, sustainable construction, sustainable development

I. INTRODUCTION

Sustainable construction is more than the fabric of the built environment [1] and it is a key to bring many benefits to the environment, society and economy of any country. It is a better solution for construction activities. Generally, increasing greenhouse gas emissions, global warming, depletion of resources and climate change can happen due to current construction practices. Global warming and climate change have become the most burning question in the earth's sustainability as a result of greenhouse gas emissions [2]. Sustainable development is defined in many [3] ways and primarily it is to meet the needs of the present without compromising the ability of future generations to meet their own needs. Further, sustainable development directly affects the development of any country. To achieve sustainable construction, the construction industry must increase the use of renewable, reused, and recycled resources and construction practices; optimize resource use; use minimal energy; employ effective equipment; employ effective waste and water management practices; and provide comfortable and sanitary working conditions [4].

With this background, the main aim of this research study is to identify how sustainable construction can be used to promote sustainable development in a country from the perspective of environmental, social and economic development. To achieve this aim, first, indicators of sustainable development were identified. Then, the contribution of sustainable construction indicators for sustainable development was investigated and critically analyzed.

II. LITERATURE REVIEW

A. Sustainability and Sustainable Concept

With the rapid increase of the global population, the construction sector has become mandatory and fast-growing even though it is highly impactful on environmental sustainability. With the global trend towards sustainable development, sustainable construction is

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becoming the latest and most popular practice in the modern-day building sector.

The main goal of sustainability is to ensure the continuity of human beings and natural resources by protecting the natural and built environment [5]. Sustainability has three main dimensions: environmental, economic, and societal. Interactions between these dimensions, such as environmental conservation, economic advancement, and social fairness, are some of the keys to a country's long-term viability. These three dimensions are inseparable units that cannot exist alone in a system as they are integrated. This concept is described by many researchers [6], [7] and Fig.1 is one example. It facilitates to understand how sustainable development practically can be achieved by combining various sustainable factors. Further, this is the requirement for 'systems thinking' in sustainable development [7].

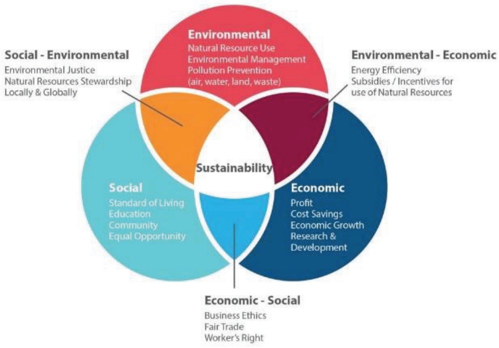

Fig. 1. Different spheres of sustainable development

Sustainable development strategies as mentioned by [8] can be considered in sustainable construction. Those are related to respect and care for communal living, human life quality, aliveness and diversity on the earth, unrenewable resource consumption, bearing capacity of the earth, individual behaviors and habits, respect for the environment by societies, integration between development protection, application of sustainability in a global scale.

B. *Sustainability in Construction Sector*

Construction, operation, maintenance and the destruction of buildings are causing detrimental environmental issues. Construction energy exploits vast amounts of energy, natural resources and degrades the quality of air and water in cities leading to climate change and global warming [9]. A study conducted in 2010 showed that the construction industry consumes 45% of global energy and 50% of the world's water resources. Moreover, the buildings are responsible for 23% of air pollution, 50% of greenhouse gas production, 40% of water pollution, and 40% of solid waste in cities [10]. Environmental and socioeconomic repercussions are the most explicit or observable effects of the building sector, and they can generate a variety of problems [11]. However, changing the practices in the construction industry towards sustainability will reduce the negative impacts such as overconsumption of resources and make it more beneficial. It is the ideal approach to bring sustainable construction into convention construction. The use of sustainable approaches to building construction helps to improve architectural design and retrofitting the existing residential buildings can greatly improve not only the indoor environment; but also offer the potential of reducing energy consumption along with long-term running costs of the buildings [12].

Green buildings have a minimal impact on the environment throughout their lifespan [13] starting with the design phase and continuing through construction, repair, and maintenance. The green idea highlights the importance of environmental values as well as responsibility for resource efficiency. Jayalath and Perera [14] have evolved the importance of focusing on policy components such as traditional knowledge to sustainable bid selection, deconstruction, adaptive reuse, tax and levies reduction, sustainable products, and low carbon initiatives.

According to the World Green Building Council (WGBC) initially, green buildings rise in response to the excessive consumption of energy and natural resources; but for the time being, green building construction means more than merely the effective usage of energy by further developing the concept of green building [15]. Buildings that meet these criteria receive certification as green buildings. Among these certificates, the most commonly accepted ones are LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Method). The Green Building Council in Sri Lanka was established in 2009 and it is the leading authority in implementing green concepts and green building practices. The main purpose of the GREENSL®

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Rating System is to encourage the design of buildings in an environmentally acceptable manner. GREENSL® Rating System is used as a tool to evaluate the efficiency of the built environment in the areas of Management, Energy, Indoor Environmental Quality, Materials to name a few and points are assigned for each category and the rating is given upon the total marks earned by each design or building solution [16].

III. METHODOLOGY

36 factors related to sustainable construction which are affecting for the sustainable development of a country were identified under three categories of Environmental, Social and Economic. Those factors are shown in Table I. A questionnaire was prepared to get the importance level of identified factors using five-point Likert scale.

There are 503 contractors registered with Construction Industry Development Authority (CIDA) in 2020 [17] from grades CS2 to C5. The sample size was calculated statistically considering 80% confidence interval and 10% error margin to represent that population and it was 38 respondents. 55 responses have been received covering 38 construction companies from the questionnaire survey which was carried out through a google form and direct interviews. The importance of sustainable factors was identified using the Relative Importance Index (RII). Identification of interrelationships between factors within each category, Identification of interrelationships between three categories and factor analysis were conducted through SPSS statistical software.

TABLE I. IDENTIFIED FACTORS RELATED TO SUSTAINABLE CONSTRUCTION

Category	ID	Factor
Economic	EC1	Provide job opportunities (minimize unemployment)
	EC2	Reduce cost of energy
	EC3	Sustainable building features promotes better health, comfort, well-being and productivity of building occupants, which can reduce levels of absenteeism and increase productivity
	EC4	Reduce expenses for dealing with complaints and reduce cost of risk
	EC5	Reduce cost of environmental pollution damage and lower infrastructure costs
	EC6	Selecting sites for constructions where the required resources and facilities (materials, storage facilities) are available closely
	EC7	Store the materials properly and minimized the damages to them
	EC8	Maintain the equipment and machineries properly in site and increase their life time
	EC9	Use of existing structures as much as possible for future construction works
	EC10	Use latest technologies, machineries for construction works and save the time
	EC11	Use low cost plastering solutions as an alternative for traditional cement sand plaster
Environment	E1	Usage of sustainable building materials
	E2	Follow sustainable construction practices
	E3	Hire green management team for projects
	E4	Reduce water usage and waste generation
	E5	Reduce the use of non-renewable energy sources
	E6	Selecting a lands for constructions without harming natural resources and environment
	E7	Effectively use/manage lands for construction projects
	E8	Carrying out construction activities without releasing harmful pollutant/chemicals to water resources
	E9	Use of lands which are not protected under the wild life acts for construction works
	E10	Use rainwater and grey water for toilet flushing
	E11	Provide treatments for radioactive chemicals, heavy metals and toxic materials before dispose from the site
	E12	Minimizing the amount of air pollution caused by construction processes
	E13	Recycling the usable materials in site
	E14	Disposing toxic materials according to the standards (landfilling, incineration)
	S1	Provide safe and clean work environment
	S2	Provide welfare facilities for workers
	S3	Keep surrounding areas clean and without disturbances

Social	S4	Sustainable construction renders a significant positive psychological effect on the building occupants like comfort, satisfaction and well-being
	S5	The community as a whole will be more motivated towards sustainable design practices and behavioral changes
	S6	Introduce sign boards and safety measures for workplace
	S7	Install fire extinguishers and security system in workplace
	S8	Provide training programs, awareness programs and supervision to ensure health and safety
	S9	Carrying out construction activities without causing any harm to cultural heritage
	S10	Avoid noisy construction activities (eg - concreting) at night time in highly populated areas
	S11	Taking special care regarding public places near to the construction site such as preschools, schools, hospitals and religious places

IV. Results and Discussion

The internal consistency of the collected responses was first calculated using SPSS and it gave Cronbach Alpha value of 0.881. As per statistics, if that is more than 0.7, the collected data has high internal consistency.

A. Relative Importance Index Analysis

The Relative Importance Index (RII) of factors in three categories was separately calculated with the aim of ranking all the factors. Fig. II graphically shows the importance of factors that contributes to development under three categories. According to the results of the RII calculation, “Selecting sites for constructions where the required resources and facilities (materials, storage facilities) are available closely” (EC6), “Usage of sustainable building materials” (E1) and “Introduce sign boards and safety measures for workplace” (S6) contribute mostly to the economic, environmental and social development of a country.

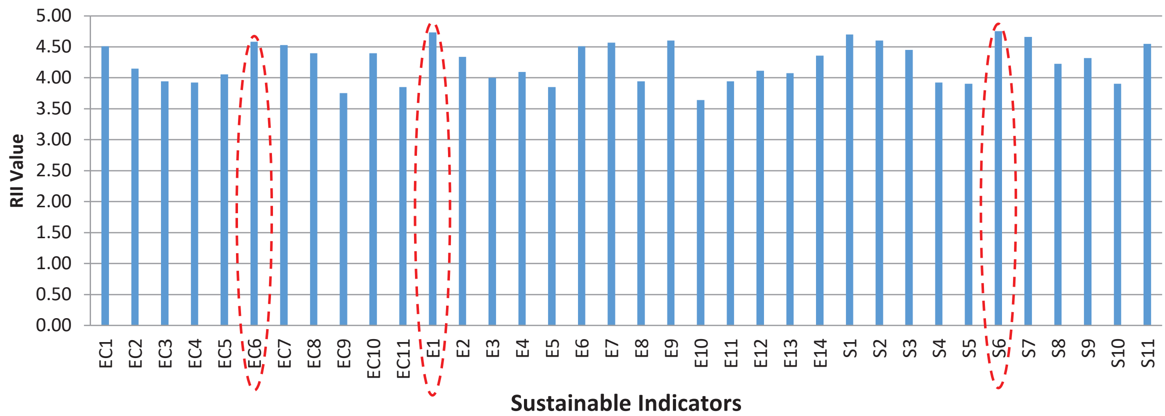

Fig. 2. Relative Importance Index Values for Sustainable Indicators

B. Correlation Analysis

Pearson correlation between factors in each category was separately analyzed by SPSS software. It provides information on the degree of the link, its correlation, and its direction.

According to the Pearson correlation values of factors contributing to environmental development (Table II), “Usage of sustainable building materials” (E1) moderately correlates with “Follow sustainable construction practices” (E2) with a 0.01 level of significance and higher accuracy. Further, E1 factor has a correlation which is closer to moderate correlation with “Use rainwater and grey water for toilet flushing” (E10). Similarly, co-related factors can be identified using the results shown in Table II. Based on these results, it can be identified the factors that can be treated together towards sustainable development.

Then, the relationship between the three categories was also analyzed and it is shown in Table III. According to that, the Environment category is moderately correlated with the social category and the Economic category. In addition to that, the social category is strongly correlated with the economic category.

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TABLE II. CORRELATION BETWEEN FACTORS CONTRIBUTING TO THE ENVIRONMENTAL DEVELOPMENT

		E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14
E1	Pearson Correlation	1	.402**	.165	.218	.217	.108	.237	.096	.146	.391**	.150	-.015	.279*	.150
	Sig. (2-tailed)		.003	.237	.117	.118	.441	.088	.494	.298	.004	.282	.915	.043	.284
E2	Pearson Correlation	.402**	1	.278*	.079	.152	-.093	.143	.147	.076	.467**	.080	-.093	.198	.106
	Sig. (2-tailed)	.003		.044	.572	.278	.510	.308	.293	.590	.000	.571	.508	.156	.449
E3	Pearson Correlation	.165	.278*	1	.223	-.019	.061	.146	.053	.026	.346*	.397**	.176	.149	.120
	Sig. (2-tailed)	.237	.044		.108	.892	.662	.297	.708	.856	.011	.003	.207	.287	.392
E4	Pearson Correlation	.218	.079	.223	1	.349*	.017	.234	.042	-.032	.086	.186	.230	.222	-.104
	Sig. (2-tailed)	.117	.572	.108		.010	.903	.092	.766	.819	.542	.183	.097	.110	.459
E5	Pearson Correlation	.217	.152	-.019	.349*	1	-.056	.018	.014	-.126	.264	-.094	-.044	.117	-.176
	Sig. (2-tailed)	.118	.278	.892	.010		.688	.896	.922	.368	.057	.505	.754	.402	.208
E6	Pearson Correlation	.108	-.093	.061	.017	-.056	1	.320*	-.019	.262	.047	-.021	.336*	-.058	.199
	Sig. (2-tailed)	.441	.510	.662	.903	.688		.019	.892	.058	.738	.884	.014	.679	.153
E7	Pearson Correlation	.237	.143	.146	.234	.018	.320*	1	.130	.274*	.025	.243	.145	.263	.397**
	Sig. (2-tailed)	.088	.308	.297	.092	.896	.019		.355	.047	.858	.079	.301	.057	.003
E8	Pearson Correlation	.096	.147	.053	.042	.014	-.019	.130	1	-.074	.406**	.293*	.126	.275*	.161
	Sig. (2-tailed)	.494	.293	.708	.766	.922	.892	.355		.600	.003	.033	.370	.046	.249
E9	Pearson Correlation	.146	.076	.026	-.032	-.126	.262	.274*	-.074	1	-.036	-.007	-.130	.085	.059
	Sig. (2-tailed)	.298	.590	.856	.819	.368	.058	.047	.600		.800	.961	.354	.544	.677
E10	Pearson Correlation	.391**	.467**	.346*	.086	.264	.047	.025	.406**	-.036	1	.205	.204	.364**	.050
	Sig. (2-tailed)	.004	.000	.011	.542	.057	.738	.858	.003	.800		.141	.144	.007	.725
E11	Pearson Correlation	.150	.080	.397**	.186	-.094	-.021	.243	.293*	-.007	.205	1	.167	.112	.259
	Sig. (2-tailed)	.282	.571	.003	.183	.505	.884	.079	.033	.961	.141		.233	.426	.061
E12	Pearson Correlation	-.015	-.093	.176	.230	-.044	.336*	.145	.126	-.130	.204	.167	1	.114	.226
	Sig. (2-tailed)	.915	.508	.207	.097	.754	.014	.301	.370	.354	.144	.233		.418	.103
E13	Pearson Correlation	.279*	.198	.149	.222	.117	-.058	.263	.275*	.085	.364**	.112	.114	1	.128
	Sig. (2-tailed)	.043	.156	.287	.110	.402	.679	.057	.046	.544	.007	.426	.418		.363
E14	Pearson Correlation	.150	.106	.120	-.104	-.176	.199	.397**	.161	.059	.050	.259	.226	.128	1
	Sig. (2-tailed)	.284	.449	.392	.459	.208	.153	.003	.249	.677	.725	.061	.103	.363	
	N	53	53	53	53	53	53	53	53	53	53	53	53	53	53

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

TABLE III. CORRELATION BETWEEN SUSTAINABLE CATEGORIES

		Environment	Social	Economic
Environment	Pearson Correlation	1	.679**	.588**
	Sig. (2-tailed)		.000	.000
Social	Pearson Correlation	.679**	1	.771**
	Sig. (2-tailed)	.000		.000
Economic	Pearson Correlation	.588**	.771**	1
	Sig. (2-tailed)	.000	.000	
	N	53	53	53

**. Correlation is significant at the 0.01 level (2-tailed).

C. *Principle Component Analysis*

To find latent constructs or factors, the principal component analysis is performed. It is widely used to reduce variables into a smaller set to save time and make interpretation easier. The total variance explained for extracted Environment related factors is shown in Table IV. The factors are arranged in descending order by the amount of variance explained. The Initial Eigenvalues are identical to the Extraction Sums of Squared Loadings, with the exception that factors with eigenvalues less than 1 are not shown. Six components have initial eigenvalues which are greater than 1 under the environmental category.

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So, six principal components can be identified using Table IV.

TABLE IV. TOTAL VARIANCE EXPLAINED FOR ENVIRONMENTAL RELATED FACTORS

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.006	21.471	21.471	1.943	13.881	13.881
2	1.846	13.186	34.657	1.662	11.869	25.750
3	1.432	10.232	44.889	1.572	11.227	36.977
4	1.349	9.632	54.521	1.554	11.103	48.080
5	1.089	7.777	62.298	1.539	10.993	59.073
6	1.019	7.281	69.580	1.471	10.507	69.580
7	.854	6.100	75.680			
8	.749	5.353	81.033			
9	.610	4.355	85.388			
10	.554	3.958	89.347			
11	.484	3.458	92.805			
12	.407	2.909	95.714			
13	.338	2.412	98.125			
14	.262	1.875	100.000			

Extraction Method: Principal Component Analysis.

According to the results shown in Table V regarding the rotated component matrix for environmental factors, E1, E2 and E10 factors are highly related to the first principle component. So, the first principal component can be taken as a linear combination of E1, E2 and E10 factors. 2nd principle component can be taken as a linear combination of E7 and E9 factors. Accordingly, factor reduction can be identified from the results shown in Table V.

TABLE V. ROTATED COMPONENT MATRIX FOR ENVIRONMENTAL RELATED FACTORS

	1	2	3	4	5	6
E1	.620	.338	.032	.114	.242	.000
E2	.782	.098	.133	.064	-.003	-.169
E3	.391	-.015	.757	-.163	.061	.142
E4	-.032	.095	.299	.026	.839	.094
E5	.281	-.132	-.254	.032	.706	-.014
E6	.061	.397	-.125	-.150	-.071	.772
E7	-.031	.733	.208	.285	.186	.181
E8	.163	-.125	.085	.788	-.085	.059
E9	.154	.726	-.084	-.188	-.125	-.047
E10	.771	-.207	.106	.347	.074	.216
E11	.003	.077	.794	.282	.002	-.007
E12	-.078	-.143	.214	.184	.124	.812
E13	.242	.214	.017	.599	.293	-.061
E14	-.017	.399	.256	.396	-.324	.263

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.[a]
a. Rotation converged in 7 iterations.

A similar analysis was done on the other two categories also. For social category and economic category, four principal components can be extracted from each through the analysis. The behavior of the selected components in each category is shown through principal component analysis.

V. CONCLUSION

This research focused to identify how sustainable construction contributes to the sustainable development of a country. 36 sustainability construction-related factors were identified through a comprehensive literature review and evaluated under three different categories called factors contributing to the environmental development, social development and economic development of a country. The questionnaire survey was conducted among the professionals in construction companies who have registered under CS2 to C5 grades. 53 responses were collected for the questionnaire and analysis was done based on those responses.

According to the respondents, most of the identified factors are contributing to the sustainable development of the country at a higher level. The correlations between factors help to improve all related factors simultaneously with smaller effort. So, it saves time as well as cost. According to the analysis, all three categories are also correlated with each other. So, it concludes that all 36 factors are contributing to the sustainable development of the country and those factors can be improved by looking at a single factor that correlated with others also.

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