Journal of Civil Engineering and Environmental Technology
p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume 6, Issue 4; April-June, 2019, pp. 270-277

http://www.krishisanskriti.org/Publication.html

A Study on Environmental Sustainability of Construction Projects in Tamilnadu

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Abstract—*Construction is one of the largest consumers of the global resources and is one of the principal contributors of the waste leading to environmental pollution in many ways. It is recommended that there is an immense need of implementing sustainability in the construction industry so that the needs of the present generation are fulfilled without compromising the needs of future generation. It has been observed that many researchers have designed various environmental assessment approaches which are essential for achieving the sustainability goals in the construction sector. Also, it is worthy to mention that there are a number of barriers such as low awareness level about sustainability, government policies, cost of implementing sustainability etc. that inhibits the implementation of sustainability approaches in the construction. In this research work, focus has been given on reviewing the existing environmental issues and to check the key factors that will help in implementing environmental sustainability in construction industry. It has been found that the existing research has emphasized more on economic and social pillar of sustainability and least on environmental pillar. The main aim of this research work is to have a deep insight of the current environmental issues. Based on this data, a questionnaire survey has been developed and distributed to various construction industry professionals to collect the reliable information regarding environmental sustainability in construction. This data is then analyzed using SPSS software and the results have been interpreted with the help of various statistical tests such as frequency analysis, descriptive analysis and chi square test.*

Keywords: *Assessment approaches, Challenges, Key environmental indicators, Sustainability, SPSS software.*

1. Introduction

According to the Brundtland Commission, sustainability is defined as the developments that meet the needs of the present without compromising the ability of future generations to meet their own needs. It has been recorded that both residential and commercial buildings account for more than 40% of global energy use and brings out approximately one third of global greenhouse gas (GHG) emissions (UNEP 2009). Sustainability covers all the three pillars i.e., economic, social and environmental and encompass an interaction and relationship between these three dimensions of the sustainability. Unfortunately it is observed that less emphasis is given on the environmental dimension of the sustainability although it is equally important with respect to the economic and social pillar of the sustainability. Sustainability helps us in improving the quality of life and leads to live in a healthy environment. Considering the world commission on environment and development (WCED), entitled Our Common Future (1987), sustainability has attained huge recognition in all nations. The sustainable homes have been being built for the past three decades and still sustainability has been continuously growing over this period. The record of sustainability goes back much further than the 1970's. But unfortunately it has been observed that sustainability is still somewhat a new concept in developing nations. It has been acknowledged that the cooperation among the various participants of the construction industry plays a vital role in attaining the sustainability goals. It is also obvious that there are various challenges and barriers which are posed to the implementation of the sustainability in the construction sector. These barriers and challenges include lack of sustainability perception, lack of preparedness among various stakeholders, lack of skilled workforce to support execution of sustainable construction, cost ofemploying sustainability, present economic issues, lackof lawful enforcement by the government and its policies, unsatisfactory responsibility by top administration etc.

2. Literature review summary

Many researchers have done a lot of work for last 25-30 years to examine and develop the sustainability assessments methods in order to implement them in the construction industry.It is clear from the literature that there are many definitions for the sustainability. But the mostly used one is “to meet the needs of the present generation without compromising the capabilities of the future generations to meet their needs” (WCED 1987). The combined administration fetches the stakeholders together to enhance the comfort and quality of life, while reducing the negative environmental effects and improving the economic dimension

of the sustainability [7].The environmental sustainability has attained remarkable recognition in the construction industry irrespective of various challenges and barriers posed by the different elements [15]. Environmental sustainability is considered as one of the principal execution-related matters in the construction sector, because of the high influence of the given sector on environmental and social performance [16]. The researchers have tried to identify the main methods which are followed by the construction industry for implementing sustainability techniques in the procurement, design, and governance process[16]. The two important challenges for incorporating sustainability in construction sector are credited to the industry culture and disintegrated character of the industry and the inflexible pro visions and reluctance of the clients to share the load[17]. It is also evident from the literature that there is a great improvement in the research on the environmental sustainability in developing as well as in developed nations. It should be also noted that sustainability is a global issue and hence requires global solution. It is also obvious from the literature that the sustainability is not implemented effectively in the construction sector [3]. After studying the various literatures, it is found that further dedicated studies need be undertaken to identify and analyze principles, methods, techniques, ways of doing things, and procedures used in the industry to achieve the sustainability goals. It is also identified that there is a need for shifting the traditional approach of project to innovative approach for embracing the principles of sustainable development.

3. Research methodology

This section includes the methodology to carry out the research work that is linked to the previous research work. This research work requires both qualitative approach through in-depth literature review as well as quantitative approach using the questionnaire survey for data collection and to quantify the problem. These two approaches helped to dive deep into the problem. The most flexible and suitable methods adopted in this research work include observations, questionnaire surveys, literature analysis and case study analysis. In this research work, the existing research in "environmental sustainability in the construction sector" has been reviewed. This research work is carried out by developing a questionnaire associated with environmental sustainability of construction projects with different responses on a 5-point likert scale using closed ended questions.The reason for adaption of this type of questionnaire was to collect the relevant information from the respondents within less period of time and to make the analysis as easy as possible. The questionnaire was developed in such a way that it can be easily responded by the respondents.The research has been conducted using questionnaire surveys with industry professionals such as civil engineers, builders, project consultants and project managers. The questionnaire consists of two sections, primary section providing the general information of the respondents such as designation, experience and size of the company. The secondary section consists of the questions associated with various activities in the construction sector and their impact on the environment.The collected data from the questionnaire survey was then sorted out using Microsoft Excel for preliminary investigation. The data was finally analyzed using SPSS software and statistical tests such as frequency analysis, descriptive analysis and chi square test were done.A set of 15 questions were developed associated with environmental aspect of the construction sector in this research to get to know the views of various professionals. The response choices available to each question were 5 on a likert scale, first one being the lowest and fifth one being the highest. A list of 80 construction companies was approached for questionnaire survey. A set of 200 hard copies of questionnaire were distributed to various professionals and a total of 150 copies were received. These respondents were associated with various civil engineering fields with experiences ranging from 0-40 years and working in small, medium and large companies.

4. Data collection and data analysis

A detailed survey was conducted in this study in which a set of 200 copies of questionnaire were sent to various experts associated with the construction sector. The respondents include civil engineers, builders, project managers and project consultants with experiences from 0-40 years in a particular field of work. In return, a total of 150 copies of questionnaire were received with valid response, 35 copies with incomplete responses and 15 copies with invalid responses. SPSS-25, a statistical analysis software package was used to perform the data analysis. The response copies were arranged in a certain fashion in order to make it feasible to insert the collected data in the excel format. The data was first transferred to excel sheets in order to make it feasible for analysis in the SPSS software.

4.1 Designation of the respondents

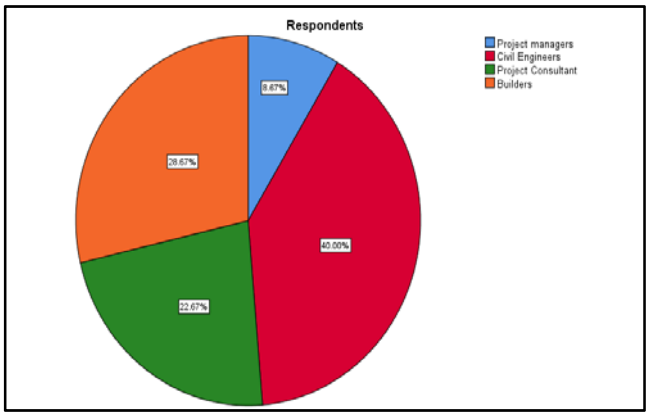

Fig. 1: Designation of the respondents

From the Figure 1, it is clearly observed that the most of the respondents are civil engineers followed by builders, project consultants and project managers. The data shows that 60 out 150 respondents are civil engineers by profession.

4.2 Experience of the respondents

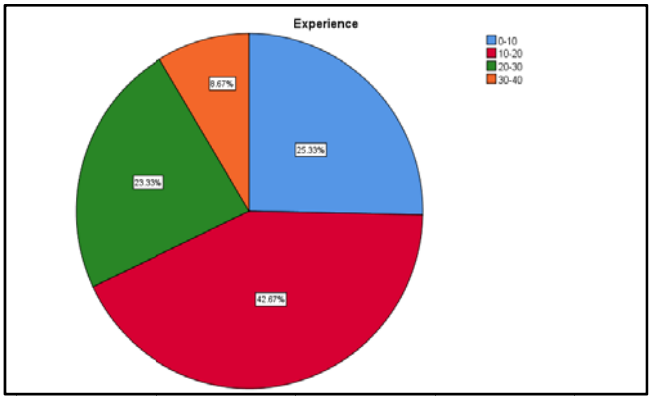

Fig. 2: Experience of the respondents

From the Figure 2, it is observed that most of the respondents are in the experience group of 10-20 years followed by 0-10, 20-30 and 30-40 groups. The above data implies that 64 out of 150 respondents belong to the 10-20 age groups.

4.3 Size of the company of the respondents

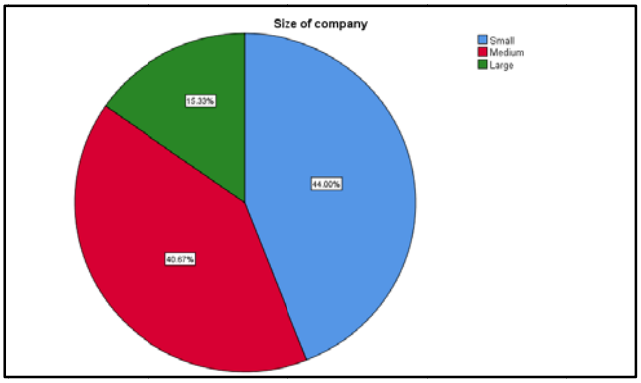

Fig. 3: Size of the company of respondents

From the Figure 3, it is clearly observed that most of the respondents are working in small companies followed by medium and large companies. As per the data, 66 out of 150 respondents work in small companies. It is also found that 40% of the respondents are associated with medium companies.

5. Results and discussions

The statistical tests such as frequency analysis, descriptive analysis and chi square test have been done to obtain various results. Each one is explained separately in this section.

5.1 Frequency analysis

It is basically the descriptive statistical analysis that provides the number of occurrences of each response chosen by the respondents. These results will help the user to interpret the results and draw conclusions.

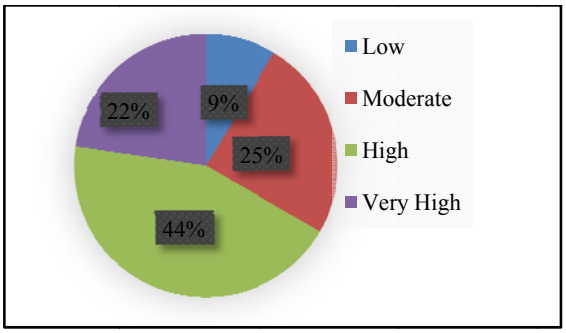

Fig. 4 Impact of FSI on environmental sustainability

From the Figure 4, it is found that 44% of the respondents have responded with “high” response choice to the impact of FSI on environmental sustainability. It implies that FSI has a significant relationship with the environment.

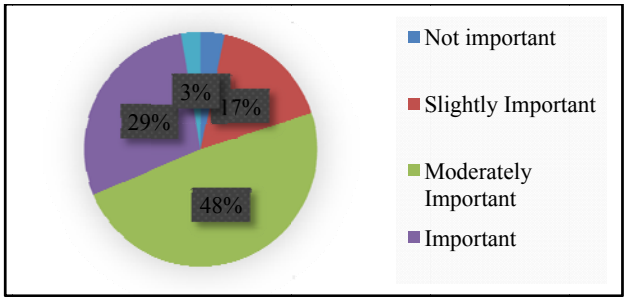

Fig. 5 Use of brown field sites

From the Figure 5, it is found that approximately 50% of the respondents have responded with “moderately important” response choice to the usage of brown field sites in construction. It implies that, this factor is moderately recommended by the respondents.

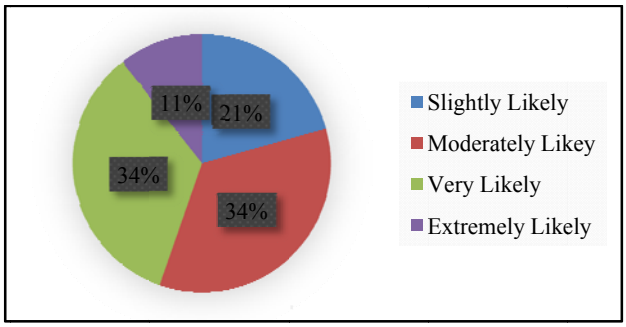

Fig. 6 Use of discarded construction materials

From the Figure 6, it is found that 34% of the respondents have responded with “very likely” and 34% with “moderately likely” response choices to the usage of discarded materials in

construction. It implies that, the given factor is moderately recommended by the respondents.

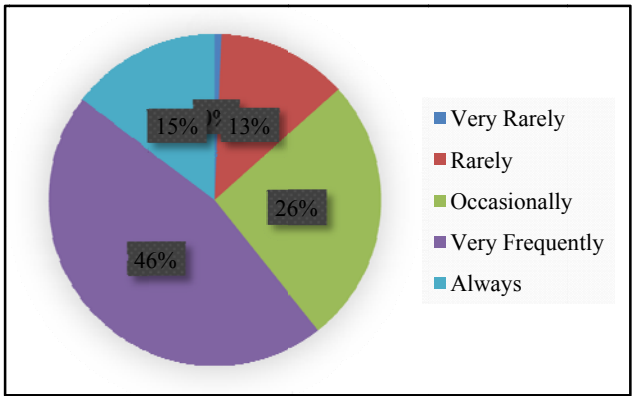

Fig. 7 Use of locally available material in construction

From the Figure 7, it is found that around 50% of the respondents have responded with "very frequently" response choice to the use of locally available materials in the construction. It implies that the given factor is almost recommended by the respondents.

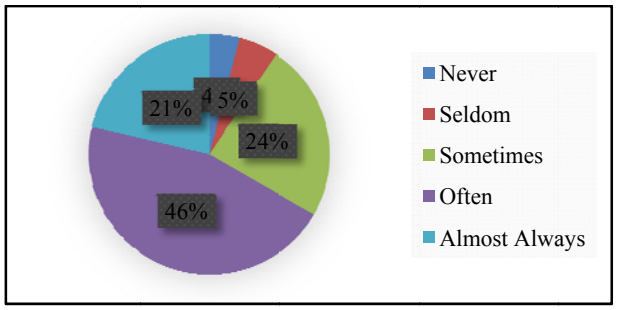

Fig. 8 Use of renewable materials in construction

From the Figure 8, it is found that 45% of the respondents have responded with "often" response choice to the use of renewable materials in construction. It implies that the given factor has been fairly recommended by the respondents.

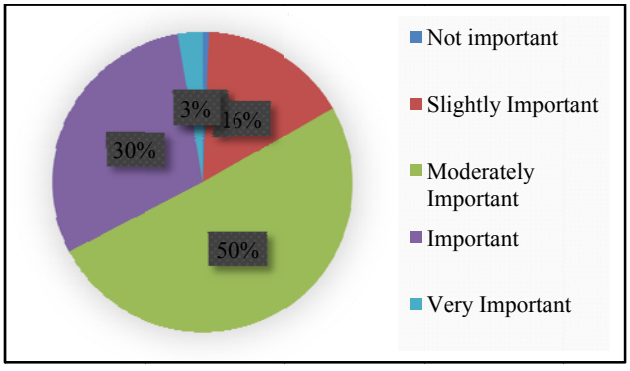

Fig. 9 Use of recycled water in construction

From the Figure 9, it is found that 50% of the respondents have responded with "moderately important" response choice to the optimum water consumption and use of recycled water in construction. It implies that the given factor is sufficiently recommended the respondents.

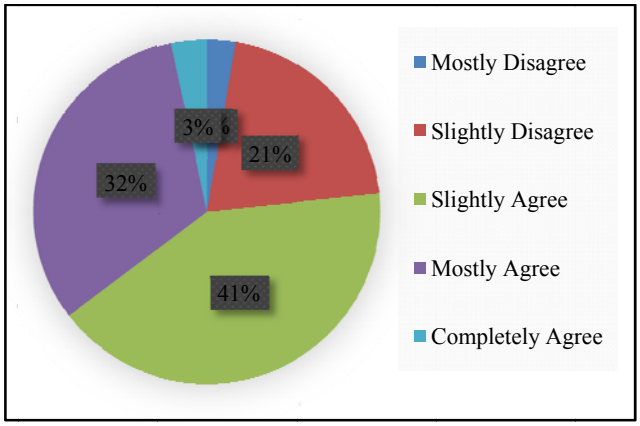

Fig. 10 Limit of resources to be used during construction

From the Figure 10, it is found that 41% of the respondents have responded with "slightly agree" response choice to the given factor. It implies that the given factor is fairly recommended by the respondents.

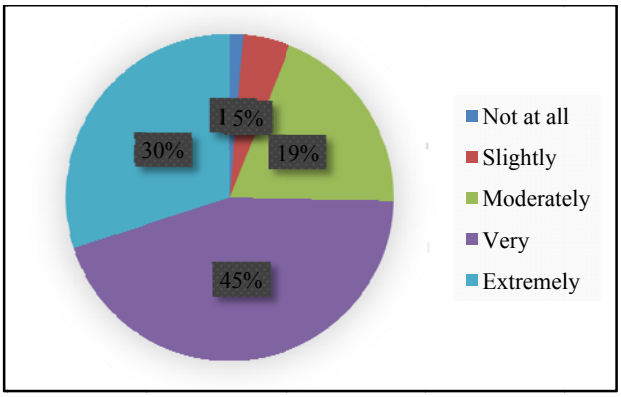

Fig. 11: Implementation of waste management in construction

From the Figure 11, it is found that 45% of the respondents have responded with "very important" response choice to the implementation of waste management in construction. It implies that the given factor is almost recommended by the respondents.

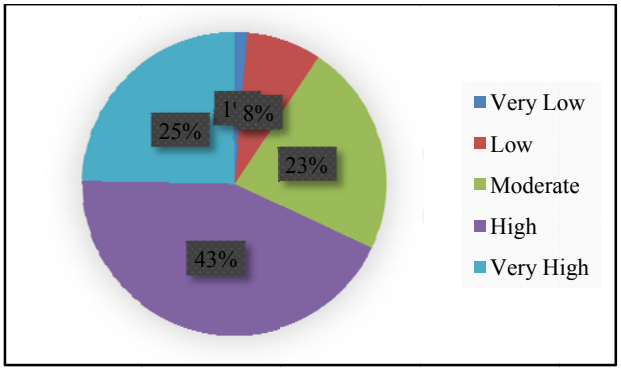

Fig. 12: Importance of rainwater harvesting

From the Figure 12, it is found that 43% of the respondents have responded with "high" response choice to the importance of rainwater harvesting. It implies that the respondents have almost agreed with this factor.

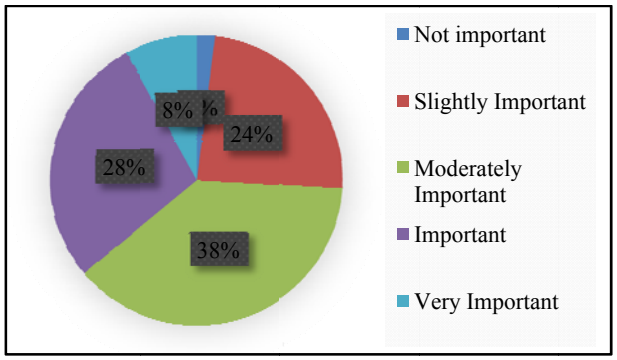

Fig. 13: Importance of green spaces

From the Figure 13, it is found that 38% of the respondents have responded with "moderately important" response choice to the importance of green spaces (green roofs & walls). It implies that the respondents have moderately agreed with this factor.

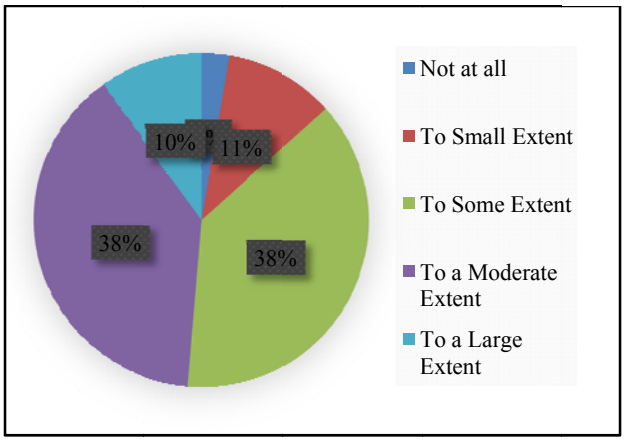

Fig. 14Impact of construction on flora and fauna

From the Figure 14, it is found that 38% of the respondents have responded with "to some extent" and 38% with "to moderate extent" response choices to the effect of construction works on flora and fauna. It implies that the respondents have moderately agreed with this factor.

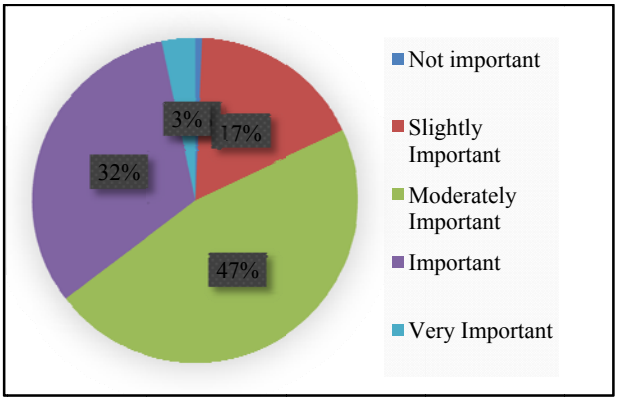

Fig. 15 Importance of installing renewable energy systems

From the Figure 15, it is found that 47% of the respondents have responded with "moderately important" response choice to the importance of installing renewable energy systems. It implies that the respondents have moderately agreed with this factor.

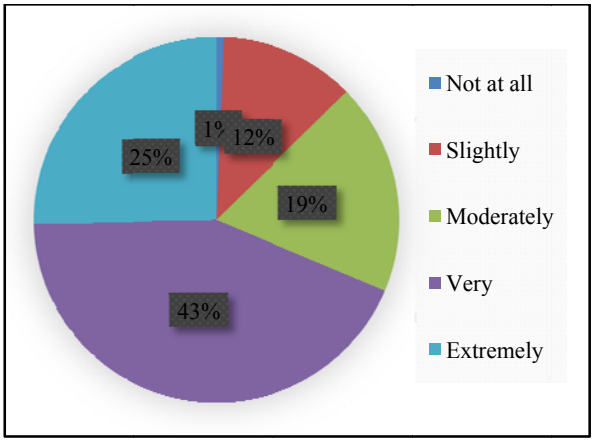

Fig. 16 Role of designer towards environmental sustainability

From the Figure 16, it is found that 43% of the respondents have responded with "very important" response choice to the role of designer towards environmental sustainability. It implies that the respondents have sufficiently agreed with this factor.

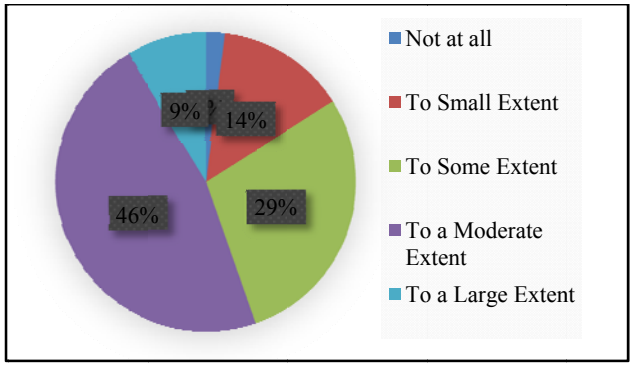

Fig. 17 Importance of participation of top management

From the Figure 17, it is found that 46% of the respondents have responded with "to a moderate extent" response choice to the role of top management towards environmental sustainability. It implies that the respondents have sufficiently agreed with this factor.

5.2 Descriptive analysis

Descriptive analysis is basically a statistical tool that is used to analyze huge amount of raw data. It helps to present the data in a way that can be understood easily and hence interpreted to draw the useful conclusions. It also allows to summarize the group data by incorporating a combination of tables, graph, charts and finally helps to discuss the results in a meaningful way. With the help of descriptive analysis, the statistics such as mean, standard deviation, variance range, score etc. can be easily calculated. The results of the mean and standard deviation by the different respondent groups (civil engineers, builders, project managers and project consultants) with different range of experiences (0-40) are summarized in Table 1.

Table 1 Descriptive analysis of the factors

Factors	Mean	Std. deviation	Analysis N
A	3.81	.888	150
B	3.11	.829	150
C	3.35	.927	150
D	3.61	.911	150
E	3.75	.984	150
F	3.18	.751	150
G	3.13	.869	150
H	3.97	.897	150
I	3.48	.739	150
J	3.82	.942	150
K	3.16	.949	150
L	3.43	.907	150
M	3.20	.786	150
N	3.81	.974	150
O	3.46	.910	150
P	2.71	.979	150
Q	2.15	.903	150
R	1.71	.717	150

From Table 1, it is found that the mean of all the factors ranges from 3.11 to 3.97 with "use brown field sites in construction" having the lowest and "implementation of waste management in construction" having the highest one.

5.2.1 Data interpretation

- The average value of the mean of all the factors comes out to be 3.48. Hence, from the average value of the mean, it can be summarized that the factors having mean value greater than the average mean value has been given high priority by the respondents. The factors having the mean value less than the average mean value have been given less importance by the respondents.
- It is also important to note that if the two mean values are equal, then the factor with the lesser standard deviation value is considered to be given high priority by the respondents. Therefore, from the above table, it can be concluded that the factors 1,4,5,8,9,10 and 14 have been given the higher priority while as factors 2,3,6,7,11,12,13 and 15 have been given less priority by the respondents.
- It is clearly observed from the above table; the highest importance has been given to the implementation of waste management in construction. The utilization of renewable and locally available materials has been also prioritized by the respondents. Similarly, the role of the designer towards environmental sustainability has been also received the highest importance in this analysis.
- However, on the other side, the usage of brown field sites, usage of discarded materials in construction, provision of green spaces in infrastructure facilities and participation of the top management towards environmental sustainability have received slightly less priority by the respondents.

5.3 Chi square test

Chi square test is one of the statistical tests that is used to whether there is a significant difference between the expected (theoretical) frequencies and the observed (experimental) frequencies in one or more categories. This test is commonly used to test relationships between categorical variables.

Table 2 Test statistics

	A	B	DC	ED	FE	FF	HG	IH	JI	KJ	LK	ML	NM	ON	PO	P	RQ	SR
Chi-Square	30.640[a]	34.907[a]	22.120[b]	38.000[a]	111.467[c]	23.920[a]	87.600[c]	84.800[c]	129.800[c]	88.333[c]	96.933[c]	75.600[a]	79.933[c]	65.400[c]	87.000[c]	113.533[c]	75.933[c]	95.600[c]
Df	3	3	2	3	4	3	4	4	4	4	4	3	4	4	4	4	4	4

Asymp. Sig	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 37.5.

b. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 50.0.

c. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 30.0.

From Table 2, it has been observed that the p-value (0) is less than the alpha value (0.05) for all the factors. Hence the results are statistically significant.

Here A-R are the various factors or variables represented in figure 1-17.

5.3.1 Data interpretation

- As per the assumptions of chi square test, the expected value of the number of sample observations in each level of the variable is at least 5. It is observed that the minimum expected cell frequency in the Table 2 is 37.5, 50 and 30 respectively which are greater than 5 (the least value). Hence, this test is not violated.
- Also, if the cells (having expected frequencies less than 5) are greater than 20%, then the assumption of chi square test is violated. It can be also observed in the Table 2, that 0% cells have expected frequencies less than 5 in all the three cases.
- Also, if the asymptotic significance, or p- value, of the chi-square in all tests of significance, is less than 0.05 (i.e., $p < 0.05$), it is concluded that there is a statistically significant relationship between the variables. Most of the times p-value is tested at 5% level of significance and that value is called alpha. Since the p-value (0) in the Table 5.35 is less than the alpha value (0.05) for all factors/ variables, hence the results are statistically significant.

6. Conclusions

It is observed that the most of the respondents are civil engineers followed by builders, project consultants and project managers. It is also observed that most of the respondents are in the experience group of 10-20 years. It is observed that most of the respondents are working in small companies. It is concluded that, on the 5-point likert scale, response no.4 has been given to 10 factors followed by the 3rd response given to 5 factors in the entire survey by 50% of the respondents. It implies that all the 15 factors have a significant value in the construction and have an impact on environmental sustainability.It is also concluded that the factors like impact of FSI on environmental sustainability, use of locally available materials in construction, use of renewable materials in construction, implementation of waste management in construction, environmental pollution due to construction activities, employing of rainwater harvesting and role of designer towards sustainability are the most critical ones and have highest impact on the environmental sustainability. It is also concluded that the factors like use of brownfield sites in construction, use of discarded materials in construction, use of recycled water in construction, limitation in the utilization of resources in construction, providing green spaces (green roofs & walls), effect of construction activities on flora and fauna, importance of installing renewable energy systems (solar energy, wind energy etc.) and participation of top management important towards sustainability have been given less priority and have less impact on the environmental sustainability. Hence these factors are not considered important in the construction as per the responses of the respondents. It has been observed that the highest importance has been given to the implementation of waste management in construction and is therefore the most critical in the construction. From chi square test, it is also observed that for all factors/ variables, the results are statistically significant which implies that all the factors/ variables have a significant relationship with the environmental sustainability.

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