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SUSTAINABILITY ASSESSMENT OF CONSTRUCTION PROJECTS IN PAKISTAN AND GEO-SAT

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Abstract- Sustainability is a philosophy focused on supply and demand considering current generations as well as potential ones. Economy, environment, engineering, and equity (social) are the four foundations of Sustainable Development (SD). The second-largest industry in Pakistan is construction (after agriculture). To evaluate current practices and recommendations for the future, an assessment of the sustainability activities carried out in this sector is required. 37 of 76 generic indicators of Environmental Geotechnics Indicators (EGI) were used for the appraisal of civil engineering ventures in Pakistan. Compared with the most viable options recommended for achieving SD, the findings showed very poor performance. The results also showed the lack of a dedicated sustainability assessment tool for geotechnics, thereby, suggesting an urgent need for the development of one such tool. This paper also presents a framework for the new tool called as Geotechnical Sustainability Assessment Tool (Geo-SAT).

Keywords- Framework, Geotechnical Sustainability Assessment Tool, Impact, Sustainability

1 INTRODUCTION

As per the Brundtland Commission report [1], Sustainable Development (SD) can be defined as "the development that meets the needs of the present without compromising the ability of future generations to meet their needs". The United Nations took decisions to ensure SD through a set of 17 SD Goals with 170 targets [2].

Civil engineering contributes to about 40% consumption of natural resources like gravel, sand, and stone annually thereby contributing most to the global changes and challenges [3]. Construction is the second-largest sector in economic development after agriculture in Pakistan contributing to more than 35% of direct or indirect employment [4]. The activities of this sector, therefore, need assessment. Several sustainability assessment tools are available such as Building Research Establishment Environmental Assessment Method (BREEAM) [5], Leadership in Energy and Environmental Design (LEED) [6], Environmental and Whole Life Cost Estimating Tool (ENVEST 2) [7], SPeAR [8] and EnVision [9]. These tools cannot be applied to geotechnical engineering that shows that geotechnics lacks a dedicated sustainability assessment tool [10]. It is also worth mentioning that no assessment of the construction industry in Pakistan has been carried out previously.

This paper presents the sustainability assessment of the construction sector of Pakistan and a framework for the assessment of geotechnical projects, encompassing the 4 Es (Engineering, Economic, Equity i.e. Social and Environmental) of sustainability as proposed by Basu et al. [11], shown in Figure 1. The new tool is termed as Geo-SAT (Geotechnical Sustainability Assessment Tool) which will serve as a potential code of sustainability for geotechnical projects.

2 METHODOLOGY

2.1 Sustainability Assessment of Construction Projects in Pakistan

All the tools mentioned in section 1 are project-specific and therefore cannot be used to assess the construction industry as a whole. Therefore, the generic indicators developed by Jefferson et al. [12] were used to carry out this assessment. 37 of 76 indicators were selected for this purpose as shown in Table 2. The assessment was carried out using a questionnaire distributed countrywide and responded by civil engineering professionals having worked as at least Project Managers.

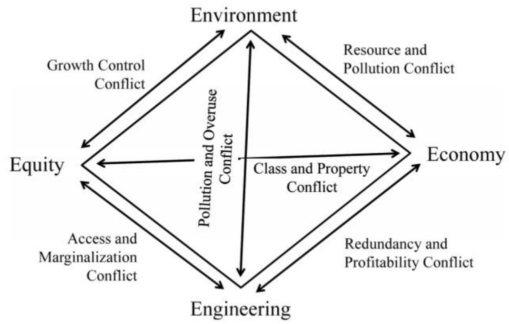

Figure 1: 4 Es of Sustainability [11]

This questionnaire was divided into two main sections i.e. Demographic information and sustainability assessment further divided into stages based on construction activities i.e. Feasibility, Design, Award and Mobilization, Construction, De-Mobilization and Monitoring, and Long-Term. Each stage was assessed using indicators measuring the impact on sustainability on a scale of 1 (detrimental/harmful) to 5 (significantly improved), as shown in Table 1 and Table 2. An effort was also made to check if any sustainability assessment technique is used in Pakistan.

2.2 Development of a Sustainability Assessment Tool for Geotechnical Projects

To develop a new tool specific to geotechnical projects, a thorough review focusing on understanding the technical dynamics of geotechnics, sustainability, and existing assessment tools used in construction industry, was carried out. The past and current practices followed, and the recommendations of researchers to achieve SD in line with the goals set by the United Nations were considered for the development of indicators along with a reliable and consistent scale.

3 RESULTS OF SURVEY

Cronbach's alpha test showed excellent reliability with a value of 0.931. The respondents' details and descriptive results of the survey are given below:

3.1 Respondents

A total of 66 responses across the country were collected. 62.12% of the firms were aged 20 and above. The firms belonged to different sectors such as government (15.15%), private (72.73%), and others (12.12%) and offering different services such as design (9.09%), construction (51.52%), and consultancy (39.39%). 72.73% of the total firms were involved in the feasibility stage, 54.44% in the design stage, 72.73% in award and mobilization activities, 84.85% in construction activities, 46.97% in de-mobilization activities and 51.52% of the firms carried out monitoring activities.

3.2 Results of the Survey

The percentages of firms responding to each indicator as per the scale developed by Jefferson et al. [12] for Environmental Geotechnics Indicators (a sample scale for some indicators shown in Table 1) are given in Table 2.

Table 1: A sample of scale developed by Jefferson et. al [12]

Indicator	**Impact on Sustainability**				
	Detrimental or Harmful (1)	**Reduced (2)**	**Neutral (3)**	**Improved (4)**	**Significantly Improved (5)**
Sustainability Policy	Actively avoids	Passively avoids	No policy	Passively promotes	Actively promotes
Percentage of site investigation costs	< 0.5%	0.5% - 1.0%	1.0% – 3.0%	3.0% - 4.0%	> 4.0%
Types of Tests	None	Simple on-site field tests	Lab tests	Field tests	Lab and field

Table 2-Summary of Questionnaire Results

Indicator	**Impact on Sustainability**				
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
Feasibility Stage					
Sustainability Policy	6.25%	8.33%	50%	20.83%	14.58%
Community Consultation Plan	4.17%	47.92%	47.92%	-	-
Percentage of site investigation costs	25%	25%	25%	18.75%	6.25%
Types of Tests	4.17%	2.08%	8.33%	10.42%	75%
Design Stage					
Land Use	11.11%	11.11%	47.22%	16.67%	13.89%
Quantified Risk Assessment (QRA)	44.44%	30.56%	13.89%	5.56%	5.56%
Risk Management Plan (RMP)	38.89%	27.78%	16.67%	8.33%	8.33%
Health and Safety (H&S) Plan	25%	22.22%	36.11%	5.56%	11.11%
Life Cycle Assessment (LCA)	41.67%	11.11%	41.67%	5.56%	-
Supplies from sustainable/recyclable resources	80.56%	16.67%	2.78%	-	-
Award and Mobilization Stage					
Type of Procurements	41.67%	25%	16.67%	8.33%	8.33%
ISO-14001 Accreditation	81.25%	18.75%	-	-	-
Nuisance notices served	22.92%	14.58%	14.58%	-	47.92%
Employees Awareness Trainings	39.58%	35.42%	8.33%	14.58%	2.08%
Internal Evaluation using KPIs	54.17%	2.08%	16.67%	16.67%	10.42%
Transportation	54.17%	16.67%	8.33%	6.25%	14.58%
Ingress and Egress	10.42%	56.25%	10.42%	18.75%	4.17%
Construction Stage					
Materials dispose off	12.5%	33.93%	21.43%	12.5%	19.64%
Renewable Energy use at site	53.57%	12.5%	5.36%	26.79%	1.79%
Dust Suppression Plan	64.29%	10.71%	25%	-	-
CO_2 emissions and Embodied Energy (EE)	87.5%	5.36%	7.14%	-	-
Air Quality: SO_2 and NO_x	55.36%	39.29%	5.36%	-	-
Air Quality: Ozone	7.14%	76.79%	14.29%	1.79%	-
Air Quality: Particulate	73.21%	19.64%	3.57%	3.57%	-
Obstruction of light by smoke	19.64%	17.86%	16.07%	21.43%	25%
Noise prevention plan	57.14%	35.71%	7.14%	-	-
Local Community services disruption	17.86%	17.86%	42.86%	10.71%	10.71%
Time lost through regulatory restrictions	21.43%	12.5%	25%	41.07%	-
De-Mobilization Stage					
Plant reuse	16.13%	35.48%	16.13%	32.26%	-
Equipment on de-mobilization	19.35%	25.81%	25.81%	19.35%	9.68%
Time Overruns	38.71%	25.81%	35.48%	-	-
Cost Overruns	32.26%	35.48%	29.03%	3.23%	-
Monitoring and Long-term Stage					
Powering monitoring stations	64.71%	17.65%	11.76%	5.88%	-
Contingency Planning	17.65%	20.59%	17.65%	41.18%	2.94%
Maintenance	47.06%	41.18%	11.76%	-	-
Client Satisfaction	11.76%	8.82%	29.41%	50%	-
Insurance & Warranties	20.59%	14.71%	52.94%	11.76%	-
Average	**35.76%**	**23.76%**	**20.75%**	**11.83%**	**7.89%**

3.3 Interpretations

From the results mentioned in Table 2, the following conclusions have been drafted:

1) 80.30% of the firms in Pakistan do not use any sustainability assessment tool at all. The rest reported using BREEAM, CEEQUEL, Eco-Points, LEED, Sigma, and SPeAR. None of the currently used assessment tools can be applied to the

field of geotechnical engineering. This is a clear indication that researchers are in a definite need of developing a sustainability assessment criterion /technique for geotechnical projects.

2) None of the firms is ISO 14001 certified even though 62.12% of the firms that participated in this survey are aged 20 and above, which reflects that Pakistan is far away from the SD goals.
3) Almost 50% of firms carry out monitoring activities. The majority of the firms carry out maintenance activities at regular intervals which highlights the poor quality-control measures during the construction. This is one of the reasons of minimal client satisfaction as the value for money is not attained as planned/expected.
4) A good percentage of the project cost is dedicated to site investigations (lab and field tests), which is appreciable because these investigations help reduce the uncertainties for design purposes and help strengthen the RMP and QRA, which ultimately help in controlling cost overruns.
5) The majority of the firms do not have an RMP and QRA which reflects why the projects face overruns in terms of both time and cost. The level of risk is unknown and therefore cannot be quantified.
6) H&S policies are not part of the majority of the projects the same as QRA and RMP.
7) LCA is not carried out by these firms, again one of the reasons for cost overruns. The reason for not doing this no monitoring and inexperience and the lack of a developed technique.
8) Firms continue with the least cost-competitive tenders which reflects no use of sustainable items along with poor construction practices, focusing on the economic aspects and ignoring other 3 Es.
9) As studied previously, the majority of the firms do not have any RMP or QRA or any H&S policy, and neither go for LCA, reflecting and confirming no awareness training. This is one of the reasons that evaluation using KPIs is not carried out.
10) Material wastage is very common, thereby compromising the economic and social aspects of sustainability.
11) More than half of the firms do not use any renewable energy systems. That is the reason that CO_2 and EE calculations are not carried out. Mostly allow VOCs to combine with air. This also shows the higher usage of coal/oil and very few firms using clean technology to maintain air quality.
12) Noise prevention plan not implemented compromises the social aspects of sustainability.

4 FRAMEWORK

4.1 Framework of Geo-SAT

The lack of a sustainability assessment tool urges the need for a new tool. Following detailed literature of assessment techniques and sustainability in general and specific to construction and geotechnics, Geo-SAT was developed using the four pillars of sustainability and the framework is shown in Figure 2. Each aspect is divided into stages which are assessed using indicators summarized in Figure 2. The number against each aspect and stage is the number of indicators developed. Each indicator is assessed on a scale of 1 to 5, similar to Table 1. The assessment for each stage is averaged and plotted on a graph as shown in Figure 3. The greater the area of the closed polygon, the more sustainable is the project. The complete details can be assessed at [13] and [14].
Geo-SAT ensures the embedment of SD targets into geotechnical projects. This required categorizing of main objectives to 5 sub-objectives as detailed below:

1) Understanding the prerequisites of sustainable design in the geotechnical field, 2) Understanding the 4 Es of sustainability and their impacts, 3) Defining the areas of least and the most impact on sustainability, 4) Defining improvements in the design process, 5) Correlating all the decisions on a project level to ensure sustainability at each stage

4.2 Framework of Assessment

These objectives can be achieved using the framework shown in Figure 4.

1) *Pre-Assessment:* All parties (engineers, clients, contractors, and suppliers) involved in the project must have clear communications to establish the concerns and understandings related to SD at this stage.
2) *Scope of Assessment:* Ensuring the scope of the assessment is necessary along with defining the boundaries of the site and project but flexibility of scope is mandatory. It also involves the identification of a realistic timeline.
3) *Data Collection*: The next step is to collect data for each indicator without compromising its quality.
4) *Baseline Assessment:* Carry out an initial assessment called the baseline assessment. This assessment will serve as a guideline for future references.
5) *Life Cycle Analysis*: Carry LCA at this stage. It is indeed an expensive and time-consuming process. Ideally, it should be done for all stages and indicators, but due to the complexities, there will always be limitations in extension. Another

difficulty is the unexpected events that may come through the whole life of a project because LCA is based on creating assumptions and scenarios to come up with some outcomes.

6) *Identification of weak areas:* Identify areas where improvements are required in line with the resources and timeline.
7) *Re-assessment:* Carry out assessment at this stage incorporating the changes made to achieve improvements.
8) *Iterative assessment:* Keep on assessing the project with changes incorporated for continuous improvement.

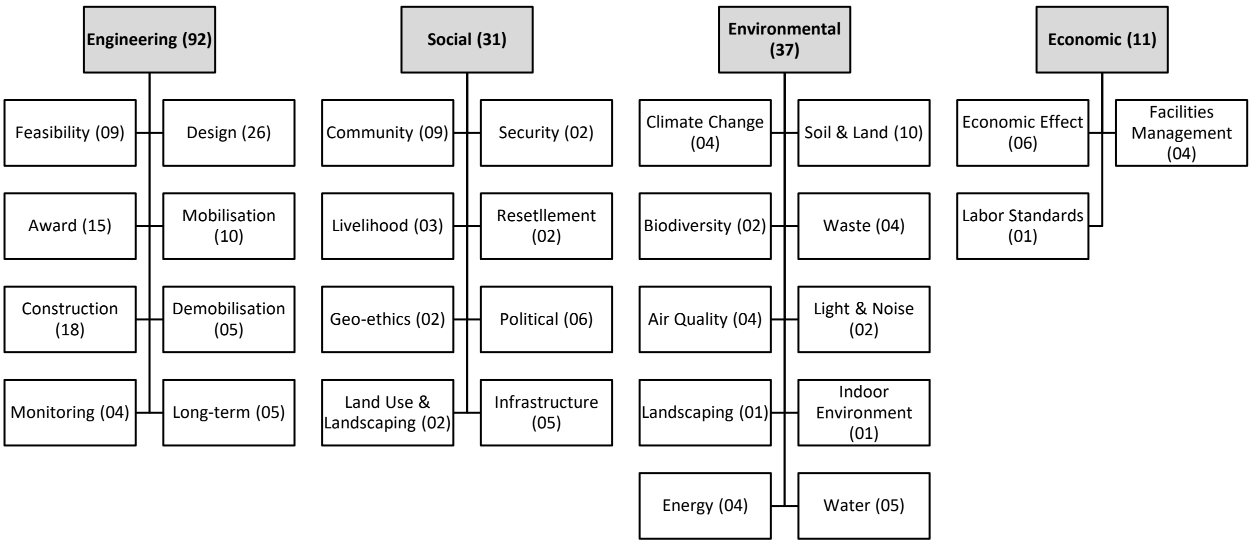

Figure 2: Framework of Geo-SAT

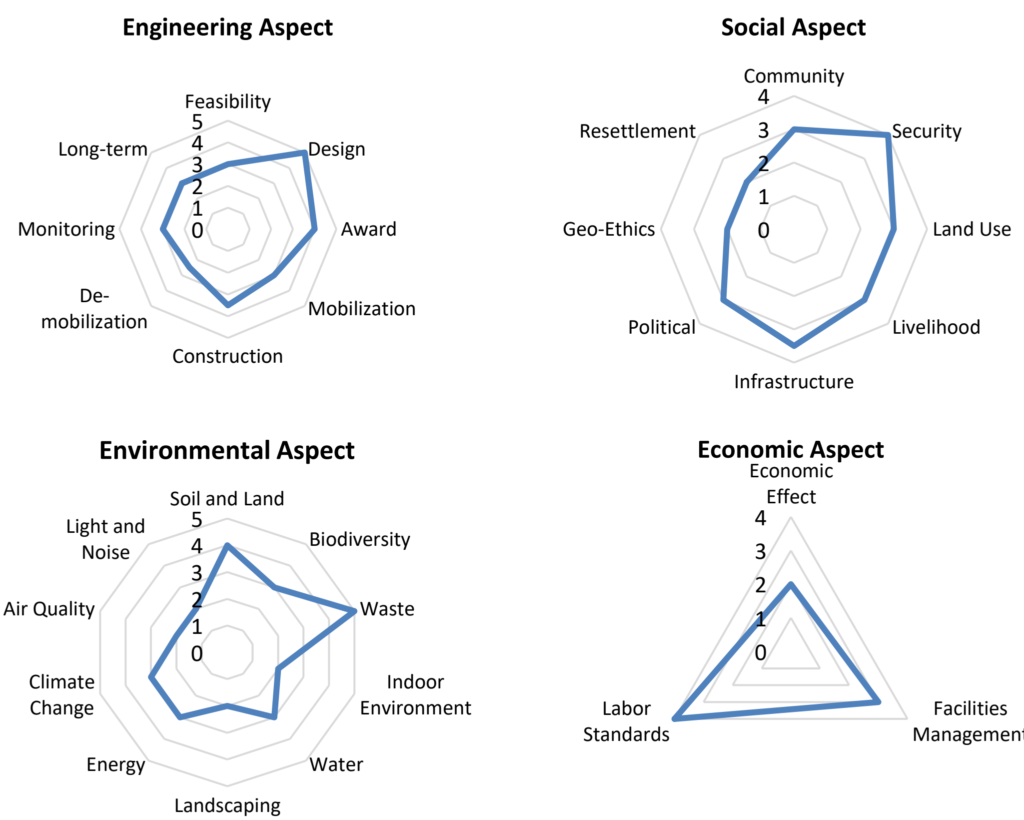

Figure 3: Sample Geo-SAT Averaged Points

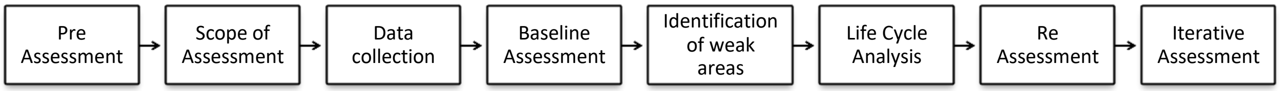

Figure 4: Framework for Geotechnical Assessment

5 CONCLUSION

Following conclusions can be drawn from the conducted study:

- The average is maximum for "detrimental" impact whereas minimum for "significantly improved" showing the poor performance of Pakistan's construction industry in terms of sustainability. The average would have been even low if it were not for types of tests and nuisance notices served. A majority of the firms have not received any formal nuisance notices, comparing with the other survey results, it is easily concluded that the local bodies have failed in terms of the social aspect of sustainability.
- Only a few of the firms have knowledge related to sustainability therefore, at the national level, it is required to incorporate this into the system through awareness lectures and seminars. Sustainability should be made part of the curriculum. The government also needs to take responsibility for arranging awareness through media.
- Community consultation plans should be developed at local and national levels and need to be followed as social aspects of sustainability are as important as the economic factors. The social aspect is majorly avoided and is one of the main reasons for being far behind the goal of achieving sustainability in the projects.
- Based on 171 indicators specific to geotechnics, Geo-SAT gives flexibility of exclusion as per the project's nature.
- The frameworks discussed will act as potential codes of sustainability in the field of geotechnical engineering.

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