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Need for rating system for assessing sustainability of built environment during construction stage

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ABSTRACT

Sustainability in construction has gained attention in recent years as the construction industry adversely impacts the environment and green construction has been emphasized. Various rating systems have been developed by various organizations across the world like LEED, USA; CASBEE), Japan; BREEMA, UK; GBCSL, Sri Lanka, IGBC, India; etc. to certify construction projects under the green projects category, based on parameters majorly considering three factors environmental, societal & economic impact during the entire span of a project from inception stage to demolition stage. In these sustainability assessment rating systems, the parameters relevant to the construction phase have not been emphasized except for a few factors which have been considered under pre-requisite. Though the construction phase has a comparatively shorter duration, it adversely impacts sustainability if considered collectively. So, a holistic approach is needed for sustainability assessment which shall include construction stage-based sustainability parameters too. In this paper, with a questionnaire survey & interaction with experts, the need for construction-based sustainability parameters has been discussed for making a holistic sustainability assessment rating system. The survey & interaction data were analyzed with an analytical hierarchical process (AHP) to understand the need for the additional parameter during the construction stage of the project.

1. Introduction

In the recent decade, issues that are a concern worldwide are environmental pollution, energy consumption, and resource depletion (Berg and BenDor, 2011). Energy consumption worldwide is increasing and consequently increases CO_2 emissions (Nejat et al., 2015). The Construction industry significantly impacts the environment, society, & economy as there is high consumption of energy and natural resources (Darko et al., 2017). As per the study, the construction sector contributes 35% of CO_2 emissions and generates 45 to 60% of waste deposits for landfills (Escamilla et al., 2016). In addition, the construction industry and its associated activities generate harmful gases like Greenhouse gases (GHG) about 30% during the construction process & operation (Escamilla et al., 2016).

The built environment of each project is unique with the involvement of numerous activities that contribute to environmental burdens (Sandanayake et al., 2016). This stage is not limited to environmental issues but causes waste pollution, dust pollution, water, and air pollution along with depletion of resources. Just in buildings, the consumption of water & energy is 45% & 50 %, respectively worldwide and it contributes to air pollution (23%), water pollution (40%), and waste pollution (40%) in cities (Dixon, 2010). So, it is important to promote a sustainable mechanism to reduce this adverse effect on the built environment in construction projects.

In the recent past, different sustainability assessment systems have been developed & implemented. These sustainability assessment systems generally evolve around environmental, social, and economic perspectives for construction projects. The construction phase sustainability parameters in most of the sustainability assessments have been limited to soil erosion, sustainable material use, etc. The other aspects of construction sustainability like energy usage, noise pollution, safety & health of workers, the impact of neighboring environment, and vice versa are not properly accounted for.

There is a need for a rating system for certification of the built environment under sustainability, keeping this need in view various rating system has been developed such as Building Research Establishment

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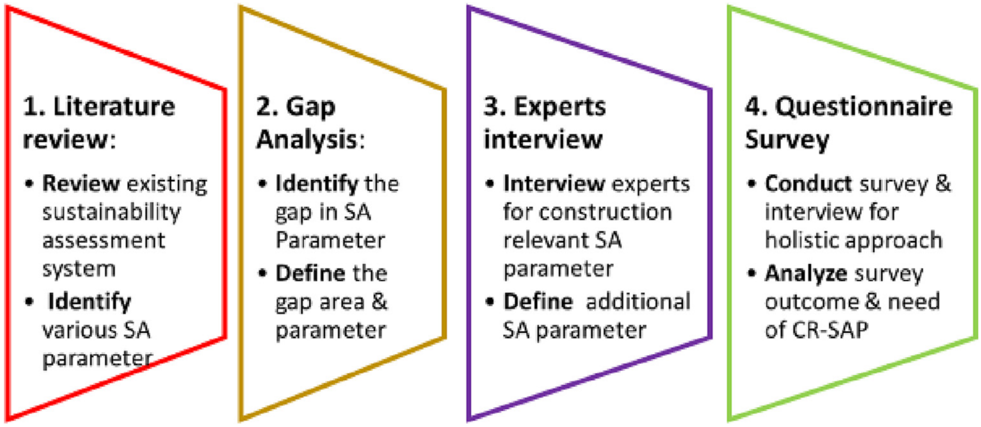

Fig. 1. Methodology of developing construction based rating system.

Assessment Method (BREEAM), United Kingdom; SBTool, international; Leadership in Energy & Environmental Design (LEED), the United States; Comprehensive Assessment System for Built Environment Efficiency (CASBEE), Japan; and other country-specific systems like Haute Qualité Environnementale (HQETM), France; Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB), Germany; Green Building Council Sri Lanka (GBCSL), Sri Lanka; Indian Green Building Council (IGBC) for India. Out of these, the leading ones are LEED followed by the United States and IGBC, used widely in India.

These rating systems are developed with consideration of most of the parameters around Site selection for sustainable view, efficiency in energy & atmosphere, water efficiency, sustainable materials & resources, indoor environment quality, and waste & pollution by inhabitants/ users. GBCSL of Sri Lanka has few additional point relevant to construction practices under management aspect wherein adoption of formal environmental management system during construction stage being highlighted (Anonymous, 2022). It may be noted that these rating systems mainly addressed the above parameters during the pre & post-construction stages. The emphasis on other factors during the built environment is not given proper accounting except that in a few sustainability rating systems, construction has been considered a prerequisite. However, sustainability assessment during the construction stage is also vital, to have a justifiable assessment of various construction projects in the built environment.

This paper aims to understand the existing parameter of sustainability assessment (SA) used to cover the construction phase of the building. Find the gap if any and then establish the need for the construction phase sustainability. Also, this paper aims to identify construction phase relevant sustainability assessment parameters (CR-SAP) for making a framework with a holistic approach.

Table 1
Number of questions in questionnaire for sustainability Assessment.

Sustainability Assessment Parameter	No. of Questions
Energy & Atmosphere	6
Health & Safety	1
Indoor Environment Quality	9
Innovation	1
Integrative Process	1
Material & Resources	2
Regional Priority	1
Site Selection	14
Spatial Location	1
Technical Sustainability	3
Water Efficiency	3
Total	**42**

Table 2
Distribution as project type worked.

Type of Projects Worked	Count Percentage
Residential Building Projects	23%
Industrial Building Projects	20%
Institutional or Commercial Buildings Projects	7%
Infrastructure projects	27%
Development project	23%

2. Overview of past research work

The sustainability assessment rating system has been reviewed & compared for its use in various types of projects and even country-specific use. Lifecycle based sustainability study was done in 2008 to improve sustainability in the construction industry (Ortiz et al., 2009). In 2010, a further LCA (Life Cycle Assessment) study for a Portuguese project was carried out (Bragança et al., 2010) to establish the better use of the sustainability since design phase. From the comparative study of different rating systems, it has been identified that parameters focus on energy efficiency, water efficiency & conservation, solid waste management, and indoor air quality (Doan et al., 2017; Akhanova et al., 2020; Yilmaz and Bakis, 2020; Chandratilake and Dias, 2013; Cordero et al., 2020; Anonymous, 2020; LEED, 2019; IGBC, 2019), and the prevalent parameter has been energy except in CASBEE (Doan et al., 2017; Vierra, 2023; Bernardi et al., 2017; Mattoni et al., 2018). A comparison study also indicates that all aspects of sustainability are not successfully considered in rating systems (Illankoon et al., 2017).

Further, various research papers and literature have been studied to identify the existing sustainability assessment parameters used for the development of the proposed rating system. From the literature review it is found that sustainability parameters were based on the entire lifecycle of the structure starting from the design phase to the demolition phase, but the construction phase is not emphasized appropriately or is considered only as a pre-requisite. Hence there is a gap in the existing approach to sustainability assessment systems.

2.1. Identification of gap in research work

Sustainability parameter involvement of various stages of structure from the inception to the demolition of the structure has been analyzed. It has been found that sustainability assessment parameters focused on environmental, societal & economical aspects and emphasize six phases (Yu et al., 2018) - (i) Initialization; (ii) Design & Planning; (iii) Construction (including Monitoring and Control); (iv) Completion (handover); (v) Operation & Maintenance; and (vi) Demo-

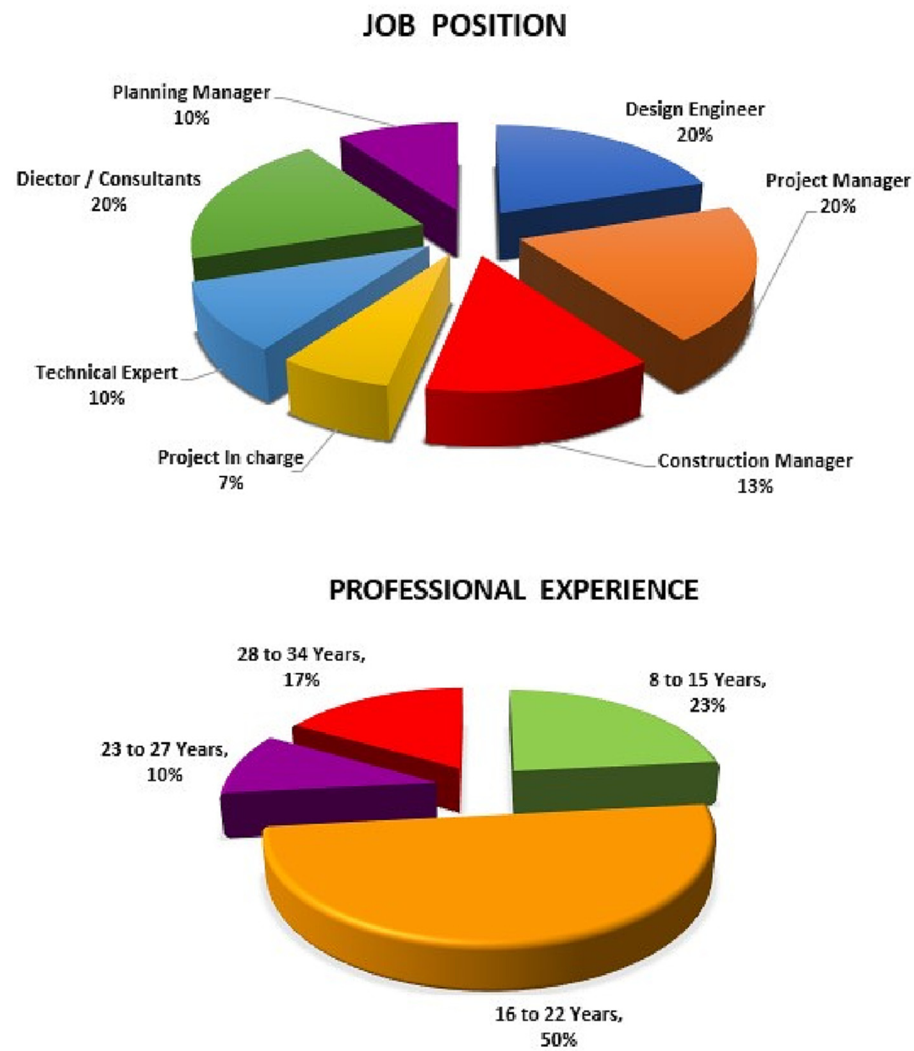

Fig. 2. Profile & Professional Experience chart of experts.

lition. But the impacts of technical sustainability during the construction stage, which includes parameters like environmental pollution, energy consumption, water consumption, etc. have not been given due consideration. In addition, two more sustainability parameters like spatial location and Health & safety also need due consideration for judicial assessment of sustainability during the construction stage of the built environment project.

Keeping the above gap in view research work has been carried out by the first author supervised by the second and subsequent authors to identify the construction-based sustainability parameters based on the above-mentioned gaps details of the research work carried out further mentioned in this paper. The process adopted in the research work consisted of a questionnaire survey & interaction with experts from the construction industry.

3. Research methodology

In recent years, sustainable construction has been increased after understanding the impact on the environment like GHG emission, resource depletion, and environmental pollution. The first-time construction sustainability was discussed in the year 1994 at Tamba, Florida, US (Hill and Bowen, 1997). Thereafter various works were carried out to assess sustainability & developing the assessment rating systems. These rating systems majorly cover three aspects:

(1) Environmental like an efficient use of water, energy & natural resource, eco-friendly material usage, control pollution -air, soil,
(2) Social like habitant health, surrounding health, regional development, and.
(3) Economical like minimum vehicle usage, cost-effective material, maintenance cost, operation cost, etc.

The above aspects mostly cover the pre & post-construction phases. The construction phase & its impact on sustainability has been covered as a prerequisite marginally in these existing rating systems, but sustainability is affected during the construction phase adversely. So going further in this paper, the sustainability impact during the construction phase will be discussed. The methodology used for the paper is mentioned in Fig. 1.

The methodology covers a literature review for the current scenario, identifying gaps of knowledge, preparing a questionnaire for survey & interview, and analysis of these data to identify the need for construction-based sustainability parameters. Statistical analysis ANOVA (Analysis of Variance) has been used to find out the significance of the sustainability parameters. The survey & interaction data were analyzed with an analytical hierarchical process (AHP) to understand the need for the additional parameter during the construction stage of any project.

Table 3
Acceptance table on Questionnaire Survey.

Question No.	Criteria	Questions	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	RII
Q.1	Integrative Process	Inter-relationships among systems should be analyzed at initial stage of inception & design for effective (performance & Cost) sustainable building/ project	7%	0%	7%	37%	50%	0.846667
Q.2	Site Selection	Project should be in authority approved area as it increase Livability, reduce inappropriate development, etc. which impact positive for sustainability	3%	10%	7%	37%	43%	0.813333
Q.3		The location of a building site should not be on environmentally-sensitive land to avoid harmful impacts	0%	0%	0%	33%	67%	0.933333
Q.4		To conserve land and protect farmland and wildlife habitat by encouraging development in areas with existing infrastructure as much as possible	0%	7%	7%	47%	40%	0.84
Q.5		Site location should be such that it has access to quality transit. Like multimodal transportation choices, so as it reduces motor vehicle usage, reducing greenhouse gas emissions, air pollution, etc	0%	7%	10%	30%	53%	0.86
Q.6		Bicycle and non-motorised transport facilities to be encouraged. It will improve public health, reduce vehicle distance traveled, etc.	0%	3%	13%	37%	47%	0.853333
Q.7		Minimize parking footprints to reduce the environmental harms associated. Like automobile dependence, land consumption, and rainwater runoff	0%	3%	17%	53%	27%	0.806667
Q.8		Alternative fuel options like electric, CNG etc. should be promoted to conventional fuels like petrol and diesel.	0%	0%	0%	37%	63%	0.926667
Q.9		Site should environmentally assessed to design sustainable options	0%	0%	7%	57%	37%	0.86
Q.10		Site development should be such that it protect or restore re-habitat. I.e. conserve existing natural areas and restore damaged areas	0%	0%	7%	37%	57%	0.9
Q.11		Promoting alternatives to conventionally fueled automobiles to reduce pollution.	0%	3%	0%	30%	67%	0.92
Q.12		Open space should be provided that encourages interaction with the environment & activities etc.	0%	3%	0%	33%	63%	0.913333
Q.13		Rain water should be managed with natural hydrology & water balance at site	0%	0%	3%	37%	60%	0.913333
Q.14		Encourage to reduce heat islands. Like use plant to shade paved area, shade with solar system, etc.	0%	0%	0%	50%	50%	0.9
Q.15		Improve nighttime visibility so that light pollution could be reduced. Like BUG rating method, etc.	0%	3%	13%	47%	37%	0.833333
Q.16	Water Efficiency	Water Usages in outdoor activities like landscaping and plantation should be reduced to minimum	0%	27%	10%	33%	30%	0.733333
Q.17		Indoor water saving should be promoted in the projects by using water efficient fitting & fixtures and all other possible means	0%	0%	0%	37%	63%	0.926667
Q.18		Use of meters for monitoring the water consumption pattern can minimize water usage	0%	10%	0%	43%	47%	0.853333
Q.19	Energy & Atmosphere	Energy performance level Should be increased for reducing the environmental and economic harms associated with excessive energy use	0%	3%	0%	43%	53%	0.893333
Q.20		Encourage not to use chlorofluorocarbon (CFC)-based refrigerants appliances (for HVAC & R systems) to reduce ozone depletion and support early compliance with Montreal Protocol while minimizing direct contributions to climate change	0%	0%	0%	53%	47%	0.893333
Q.21		Use energy metering to support energy management and identify opportunities for additional energy savings	0%	3%	3%	37%	57%	0.893333
Q.22		The use of grid-source, renewable energy technologies and carbon mitigation projects to be encouraged for reduction of greenhouse gas emissions	0%	0%	3%	47%	50%	0.893333
Q.23		Good cross-ventilation should be designed to control internal temperature thereby reducing the power utilized for HVAC	0%	0%	3%	50%	47%	0.886667
Q.24		Indoor quality should be maintained by preventing or minimizing exposure of building occupants, indoor surfaces, and ventilation air distribution systems to environmental tobacco smoke	0%	3%	27%	47%	23%	0.78
Q.25	Air Quality (Indoor Environment)	Indoor air quality should be maintained by Natural & mechanical ventilation and should be monitored	0%	0%	3%	43%	53%	0.9
Q.26		Indoor quality should be maintained by preventing or minimizing exposure of building occupants, indoor surfaces, and ventilation air distribution systems to environmental tobacco smoke.	0%	10%	7%	50%	33%	0.813333
Q.27		Low -emitting materials should be used to reduce concentrations of chemical contaminants that can damage air quality, human health, productivity, and the environment	0%	0%	17%	40%	43%	0.853333
Q.28		Indoor air quality (IAQ) management plan should be implemented for the construction and pre-occupancy phases of the building to promote the well-being of construction workers and building occupants by minimizing problems associated with construction and renovation	0%	3%	0%	57%	40%	0.866667
Q.29		Proper indoor quality management system should be implemented to establish better quality indoor air in the building after construction and during occupancy	0%	3%	0%	57%	40%	0.866667
Q.30		High quality interior lighting should be provided to promote occupants' productivity, comfort, and well-being	0%	0%	13%	57%	30%	0.833333
Q.31		Introducing daylight into the space to connect building occupants with the outdoors, reinforce circadian rhythms, and reduce the use of electrical lighting	0%	3%	0%	43%	53%	0.893333

Table 3 (*continued*)

Question No.	Criteria	Questions	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	RII
Q.32		Quality views should be provided to give building occupants a connection to the natural outdoor environment	0%	10%	13%	40%	37%	0.806667
Q.33		Effective acoustic design should be used for work-spaces and classrooms that promote occupants' well-being, productivity and communications	0%	0%	10%	50%	40%	0.86
Q.34	Material & Resources	Encourage, by recovering, reusing, and recycling construction and demolition waste materials, to reduce disposed of in landfills and incineration facilities	0%	0%	7%	40%	53%	0.893333
Q.35		Encourage to adaptive reuse and optimize the environmental performance of products and materials	0%	0%	13%	53%	33%	0.84
Q.36	Innovation	Project should be encouraged to achieve exceptional or innovative performance	0%	0%	7%	47%	47%	0.88
Q.37	Regional Priority	An incentive should be provided for points that address geographically specific environmental, social equity, and public health priorities	0%	7%	7%	53%	33%	0.826667
Q.38	Spatial Location	Spatial location of building should be given due consideration with view of sustainability like in hilly terrine Vs thick populated area	0%	0%	3%	63%	33%	0.86
Q.39	Technical Sustainability	Construction phase contribute bigger role for environmental pollution viz. air pollution, noise pollution, soil pollution, etc.	0%	3%	10%	40%	47%	0.86
Q.40		Environmental pollution should be control by proper monitoring & better practice (use of good conditions equipment, construction power through solar power, eco-friendly materials use, etc.) during construction.	0%	0%	10%	50%	40%	0.86
Q.41		Material used & technical design adopted for construction should be such that it sustains a longer life & stand with changing environment conditions like acid rains, abrupt climatic change, natural disaster- flood, earthquake, fire, etc. To contribute to sustainable environment	0%	0%	3%	43%	53%	0.9
Q.42	Health & Safety	Health & safety hazard during construction phase should be measured for sustainability of building/ New Construction	0%	0%	0%	57%	43%	0.886667

Table 4
ANOVA Test result.

Source of Variation	sum of squares (SS)	degrees of freedom (df)	mean square (MS)	$F_{calculated}$	P-value	$F_{critical}$
Between Groups	9.035955	4	2.258989	435.3836	5.9E-99	2.415694
Within Groups	1.063643	205	0.005189	–	–	–
Total	10.0996	209	–	–	–	–

Table 5
Outcome vs sustainability parameters variable interaction matrix.

Variables (criteria)→	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
Outcome-1	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Outcome-2	3.00	3.21	3.67	3.20	4.50	4.33	4.00	3.00	4.33	4.00	3.00
Outcome-3	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Outcome-4	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	4.67	5.00	5.00
Outcome-5	1.00	4.57	5.00	4.60	5.00	4.44	5.00	5.00	5.00	5.00	4.00
Outcome-6	4.00	4.64	3.67	4.20	4.00	4.33	5.00	4.00	4.33	4.00	5.00
Outcome-7	5.00	4.79	5.00	4.80	4.50	4.67	5.00	4.00	5.00	5.00	4.00
Outcome-8	5.00	4.29	3.33	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Outcome-9	4.00	3.93	3.67	4.60	4.50	4.22	3.00	5.00	4.00	4.00	4.00
Outcome-10	5.00	4.07	4.00	4.20	4.00	3.89	4.00	4.00	4.00	4.00	4.00
Outcome-11	5.00	4.93	3.67	5.00	5.00	4.56	5.00	5.00	4.67	5.00	4.00
Outcome-12	5.00	5.00	4.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Outcome-13	4.00	4.14	3.33	4.20	4.00	4.33	5.00	4.00	4.33	5.00	5.00
Outcome-14	4.00	4.07	4.67	4.40	4.50	4.56	4.00	4.00	4.67	4.00	4.00
Outcome-15	5.00	4.43	4.00	4.20	5.00	3.89	4.00	3.00	3.33	5.00	5.00
Outcome-16	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Outcome-17	3.00	3.93	4.00	3.80	3.00	3.78	4.00	4.00	3.67	4.00	4.00
Outcome-18	5.00	4.36	4.67	4.00	4.00	4.00	4.00	4.00	4.67	4.00	4.00
Outcome-19	5.00	4.21	4.33	3.80	4.50	2.89	5.00	4.00	5.00	5.00	4.00
Outcome-20	4.00	3.86	3.67	3.60	3.00	4.11	4.00	2.00	3.67	4.00	4.00
Outcome-21	4.00	4.36	4.33	4.40	4.00	3.78	4.00	4.00	4.00	4.00	5.00
Outcome-22	5.00	4.29	3.33	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Outcome-23	5.00	4.79	5.00	4.80	4.50	4.67	5.00	4.00	5.00	5.00	4.00
Outcome-24	4.00	3.93	3.67	4.60	4.50	4.22	3.00	5.00	4.00	4.00	4.00
Outcome-25	4.00	4.64	3.67	4.20	4.00	4.33	5.00	4.00	4.33	4.00	5.00
Outcome-26	4.00	4.21	4.33	4.00	3.00	4.11	4.00	2.00	3.67	4.00	4.00
Outcome-27	5.00	4.07	4.00	4.20	4.00	3.89	4.00	4.00	4.00	4.00	4.00
Outcome-28	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Outcome-29	4.00	4.21	3.67	4.00	3.00	4.11	4.00	4.00	3.67	4.00	4.00
Outcome-30	1.00	4.57	5.00	4.60	5.00	4.44	5.00	5.00	5.00	5.00	4.00

4. Survey and interaction- process, outcome, and analysis

4.1. Survey process

Though the duration of the construction phase is short as compared to the operation and maintenance phase, its impact is tremendous in terms of noise pollution, soil pollution, air pollution, health and safety, socio-economic challenges, and more. Therefore, sustainability assessment of the construction phase is of utmost importance. As a first step to identifying construction-relevant sustainability assessment parameters, a survey has been conducted through a questionnaire. The questionnaire has been derived on the basis of IGBC & LEED rating system and by interaction with the various expert at construction field. The questions were prepared with eleven different parameters as mentioned in Table 1 such as, site selection, water efficiency, air quality, energy efficiency, technically sustainable structure, etc., and are shown in Table 3.

The questionnaires have been prepared in line with the existing sustainability assessment parameters in various rating systems as well as including additional parameters linked to the construction site focused on technical sustainability, health & safety, and spatial location. As can be observed from Table 3, the parameter of site selection has the maximum number of questions among the existing parameters as it covers various aspects like the use of only designated land, nearby vicinity, fuel saving in transportation, maintaining natural hydrology, etc. Other parameters that have more questions are Indoor Environment quality, Energy & Atmosphere. Indoor Environment quality has nine questions covering maintaining indoor air quality (IAQ) naturally, IAQ management for proper ventilation: use of high-quality interiors, daylight usage for occupants, and effective acoustic design.

Among the newly introduced construction phase parameter, the technical sustainability parameter is the most pertinent although have three questions, however, these questions cover numerous aspects like dust pollution, water pollution, soil pollution, noise pollution, air pollution, sustainability in adverse environmental conditions, etc. The questions on other newly introduced parameters spatial location and Health & safety cover aspects like passing benefits to users, and measures for reducing health and safety hazards.

The survey has been conducted with thirty construction industry experts with different stakeholder profiles and having eight to thirty-four years of professional experience in residential projects, commercial projects, infrastructure project, etc. as shown in Table 2. Experts that were surveyed were those who are directly involved in the construction phase of the project so that gather the realistic responses. These construction experts were in different roles like design engineers, construction managers of the contracting firm, project managers, planning managers, and consultants. Refer to Fig. 2.

4.2. Survey outcome discussion & analysis

The questionnaire survey was carried out with a Likert scale so that quantification becomes possible. The questionnaire included forty-two questions which covers eleven different parameters of the sustainability of the built environment. From the outcome of the survey, it has been observed that all the newly added parameters have been well accepted by the experts. Which is visible in the shown questionnaire

Table 6
Relative weights of sustainability parameters.

Variable No.	Sustainability Parameter	Relative Weightage
V1	Integrative Process	0.107
V2	Site Selection / sustainable site	0.087
V3	Water Efficiency	0.092
V4	Energy & Atmosphere	0.088
V5	Material & Resources	0.090
V6	Indoor Environment Quality	0.090
V7	Innovation & other	0.088
V8	Regional Priority	0.096
V9	Technical Sustainability	0.088
V10	Health & Safety	0.086
V11	Spatial Location	0.089

Table 7
Calculation of credits points for CRSP Framework.

Variable Number	Sustainability Parameter	IGBC		LEED		CRSP- Framework				
		Assigned Points	Weighted %	Assigned Points	Weighted %	Relative Weightage from AHP (At 100 point)	Weighted points based on IGBC & LEED	Credit points with AHP & IGBC & LEED	Normalization	Final credit Points
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8) = [(4)+(6)]/2	(9) = [(8)x(7)]	(10)	(11)
V1	Integrative Process	8	10.39%	1	0.90%	10.65	5.6	60.14	6.72	7
V2	Site Selection / sustainable site	13	16.88%	25	22.52%	8.71	19.7	171.56	19.17	19
V3	Water Efficiency	6	7.79%	12	10.81%	9.20	9.3	85.60	9.56	10
V4	Energy & Atmosphere	17	22.08%	34	30.63%	8.79	26.4	231.69	25.88	26
V5	Material & Resources	13	16.88%	13	11.71%	9.02	14.3	128.95	14.41	14
V6	Indoor Environment Quality	15	19.48%	16	14.41%	8.95	16.9	151.65	16.94	17
V7	Innovation	5	6.49%	6	5.41%	8.77	5.9	52.15	5.83	6
V8	Regional Priority	–	–	4	3.60%	9.58	3.6	34.50	3.85	4
V9	Technical Sustainability	–	–	–	–	8.78	21.0*	184.29	20.59	21
V10	Health & Safety	–	–	–	–	8.63	4.0*	34.51	3.86	4
V11	Spatial Location	–	–	–	–	8.93	3.0*	26.80	2.99	3
	Total	**77**		**111**		**100.00**	**129.80**	**1161.84**	**129.80**	**131**

*:Credit point interpolated from the existing parameters with respect to AHP relative weighted.

acceptance Table 3. It could be observed that there is 73% or more acceptance by experts while the adverse responses lie between 0 and 10%. The relative importance index (RII) of the questionnaires as shown in Table 3 also reflect the same that all questionnaire had importance more than 0.73.

The significance of the questionnaire for sustainability parameters has been tested with the ANOVA technique. The ANOVA analysis is stated as ($F_{critical}$ = $F_{calculated}$, significant level p), and if $F_{calculated}$ value > $F_{critical}$ value, which signifies that the null hypothesis stands rejected. The analysis shows, since the p-value is less than 0.05 hence, it is concluded that there are significant differences between the sustainability parameters. ANOVA test result shown in Table 4.

From the results & sustainability parameters interaction matrix has been produced using survey data. The Interaction matrix has been generated with 11 parameters as variables and thirty possible outcomes which have been analyzed by AHP, a multi-criteria decision making (MCDM) process. The Interaction matrix is shown in Table 5.

For each parameter pair-wise comparison is done then a pairwise comparison matrix is generated. Then by normalization process matrix has been normalized. Thereafter ratio scale is generated with the Eigenvector principle and a consistency check has been done by consistency index. Hence by AHP analysis, the relative weightage of the parameters has been calculated which is shown in Table 6.

From so calculated relative weightage, the credits points against each parameter have been assigned by the following method:

For the existing parameters, credit points have been obtained considering the weightages of LEED & IGBC rating system, as well as relative weightage, so obtained from AHP analysis as shown in Table 7.

For newly added CRSP the credits points have been obtained by considering the relative weightage obtained from the AHP analysis as well as credits points for the existing parameter of the LEED & IGBC rating system as shown in Table 7.

Process of obtaining the credit score for CRSP-framework design has been shown in Table 7. The Credit score has been normalized on credits system for existing sustainability parameter as well as CRSP, which were mentioned earlier in this work.

5. Conclusion and future perspectives

From the above perspectives as discussed in the paper and in light of Table 7, it is evident that there is a need for including sustainability parameters like technical sustainability, spatial location, and health and safety, during the construction stage in the rating system for assessing the sustainability of built environment projects. From the perspective of technical sustainability, there were factors like air pollution caused by exhausted gas coming out of outdated or poorly maintained construction equipment; there is dust pollution by the movement of the heavy vehicle; noise pollution by construction equipment; water pollution by disposing of polluted construction water in nearby water body/water drain and many more which pollute the environment & surroundings at construction stage. The health & safety parameter which covers following safe practices during construction sites impacts societal and economic factors of sustainability.

It can be concluded that there is a gap in analyzing the sustainability impact due on the built environment at the construction stage of the civil project. It is therefore recommended that the rating system to be used in the future for assessing the sustainability of constructions project of the built environment should also include these parameters as an essential component.

CRediT authorship contribution statement

Mukesh Kumar Dubey: Conceptualization, Methodology, Writing – original draft. **Vijay Raj:** Methodology, Supervision. **Manish Kumar:** Supervision. **Vikas Garg:** Supervision.

Data availability

No data was used for the research described in the article.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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