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Key performance indicators of sustainability

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Abstract. Sustainable construction involves the judicious use of resources so as to satisfy the demands of both present and future generations. It is supported on three pillars namely economic, environmental and social. This study aims to understand the key performance indicators of sustainability. Based on the literature review, this study develops a set of performance indicators relevant to Indian construction industry. Questionnaires and interviews are conducted among the architects and engineers. Using Relative Importance Index, the identified indicators are prioritised.

Keywords: Sustainability, Performance Indicators, Relative Importance Index

1. Introduction

Construction sector is the second largest in India after agriculture. In their entire life cycle, buildings have a large impact on the environment. Buildings worldwide consume 30% of the planet's energy and 40% of its resources, generating about 40% of the waste and emitting 35% of the green house gases.

Sustainability is no longer just a buzzword but a reality that must be addressed. The concept of sustainable development gained momentum with the Brundtland Report. The Brundtland Commission, formerly known as the World Commission on Environment and Development was formed to unite the countries to pursue sustainable development together. According to the paper *Our Common Future*, "Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs". It is the organizing principle for meeting human development goals while at the same time sustaining the ability of natural systems to provide the natural resources and ecosystem services upon which both the economy and society depend. Thus sustainable construction of buildings can contribute significantly to the environment and thereby the society, satisfying both present as well as future generations.

A green building is defined as environmentally sustainable building, constructed and operated to minimize environmental impacts; it uses less water, conserves natural resources, generates less waste, optimizes energy efficiency and provides a healthier space for its occupants. Markelj et al. [1] conducted a review of different sustainability assessment systems and distinguished between sustainability and green. According to the study, for a building to be called sustainable, it must consider economics, urban planning, transportation issues and social and cultural issues. In other words, green is considered as a subset of sustainability.



Sustainability has three pillars namely economic, environmental and social [2]. Various studies identifying the Key Performance Indicators of sustainability were conducted in different places like China, Australia, Malaysia, Taiwan etc. Since these dimensions are contextual to the location, it is imperative that the performance indicators of sustainability in the local context are studied and prioritized.

Therefore, this paper aims to prioritise the Key Performance Indicators of Sustainability in buildings in Indian construction industry through expert opinion surveys conducted with professionals from the field.

2. Literature review

Shen et al. [3] developed a checklist for assessing sustainability performance of construction projects across its lifecycle. The developed framework enabled to assess the project performance in a holistic and consistent way. Abidin [4] conducted a qualitative work in Malaysia that included field studies, surveys and interviews to investigate the level of awareness, knowledge and implementation of sustainable practices based on project developers in Malaysia. A sample size of 20-30 was selected for the questionnaire response and about 12 interviews with well established developers were chosen. Implementation of sustainable practices was observed to be poor due to lack of knowledge, experience and poor enforcement of legislation. Shen et al. [5] identified the key assessment indicators for the sustainability of infrastructure projects. Questionnaire surveys were conducted with three expert groups that included government officials, professionals and clients in the Chinese construction industry. Here fuzzy set theory was used to establish the key indicators. Lopez and Sanchez [6] discussed the approaches to sustainability assessment by indicators which included cost benefit analysis and multi-criteria analysis. According to them, an indicator set must be described through its social, economic and environmental pillars of sustainable development. The study also focused on the need of indicators in considering the various project alternatives. The requirements for implementation of indicator system was identified that included setting up of a common ground on the identification and selection of indicators, sensitivity ranges for the indicators according to the regional variations and a need for integrated sustainable management. A need for continuous monitoring and a feedback system was also identified. Tam and Zeng [7] developed sustainable performance indicators for residential buildings with reference to the Australian industry. Questionnaires and structured interviews were conducted and the target groups included residents from overseas, local residents, industrial professionals, and real estate agents. Five point Likert scale was adopted for the survey. Data collected were analyzed using the SPSS software. Relative Importance Index was calculated and used to prioritize among the 62 indicators. Connor et al. [8] discussed sustainability actions during the construction phase as most of the indicators focused on the early project phases – planning and design. A research team of fifteen members that included owners, contractors, design consultants and suppliers was chartered. Fifty three sustainable actions were developed for the construction phase. Cheng et al. [9] measured sustainability of Taiwan construction projects throughout their life-cycle. A Construction Project Sustainability Assessment System (CPSAS) considering the three pillars of sustainability was proposed. Indicators in different project phases were suggested according to prioritization through questionnaire surveys. The feasibility of the proposed CPSAS was tested in real life projects. The proposed CPSAS was found useful for construction stakeholders to achieve sustainability more effectively during the execution of project. Li et al. [10] studied on the social sustainability indicators of public mega projects in China. Questionnaire survey was chosen and a seven point Likert scale was incorporated to facilitate the rating process. The responses collected were analyzed by using the mean score ranking technique. Kendall's coefficient of concordance and Spearman's rank correlation test were done to examine the internal consistency of the data. Factor analysis was also done. Twenty two indicators were identified.

3. Research methodology

For the study, an extensive literature survey was done. Questionnaire survey approach was used to identify the performance indicators of sustainability. The questionnaire was framed and categorised from relevant literature. The questionnaire had three sections and a five point Likert scale was adopted. A pilot survey was done to restructure the questionnaire developed. The indicators were prioritised through expert opinion survey with respondents being architects and engineers. Relative Importance Index (RII) method was used to prioritise among the identified indicators. Thus key performance indicators of sustainability were obtained. Figure 1 summarises the adopted methodology.

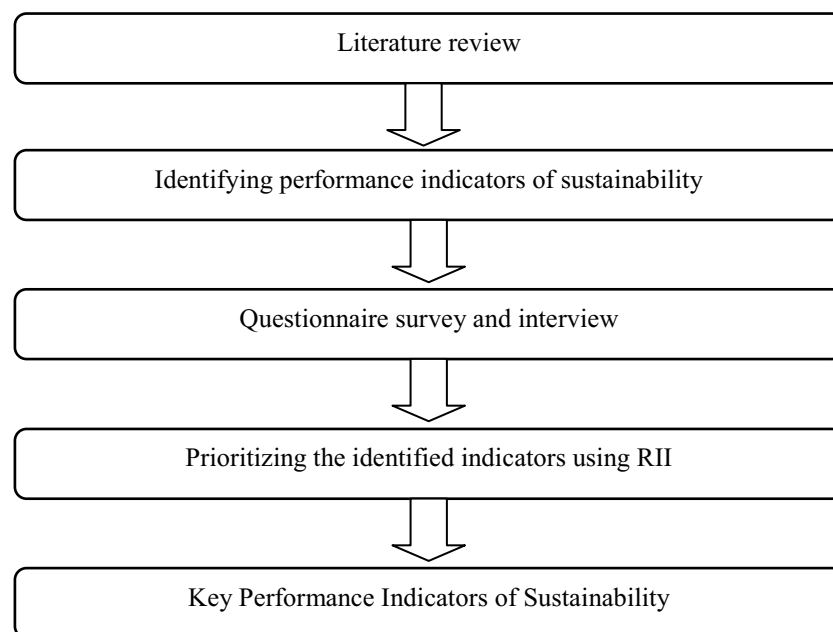


Figure 1. Adopted research methodology

3.1 Identified indicators

The performance indicators of sustainability were identified from literature review. Forty eight indicators identified from the three pillars of sustainability- environmental, social and economic are as shown in tables 1, 2 and 3.

Table 1. Identified indicators

Environmental	Social	Economic
<ul style="list-style-type: none"> ▸ Project development area ratio ▸ Amount of borrowed soil ▸ Amount of concrete usage ▸ Measure of water saving ▸ Recycling of water ▸ Reduction of water pollution ▸ Reduction of air pollution ▸ Reduction of solid waste ▸ Noise reduction ▸ Energy saving 	<ul style="list-style-type: none"> ▸ Design of the building ▸ Levels of insulation of walls and roof ▸ Interior air quality ▸ Ventilation ▸ Daylight ▸ Prevention of electro magnetic pollution ▸ Solvent-free paintings ▸ Entertainment features 	<ul style="list-style-type: none"> ▸ Initial cost ▸ Operation cost ▸ Maintenance cost ▸ Renovation cost ▸ Cover against environmental risks ▸ Adaptability to utilisation change ▸ Early project planning ▸ Fire prevention

<ul style="list-style-type: none"> ▸ Low GHG emissions ▸ Ratio of planting area ▸ Usage of bio-degradable material ▸ Avoiding bio-sensitive area ▸ Avoiding disaster-sensitive area ▸ Vertical green planting usage ▸ Number of green certified building items ▸ Usage of green energy 	<ul style="list-style-type: none"> ▸ Barrier-free construction ▸ Conservation of cultural monument ▸ Participation of local residents ▸ Fair sharing of benefits ▸ Incorporation of safety features ▸ Quality of living ▸ Well-being and comfort of users ▸ Security within building ▸ Level of awareness of sustainability 	<ul style="list-style-type: none"> ▸ Marketability ▸ Provision of local employment ▸ Construction time ▸ Price for sale or rental ▸ Return on investment
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3.2 Questionnaire survey

Of the three sections in the questionnaire, Section A comprised of personal information of the respondent, section B included the responses regarding the indicators and section C consisted of some open ended questions. A five-point Likert scale ranging from 1(strongly disagree) to 5(strongly agree) was used to obtain the responses.

3.3 Sample selection

The responses were collected through Google forms as well as face-to-face interviews. Responses were collected from construction professionals including architects and engineers from Trivandrum, Ernakulam, Thrissur in Kerala and Chennai region. A total of forty eight responses were obtained. Among them, fifteen face to face interviews were conducted to gain a better insight into their perceptions, opinions and attitudes regarding sustainability.

About 55% of the total respondents had worked in green buildings and 60% of the total had an experience of more than 10 years. Figures 2 and 3 represents the respondent details of questionnaire survey and interviews respectively.

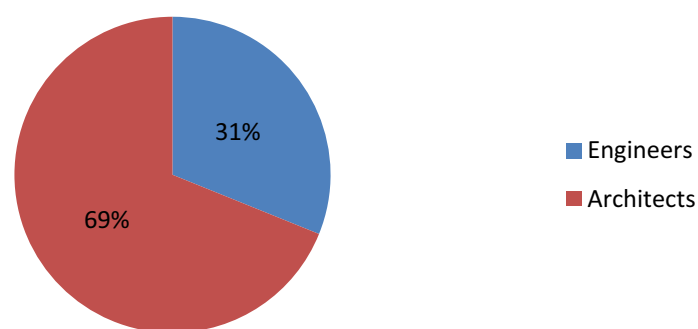


Figure 2. Respondent details of questionnaire survey

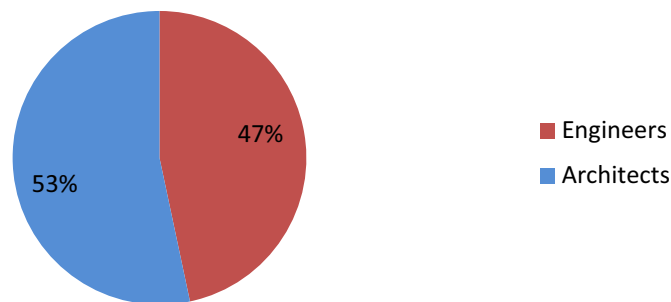


Figure 3. Respondent details of interview

3.4 Ranking of indicators

Relative Importance Index (RII) was used to prioritise among the identified indicators. RII is calculated using the formula

$$RII = \frac{\sum w}{A \times N} \quad (1)$$

where w – weightage given to each indicator, A – highest rating given and N – total number of samples.

Based on the RII obtained, rank was allotted to each indicator under the three heads, namely environmental, social and economic.

4. Results and discussions

Based on the RII obtained, indicators are ranked as shown in tables 2, 3 and 4.

4.1 Environmental indicators

Water savings, recycling and reduction of water pollution were given prime importance by the respondents. This clearly shows the need for implementing efficient water conservation measures while designing buildings. Project development area ratio and the usage of green certified items used in the building were given the least priority.

Table 2. Environmental indicators

Sl. No.	Indicators	Rank
1	Water saving	1
2	Recycling of water	2
3	Reduction of water pollution	2
5	Reduction of air pollution	3
6	Reduction of solid waste	3
7	Ratio of planting area	4
8	Usage of bio-degradable material	5
9	Low GHG emissions	6
10	Usage of green energy	7

11	Avoiding bio-sensitive area	8
12	Avoiding disaster-sensitive area	8
13	Noise reduction	9
14	Amount of borrowed soil	10
15	Amount of concrete usage	11
16	Vertical green planting usage	12
17	Project development area ratio	13
18	Usage of green certified items	14

4.2 Social indicators

Daylight, building design and ventilation secured the top ranks. This indicates the importance of orientation of buildings such that maximum daylight can be captured. Proper design of the building in the pre-project planning phase can help contribute in achieving a sustainable construction. Security within building, entertainment features, fair sharing of benefits and solvent free paintings were given least priority.

Table 3. Social indicators

Sl. No.	Indicators	Rank
1	Daylight	1
2	Design of the building	2
3	Ventilation	3
4	Interior air quality	4
5	Level of awareness of sustainability	4
6	Quality of living	5
7	Well-being and comfort of users	6
8	Levels of insulation of walls and roof	7
9	Barrier-free construction	8
10	Participation of local residents	9
11	Incorporation of safety features	9
12	Conservation of cultural monument	10
13	Prevention of electromagnetic pollution	10
14	Security within building	11
15	Entertainment features	11
16	Fair sharing of benefits	12
17	Solvent-free paintings	13

4.3 Economic indicators

Maintenance cost, fire prevention, early project planning, operation cost and adaptability to utilisation change were identified as the major key performance indicators. Return on investment, price for sale or rental, marketability were not identified as major indicators.

Table 4. Economic indicators

Sl. No.	Indicators	Rank
1	Maintenance cost	1
2	Fire prevention	2
3	Early project planning	3
4	Operation cost	4
5	Adaptability to utilisation change	5
6	Renovation cost	6
7	Cover against environmental risks	7
8	Provision of local employment	8
9	Initial cost	9
10	Return on investment	10
11	Construction time	11
12	Marketability	12
13	Price for sale or rental	13

Some of the new indicators identified as part of the survey include:

- *Exploration of the site potential*: At the planning stage, the site can be thoroughly studied and the natural potentials of the sites can be utilised. For example, if a water body is passing through the site, it can be widened and used as rain water harvesting ponds.
- *Usage of permeable paving*: Permeable paving will help the accumulated water to infiltrate into the ground thereby recharging the underground water level.
- *Reduced use of artificial cooling system*: Helps to reduce the initial costs, energy and water sources consumed. It can be achieved by proper insulation of walls and roof.
- *Community development*: Indicates the development of a community by caring and sharing, including the social aspects.
- *Affordability of schemes*: Makes the practices affordable to the common man so that they can be accepted and welcomed.
- *Usage of regionally available and manufactured materials*: Helps in reducing the consumption of fuel and the involved costs.

5. Conclusions

With the rise in population, there is too much pressure on the existing resources that their availability for the future generations is at stake. Since sustainability is all about utilising resources without compromising on the future generations to meet their own needs, it is the responsibility of each individual who lives on this planet to use the resources judiciously. The present study revolves round the three dimensions of sustainability - environmental, social and economic.

Under the three sustainability dimensions, forty eight Key Performance Indicators were identified from literature. Their ranking was done through questionnaire surveys and interviews on engineers and architects. Some additional indicators like usage of permeable paving, reduced use of artificial cooling system and exploring the site potentials were also recognized. These new indicators are best suited to be in the environmental dimension of sustainability and are found to be specific to the tropical climate.

A deeper probe into the top ranking indicators of each of the three dimensions is done here. Under the environmental dimension, top rank was given to water savings. It is mainly due to the anticipated water shortage for the coming generations. Currently, water scarcity has started to rise because of the depletion of natural forest cover and reduced ground water levels. Therefore it is important to ensure careful use of water sources and methods like rain water harvesting, less water consuming fixtures etc. can be promoted by the government itself.

Daylight secured the top rank in social dimension. Maximum daylight into the building can be achieved without much investment provided proper studies are conducted before deciding on the orientation of the building, locating fenestrations and shading devices. It will also ensure improved comfort for the users.

One of the common obstacles to implementing a sustainable practice is the inability of the common man to assess its life cycle costs. Though the initial cost may be high for many of the practices, in actual practice, the operation and maintenance costs are low. The survey ranked maintenance cost first among the economic indicators. Return on investments is ranked low, which is one of the reasons for people not being aware of the benefits of going sustainable.

The ranking given to usage of green certified items in the building is low though their impacts on the environment are minimal. This is mainly due to lack of awareness and their high cost. The indicators like barrier free construction and adaptability to utilisation change are ranked important though they are not implemented in practice.

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