SUSTAINABILITY DEVELOPMENT INDEX FOR BUILDINGS

Prof Neeraj Gupta

Professor
Institute of Architecture & Town Planning
Bundelkhand University, Jhansi
+91-9415135725, ngneeraj@yahoo.com

Abstract

The paper focuses on the Sustainable Development Index (SDI) for buildings, particularly in the context of environmental impact. It emphasizes the substantial energy and material consumption in construction and maintenance, which leads to significant waste, pollution, and global warming. The document highlights the urgency in addressing the depletion of non-renewable resources and proposes the integration of sustainability development indicators to aid decision-making. Emphasizing the substantial contributions of buildings to global energy consumption and carbon dioxide emissions, the study critiques current assessment methodologies for not considering critical engineering properties and proposes an integrated ASP-SDI model. This model assesses sustainability levels of buildings and construction materials, aiming to minimize the environmental impact and contribute to a more sustainable urban development, particularly relevant for rapidly urbanizing countries like India. The document is a call to action for more responsible use of resources and the adoption of sustainable practices in the construction industry.

Key Words : *SDI, ASP-SDI Model, Sustainable Building*

Introduction

Impact of built environment on natural environment is a serious concern all over the world. Large amounts of materials and energy are used in material extraction, processing, product manufacturing, construction and maintenance. This whole cycle entails into huge amount of waste generation, pollution and global warming. Materials drawn from non-renewable sources signify depletion of natural resources and calls for immediate remedial measures. Charles Kibert, in his book "Sustainable Construction' observes, two fifths of world's energy flow and material are due to buildings.

Reports generated on Trends in global CO2 emissions by **Planbureau Voor De Leefomgeving, (PBL) Netherlands, 2015**, an Environmental Assessment Agency, observe that India, USA, China and EU contribute 6.0 %, 15%, 30% and 10% respectively to the global carbon dioxide emissions totalling to 61%. According to **World Health Organisation Report, 2016**, by 2030, majority people live in urban areas. The global urban population is expected to grow at 1.44% per annum between 2025 and 2030. This unprecedented growth in population will impart enormous pressure on infrastructure development including buildings. Hence sustainability scenario varies with growth and will imply imbalance.

As per the report by **Indian census 2011**, 31.5% of the total Indian population of 1.21 billion lives in urban areas and this number will swell to 50% by 2030. Studies carried out estimate construction sector contributing 22% to Green House Gas (GHG) emissions in India and the demand for Indian housing sector is ever growing. According to **UNEP 2011 report,** about 66 million households were in urban areas in 2010 and projected to be doubled by 2050. The expected growth in commercial building spaces will also increase to 890 million square meters by 2030 from present scenario of 200 million square meters in 2009. Thus, Sustainable development and realistic assessment of energy impact of buildings attain greater importance in urban habitat all over the world in general and more so in developing countries like India. While addressing the issue of sustainability assessment, it is relevant to note the United Nation's call for evolving sustainability development indicators by each country that assist and improve decision making at all levels (**UNCED, 1992; Agenda 21, Chapter 40). Intergovernmental Panel on Climate Change (IPCC) 2001** reports that 40% of the global energy consumption is by the building sector and contributes to about 25% of global carbon dioxide emissions.

In the past, there are efforts in assessing energy impacts of buildings using embodied energy of materials constituting a building system. Most assessment methodologies do not take critical engineering properties into consideration. Whole building as a system comprises of many subsystems like foundation, masonry, formwork etc. These subsystems in the present discussion are referred to as primary parameters. Further, subsystems in a building by themselves are a combination of several building materials. Longitivity of a building depends on right selection of building subsystems.

Most embodied energy data currently available are based on energy consumption and do not provide values for all subsystems. For example, cement is never used as a standalone building material but used as a constituent in manufacturing of concrete. In mortar, it is used along with fine aggregates. Hence, engineering characteristics of concrete and mortar as subsystems play a vital role in the overall assessment. Similar analogy can be applied to Glass as building material. Glass forms an indispensable part of windows and other envelope subsystems along with other components such as frames and fixtures. However, some inventory data available include impact assessment of window systems independently. Hence, there is a need for developing an assessment tool integrating engineering characteristics along with other eco parameters.

In terms of sustainability, there is a need to reduce consumption of global reserves of raw materials that are anthropogenic in nature. Environmental impact due to consumption of non-renewable resources such as fossil fuels and minerals attract higher attention in assessing the impact of built environment on natural environment. These resources are provided by the nature by slow geological processes and their unscrupulous use diminishes available stocks and soon critical thresholds will be crossed.

Increase in population demands increase in infrastructure development and in turn exerts pressure on natural resources. Studies carried out by **National institute for Public Health and Environment, Netherlands, 2010**, have shown that worldwide demand for fossil and mineral resources are continuing to grow at rapid pace. Unavoidable industrial growth in developing countries has also added to this demand. Use of raw materials by built-environment is directly proportional to natural resources consumption.

Importance of Construction Phase Assessment

There have been several studies assessing energy consumption during maintenance and operating phases of building‘s life cycle. Energy consumption and GHG emissions that occur during construction phase peak in a short period and are more detrimental in comparison to the emissions that occur during the operational phase. In operative and maintenance phase the impact is distributed throughout the design life of a building and more or less controlled. Thus, the relative importance of energy consumption and GHG emissions in the pre use phase of building‘s life cycle attains higher importance.

Sustainability assessment during the conceptualisation stage using important environmental criteria will not only assist in decision making but also will provide necessary information to minimise the detrimental effect of built environment and depletion of natural resources. Sustainability assessment in its true sense is a measure of progress towards sustainability.

There are two types of widely accepted building assessment tools namely, Criteria based and Life Cycle Analysis (LCA) based. Criteria based tools assign ascending or descending performance points to building parameters which are pre-determined. Most current green rating systems fall under this category. In these cases, building performance assessment is based on design intent and not on energy performance of a building. LCA based tools consider energy consumed by building constituents at various stages of building‘s life cycle including GHG emission, transportation and other eco parameters. All over the world, LCA is accepted as a tool used for assessing environmental performance of buildings that takes energy flows into consideration. As observed by **Treloar et al. 2000**, LCA methods have their own limitations due to lack of reliable data available and various processes involved. However, LCA methods do not take engineering characteristics and cost factors of materials into consideration. Bureau of Energy Efficiency (BEE), Government of India, has developed a rating program based on actual energy usage per unit area per year to rank the buildings from sustainability view point.

Need for Sustainability Development Index (SDI) in Buildings

Sustainability assessment is a complicated process as it involves several complex interactions as described by S**abnis A and Pranesh M R, 2015** and 2016. Hence, an integrated approach, satisfying structural integrity of materials and helps in decision making, in order to judge, as to which action leads to a sustainable society, attains higher importance. Advances in material science lead to more building materials with different properties. Erroneous selection of materials makes buildings more susceptible for failures defeating the very purpose of sustainability. Hence, material selection using engineering characteristics is essential for a sustainable design.

This research proposes an integrated sustainability development index, designated as ASP-SDI, using the concept of FoM in the framework of interactions between construction materials, embodied energy and global warming. SDI methodology suggested here is a comprehensive assessment model by applying which, sustainability level of a building is expressed in terms of percentage. The proposed model applies normalisation to ten primary parameters or subsystems in the whole building system to compute the overall energy impact per square meter of a building prior to actual construction process. ASP- SDI model provides two levels of sustainability indicators namely;

Impact contribution of a subsystem and Impact contribution of the whole building system.

In the current proposal, Indian conditions are represented for illustrating sustainability evaluation but can be applied to all geographic locations. Inputs from bill of quantities estimated prior to construction provide the real time data and hence, attain importance in the entire assessment process. Interpretation of sustainability levels helps in replacing energy intensive materials with low energy materials to reduce global warming.

Definitions and Terminologies

Various terminologies that appear in ASP-SDI assessment methodology are briefly discussed below:

Figure of Merit (FoM)

FoM has several contextual definitions and has been extensively used in various fields of engineering to assess the most suitable option amongst available alternatives. To cite a few applications, in engineering designs FoM is applied to find out material suitability, compare utility, applicability and design options. Studies show many examples of FoM applications and formulations using engineering parameters.

In the absence of specific guiding rules for constructing FoM equations, it is recommended to identify a range of desirable attributes and include them in formulating the FoM equation. FoM, in the present application, is designated as ZC and constructed using two reference properties and two construction industry cost stimulants. While modulus of elasticity and density are the two important engineering properties, unit cost of material and cost of construction per unit area, become two cost stimulants. FoM in the proposed application is a non-dimensional parameter. Proposed ASP-SDI model evaluates FoM (ZC) values for each subsystem in a building and applies it in the assessment process.

Sustainability Level of a Building

Civil engineering projects comprise different domains categorised under civil, electrical, HVAC, plumbing, sanitary, landscaping and finishes. Each domain consists of several subsystems and each subsystem has several materials. Thus, a building with several system complexities makes computation of energy impact intricate. Sustainability level with respect to a building or an infrastructure project can be viewed with internal and external attributes. Within a project, sustainability level acts as an indicator enabling us to evaluate the energy impact of each subsystem as compared to overall impact. Following sections show the usage of SDI distribution within a building. This helps in identifying those subsystems imparting maximum impact. Maximum impact subsystems are to be addressed on priority basis with suitable low energy alternative materials or subsystems to reduce the overall energy impact.

Applying the same principle to a building as _whole system‘, sustainability level of a building indicates the extent of building‘s sustainability, as compared to a benchmark project (BMP) with least energy consumption. Sustainability levels in either case are expressed in terms of SDI percentage. Ten primary parameters or subsystems namely; Concrete, Reinforcement, Plaster, Structural Steel, Formwork, Walls, Doors, Windows- Glazing, Water Proofing and Painting, involved in construction phase are considered to compute the sustainability level of a building.

Global Warming Potential (GWP) Time Period

GWP is one of the important impact assessment indicators considered in Life Cycle Assessment (LCA). Higher concentrations of GHGs present in the atmosphere result in global warming. Each GHG differs from other in terms of radiative efficiency and the time it stays in the atmosphere. The time period GHGs stay in the atmosphere is referred as GWP Time period. CO2 is considered as base GHG and other gasses expressed in terms of CO2 equivalent. According to Intergovernmental Panel on Climate change (IPCC) Assessment report, 2014, this GWP time period is usually considered as 100 years.

Design Period

Buildings during their life time undergo many changes, form to function, resulting in varying environmental impacts. Assessing the total energy impact of a building using LCA through cradle to grave boundary condition, calls for defining a life time period from 25 years to 100 years. In the present discussion, the life time or design period of material is taken as 50 years. Hence, the ratio of design period to GWP is found to be in the order of 0.5.

Interaction Phenomena

Construction process consumes vast amount of potential energy from depletable resources and construction materials interact with embodied energy footprints resulting in Global Warming. The interaction between the above three eco-attributes is a complex phenomenon. The complex interaction phenomena between Construction Materials, Embodied Energy footprint and Global warming are discussed in chapter 4 elaborately.

Interaction Equations

Three Interaction equations namely, I1, I2 and I3 described in chapter 4, are derived by integrating 12 fundamental eco-parameters in combination including four critical parameters used to construct Figure of Merit equation. Details of Interaction indicators are explained. In the absence of any specific guidelines available for the construction of Interaction Equations, predominant parameters in respective interaction response were included as principal parameters. For example, in Interaction I1, between materials and embodied energy, material properties, economics of materials, cost of construction, energy consumed in the initial stages of building‘s life cycle and transportation play a vital role. Hence, Interaction equation, I1, integrates these characteristics. On similar grounds, I2 and I3 integrate principal parameters namely greenhouse gases emission, GWP, Design Period, and coefficients of embodied energy, transport energy and embodied carbon. Outcome of three interaction equations are non-dimensional values.

While determining Interaction Values, four function formats were considered namely, normal, square root, cube root and fourth root. Magnitudes of interaction values were found to be too large or too low under normal, cube root and fourth root computations. Hence, three interaction equations (I1, I2 and I3) are represented as square root functions as 1, 2 and 3.

Where;

$I1 = \sqrt{(ZC \times EEC \times TEC)}$ ……… (1)

$I2 = \sqrt{(ZC \times ECC \times TEC \times \mu)}$ ……… (2)

$I3 = \sqrt{(ZC \times EEC \times ECC \times TEC}$ ..

I1, I2, I3 are Non-dimensional Interaction Values,

ZC = Figure of Merit (FoM- As described in chapter 3)

EEC = Embodied Energy Coefficient, ratio of material EE to EE of stone,

ECC = Embodied Carbon Coefficient, ratio of material ECe to ECe value of stone,

TEC = Transport Energy Coefficient, ratio of transport energy and EE of stone,

μ = Time-Period Coefficient, product of EEC and ratio of Design

Period to GWP Time Period = EEC x 50 years/ 100 years= EEC x 0.5

In the above interaction equations1, 2 and 3, EE and EC equivalent (ECe) values are obtained from LCA based ICE inventory, version 2.0, 2011, Design period as 50 years, GWP time period as 100 years, for reasons described in chapter 4. Miller, 1998 observed the energy consumption during transportation by road varies between 1.18 and 4.5 MJ/tonne/km and hence average of 2.85 MJ/tonne/km is taken as Transport energy value with cradle to site system boundaries. This is in consistent with the data published by TERI-The Energy Resources Institute, India, 2009. Assuming the product experiences one km of travel within the process chain and up to factory gate, the transport energy coefficient in the above interaction equations becomes unit free. From earlier discussion in chapter 3, we have also seen Figure of Merit ZC is also a non-dimensional number. Hence, all interaction values appear as non-dimensional values.

Methodology

Objective of developing ZC for various construction materials is, to assess their suitability from sustainability viewpoint and effectively integrate it with other eco-parameters such as embodied energy (EE), embodied carbon (EC), global warming, design period, GHG, transport energy and formulate interaction equations. Interaction equations (IE) derived using FoM as a tool, enable us to assess the sustainability levels in buildings and infrastructure projects through a unique index called ASP-SDI expressed in percentage. Methodical interpretation of sustainability levels in pre- use phase lead to sustainable engineering design which in turn leads to a systematic building performance evaluation.

ASP-SDI (ASP-Sustainability Development Index)

Three interaction values described in subsection 4 above, results in the net outcome of a Sustainability Development

Index, designated as ASP-SDI. This new index, enable us assessing the sustainability level of a building during pre-use phases of building's life cycle. Flow chart of ASP-SDI model is shown in Figure 1. SDI proposed in the current research is the algebraic sum of three interaction values I1, I2 and I3 and represented as in equation 4. Sustainability ASP-Development Index is mathematically represented as;

ASP-SDI = I1+I2+I3 (4)

Where,

ASP-SDI = Sustainability Development Index;

I1, I2, I3= Interaction Values (IV) computed using equations 1, 2 and 3 respectively.

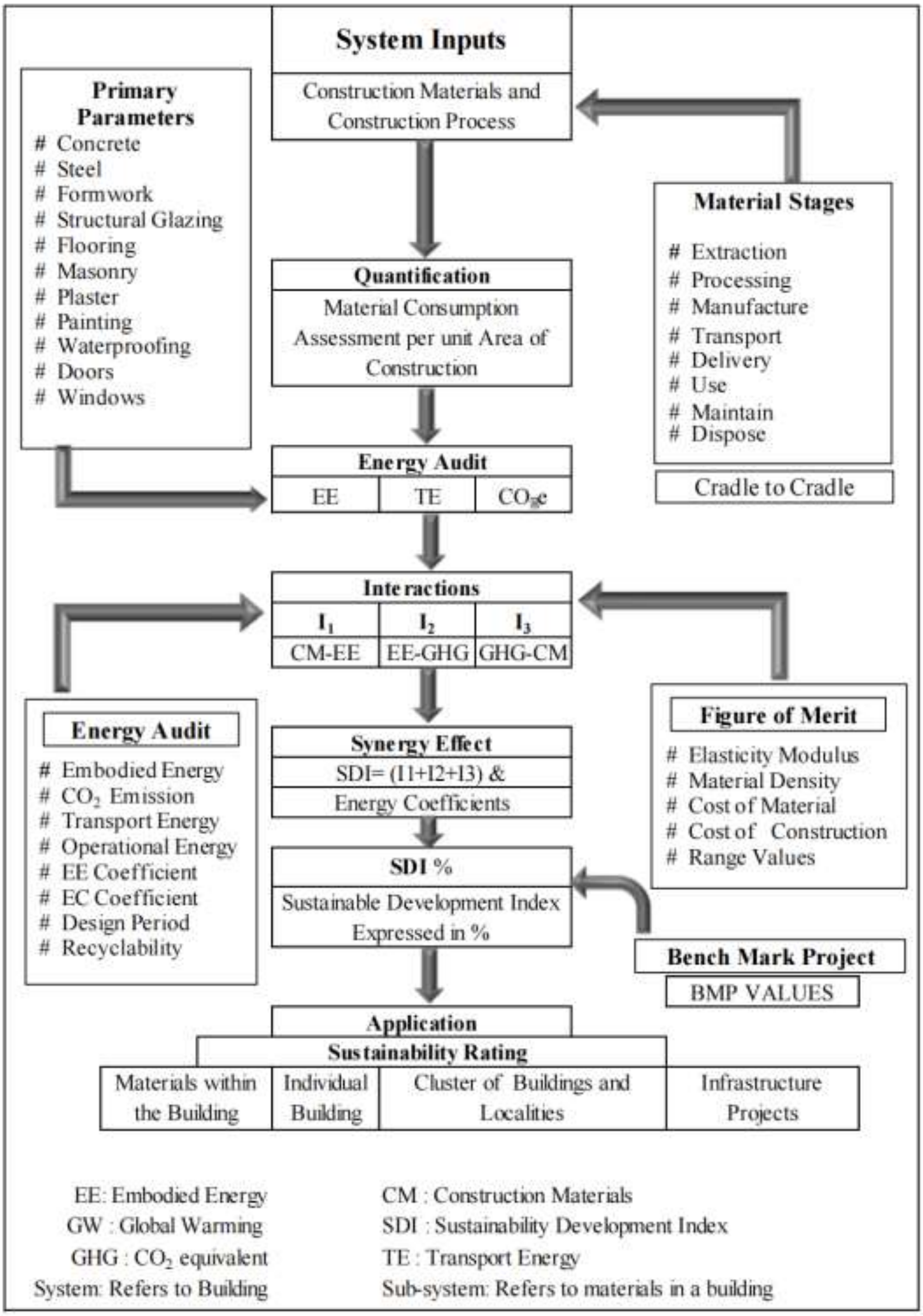

Fig 1 ASP-SDI

Figure 1 explains different stages involved in the computation of three interaction equations leading to ASP-Sustainability Development Index. The input stages of different materials, system boundaries and important primary parameters are indicated in the flow chart. Four application possibilities are also indicated in Figure 1. Complete methodology of computation and interpretation is illustrated using an Illustrative project in the following sections.

Illustrative Example of ASP-SDI Procedure

High-rise buildings in urban scenario have now become a necessity due to urbanisation and industrialisation. Hence, as an illustration while explaining the applicability of ASP-SDI model, a multi storey building is taken as Illustrative Project (IP). Detailed study was carried out on a completed residential building project, located in Bangalore, India. Bangalore falls within Warm-Humid climatic region with an average temperature variation 14-39 degree centigrade at an altitude of 920 meters above MSL. It is positioned at latitude 12.97°N and longitude 77.56° E and has a population of about 11.5 million, as per 2016 Indian census and projected to reach 15 million by 2025. Salient features of IP are tabulated in Table Below.

Table 1 : Salient features of IP

FEATURES	SPECIFICATIONS
Type of Project	Residential Apartment
Area of Construction	25076 m2 (super built-up area)
Number of Floors	18
Floor height	3.0 m (Average)
Structure Type	RCC Frame
External Walls	Solid Concrete Blocks (400x400x200) mm
Internal Walls	Solid Concrete Blocks (400x150x200) mm
Doors	Wooden Frames with Flush door shutters
Windows	UPVC windows with plain single glass shutters
Water Proofing	Roof, Exposed balconies, treated with Membrane type and protective layer of screed or tiles. Toilet water proofing as above + crystalline method for RCC slab.
Flooring	Combination of Natural stones, Vitrified and Glazed tiles of varying size.
Formwork	Conventional type with steel floor plates, adjustable props and spans, wood for primary and secondary supporting joists, ply for beam sides.

Illustrative Project (IP) was constructed as an item rate contract and several specialised agencies were involved in completing the project. The project is in a busy area with accessibility to metro station, market place, educational institutions, recreation centres and hence true representative of urban scenario. Project provides opportunity to its purchasers ready to occupy status.

The applicability of SDI in the present discussion is limited to activities related to civil construction. For comparison rationale, results have been normalised per square meter of super-built-up area. Steps for computation of SDI are as under. Embodied energy and Embodied carbon evaluated for IP are based on actual bill of quantities and stipulated specifications.

Step 1: Computation of FoM

Computation of Figure of Merit (FoM)

Step 2: Computation of Embodied Energy (EE)

Total EE consumed per square meter by IP is assessed based on the actual quantum of work executed based on bill of quantities. Various items of work in BOQ are grouped into ten primary parameters as tabulated in Table 2.

Table 2: Total Embodied Energy and Carbon per Square meter

Primary Parameters	EE (MJ)	kgCO2e
Concrete works	2724.74	285.99
Steel works	1120.33	93.44
Block masonry	181.09	19.69
Plastering	148.95	10.87
Doors	36.31	4.04
UPVC Windows	179.29	9.75
Flooring	157.40	10.65
Painting	39.24	3.59
Formwork conventional	595.40	47.92
Water Proofing	2.98	0.83
Total / m2	5185.73	486.77

EE per square meter is computed using density of material, and EE coefficient taken from inventory. For example, total quantity of reinforcing steel used in the IP as per BOQ is 986000 kg. Based on the total area of 25076 m2, reinforcing steel works to be in the order of 39.32 kg/m2. By multiplying mean value of best range EE coefficient of steel (21.60 MJ/kg) and steel per square meter, we get EE for steel in the IP as 849.33 MJ. Similarly, for structural steel, EE value per square meter works out to be 271 MJ. In Table2 sum of these two values, (849.33+271=1120.33) MJ, reflected under steel works. Thus, grand total EE per square meter is of the order 5185.73 MJ.

From Table 2 and from EE, EC perspective, it is inferred that concrete, steel and conventional formwork contributes high impact. Block Masonry, plastering, UPVC (UV resistant PVC) windows, flooring impart medium intensity impact while wooden doors, waterproofing and painting impart minimal impact. In terms of percentage representation, concrete, steel and formwork contribute about 53%, 22% and 11% to the overall impact as shown in Figure 2.

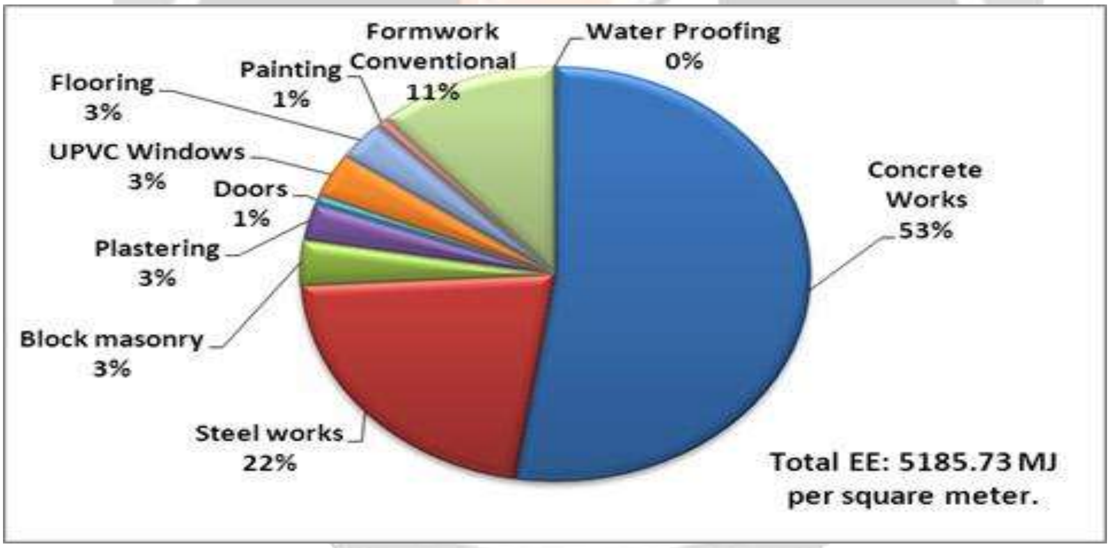

Figure 2: EE Distribution per Square meter

Step 3: Computation of Embodied Carbon equivalent (ECe)

Computation of ECe is similar to EE. Based on the input data, GHG emission is expressed in terms of CO2 equivalent. From Table 5.2 and ECe perspective, total EC for IP was found to be in the order of 486.77 kgCO2e per square meter. From GHG perspective, concrete, steel and formwork with 59%, 19%, and 10% respectively impart higher impact. Wooden doors, Painting and waterproofing activities cause least impact. Masonry with 19.69 kgCO2e contributes to 4% in the overall impact. These are represented in Figure 3.

Variation between ECe and EE percentages are due to varying values of two critical indicators namely EE and ECe, per square meter. This critical information helps in deciding whether to focus on materials with low EE or materials with reduced carbon footprint.

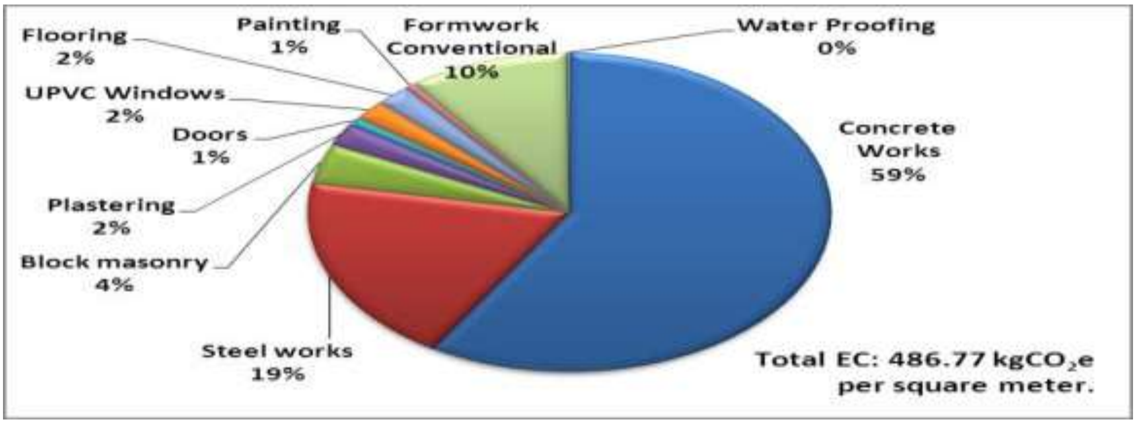

Figure 3: ECe Distribution per Square meter

Step 4: Computation of Coefficients
EEC, ECC, TEC and µ, are different coefficients integrated in equations 1, 2, and 3 to compute interaction values I1, I2 and I3. Embodied energy coefficient (EEC) and Embodied carbon coefficient (ECC) for each of the primary parameter, i.e., each item of work, are obtained by dividing the EE and EC per square meter values by EE and EC values of hard stone. Hard stone is the first construction material in material timeline chart and hence taken as base material. TEC is derived by dividing the road transport energy value of 0.00285 MJ/kg by embodied energy of material. Time period coefficient (µ), is defined as product of EEC and ratio of Design Period to GWP Time Period. Thus, µ value becomes 50% of EEC, as the ratio of design period to GWP time period is 0.5.

Step 5: Computation of Interaction Values (I1, I2, and I3) Computation of Interaction values I1, I2 and I3 is carried out using equations 1, 2 and 3 for all the primary parameters in a building.

Step 6: *ASP- SDI Computation*
ASP-SDI is the algebraic sum of I1, I2 and I3 representing the synergistic effect of all the three interactions (Equation 4). Low and High range values of three interactions determined from Table 5.3 are aggregated and summation of range values tabulated as in Table 4. From Table 4, it is seen that summation of low and high range values to be in the order of 16977.98 and 30291.65 respectively. ASP-SDI value of each parameter constituting a building system is evaluated and expressed in terms of percentage compared to overall impact. These percentages facilitate in understanding the first level of impact in a building due to individual primary parameters of a building system. Interpretation of results is discussed in the following section.

Step 7: Interpretation of Subsystem Impact using Mean ASP-SDI%
It is observed that Concrete and its variants, Steel and its variants, Formwork, contribute to the extent of 7.4% (5.48+0.63+1.29), 41.59% (30.36+11.23) and 43.17% respectively to the overall energy impact within the building. For example, conventional Formwork, the field often neglected in the sustainability impact analysis, has highest contribution of 43.17 %. Study shows high Mean SDI% in IP is due to reduced repetition of formwork materials. Specifications stipulated plywood is used for floor plates, beam sides and bottom and did not allow more than five repetitions. IP also had considerably varying column sizes from level to level. This necessitated fabrication of formwork repeatedly, resulting in cost increase, material, time and labour wastage. Thus, high SDI %, in case of subsystem interpretation, indicates higher negative impact. This calls for using alternative formwork options having lesser impact.

Studies carried out by Sabnis A and Pranesh M R, 2016, on energy impact of commonly used three formwork systems in India has showed conventional formwork with steel floor plates gave total interaction value of 90254 per m2 as against values of 31781 and 30490 per m2 for formwork systems with plywood and aluminium floor plates. Thus by choosing aluminium formwork, total energy impact can be reduced by about 33%. This is consistent with the findings made by Reddy and Jagdish, 200, who concluded that by using alternative building materials and technologies, energy consumption, can be reduced by about 30% to 52%. In case of traditional concrete, ordinary Portland cement (OPC) has high embodied energy. Studies carried out in this area recommend using blended cements in place of OPC to reduce the energy impact. Blended cements replace part OPC by other supplementary cementitious materials like fly ash, GGBS to reduce the embodied energy of concrete. Supplementary cementitious materials replacing cement are referred as sustainable binders.

Table 4: Sustainability Development Index (SDI) Values

PRIMARY PARAMETERS	SDI= (I1+I2+I3)	SDI % MEAN			SDI%
	Low	High	Low	High	
Reinforced Concrete	859.32	1788.81	5.06	5.91	5.48
Plain Concrete	98.48	205.00	0.58	0.68	0.63
VDF Concrete 100 mm th	201.74	419.95	1.19	1.39	1.29
Reinforcement (Fe 500)	5373.11	8808.47	31.65	29.08	30.36
Concrete Blocks(LW)	72.39	151.85	0.43	0.50	0.46
Plaster(CM 1:6)	58.54	112.83	0.34	0.37	0.36
Wooden Doors	90.60	158.29	0.53	0.52	0.53
UPVC Windows / Doors	190.98	421.36	1.12	1.39	1.26
Ceramic tiling	661.73	1118.43	3.90	3.69	3.79
Granite tiling	79.41	137.48	0.47	0.45	0.46
Natural Slate stone	133.11	242.95	0.78	0.80	0.79
Steel Works	1986.46	3256.52	11.70	10.75	11.23
Painting works(3 coats)	22.40	48.71	0.13	0.16	0.15
Formwork Conventional	7143.39	13407.26	42.07	44.26	43.17
Membrane Water proofing	6.32	13.73	0.04	0.05	0.04
Total	16977.98	30291.65	100.00	100.00	100.00

Similarly, UPVC window system has very high EE value of 1600 MJ/kg. But, its contribution in the overall system is only 1.26 % from SDI % perspective. Considering the elegance, long life and low maintenance, PVC window system with UV stabiliser (UPVC) is accepted sustainable. Alternative sustainable building materials as suggested by several researchers offer adequate guidance in this direction.

Discussion

ASP-SDI is a two pronged analytical tool that allows computation of sustainability levels of subsystems constituting a building and secondly, sustainability level of a building as a whole system. This can be applied to evaluate buildings at construction phases and retrofitting stage. The prescribed methodology, when applied to cluster of buildings in a locality, provides us an indication of sustainability level of a locality. First level impact assessment due to primary parameters constituting a building system are presented in this Paper.

The interaction phenomenon that exists between construction materials, embodied energy and global warming is discussed and computation methodology presented. Interaction between any two of the attributes (I1, I2, and I3) gives rise to a unique sustainability development index (SDI). The synergy factor due to three interactions discussed above will be higher than the algebraic summation of interaction factors computed using equations 1, 2 and 3. In the present investigation, algebraic summation is used. SDI can be assessed prior to the commencement of construction, as properties of materials and other supporting systems of construction and transportation are finalized before placing the work order for construction. Hence, FoM for construction materials can be determined and I1, I2 and I3 evaluated. Based on SDI, modifications either in type of materials or methodology or transportation, can be suitably applied to attain a higher sustainability.

In the proposed method, environmental impact due to a subsystem is assessed based on interaction value and individual ASP-SDI %. Higher the interaction value, higher will be the SDI % indicating higher impact or reduced sustainability. The parameterization done at various subsystems will yield large number of combinations for material selection. Concept of determining the SDI using the concept of Figure of Merit is introduced. The methodology prescribed involves computation of twelve primary indicators including four inbuilt properties of materials of FoM. SDI% computed provides a conservative assessment as compared to embodied energy perspective and hence can be used as an effective assessment tool.

Conclusion

Most existing sustainability assessment methods are criteria based and neglect critical engineering characteristics of materials. Increase in population impels infrastructure growth resulting in enormous raw material consumption. The need of the hour is judicious usage of raw materials, reduced energy consumption during the life cycle of buildings by applying scientifically valid measures and techniques. Sustainability level of a building cannot be assessed only from embodied energy perspective. A tool that integrates energy parameters, critical material properties, life time of materials, is proposed. A new sustainability development index, designated ASP-SDI provides an opportunity to all the stakeholders of the industry in applying suitable modifications in their designs towards a more sustainable building with reduced carbon footprint.

The methodology provides an opportunity to the designer to reduce the energy impact during drawing board stage by striking balance between aesthetics, economy and utility; using alternative materials with low energy; exploring possibility of locally available resources; limiting material wastages; adopting to recyclability of materials; bringing in innovations in construction methodologies and making right decisions; all towards reducing the overall energy consumption and global warming.

It is concluded from the current study that higher SDI % in case of an individual parameter represents higher interaction value and hence lower sustainability provided by the individual parameter. Our endeavour is to reduce the interaction value of a building system by implementing alternative materials and methodologies. In addition to quantification of primary parameter sustainability level, the proposed methodology provides; An insight into performance of individual primary parameters forming a building system. Information in assessing the overall impact of a whole building system well before the actual construction so that all stakeholders are involved in the decision making process of reducing the impact of built environment on natural environment. Information in respect of selection of suitable alternative materials from recyclability, embodied energy or embodied carbon perspective. Necessary tool in Selection of materials using the concept of Figure of Merit which integrates four critical engineering and cost parameters. Information in ranking a building beyond criteria based evaluation. ASP-SDI model developed and proposed is a preventive approach rather than curative approach. Figure of Merit hence can be deemed as a new tool for assessing sustainability levels for Pre-use phase of a building‘s life cycle.

Reference :

- Voor de Leefomgeving, P. (2015). DE ECONOMIE VAN DE STAD PBL-CPB-notitie Otto Raspe (PBL), Peter Zwaneveld & Sara Delgado (CPB).
- World Health Organization. (2016). World Health Statistics 2016 [OP]: Monitoring Health for the Sustainable Development Goals (SDGs). World Health Organization.
- Indian census 2011,
- United Nations Environment Programme. Division of Early Warning. (2011). UNEP year book 2011: emerging issues in our global environment. UNEP/Earthprint.
- Virmani, S. M. (1994). UNCED agenda 21: The new challenges for soils research. Journal of the Indian Society of Soil Science, 42(4), 516-524.
- CHANGE, O. C. (2007). Intergovernmental panel on climate change. World Meteorological Organization, 52.
- Jambroes, M., Van Honschooten, R., Doosje, J., Stronks, K., & Essink-Bot, M. L. (2015). How to characterize the public health workforce based on essential public health operations? environmental public health workers in the Netherlands as an example. BMC Public Health, 15(1), 1-9.
- Fay, R., Treloar, G., & Iyer-Raniga, U. (2000). Life-cycle energy analysis of buildings: a case study. Building Research & Information, 28(1), 31-41.
- Sabnis, A., & Pranesh, M. R. (2017). Life cycle energy analysis in buildings and sustainability assessment: a literature review. Am J Eng Res, 6, 123-135.
- Reddy, B. V., & Jagadish, K. S. (2003). Embodied energy of common and alternative building materials and technologies. Energy and buildings, 35(2), 129-137.