A Conceptual Framework for Sustainability Indicators in Retrofitting Existing Housing

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Abstract: There is an urgent necessity for retrofitting existing housing stock for minimizing their impact on the environment, improving social and economic well-being of occupants in line with the triple bottom line approach of sustainability goals. The current research aims to establish a methodological framework for developing sustainability indicators for retrofitting housing complexes as no universal indicators are applicable to existing mid-rise multistoried housing stock in the National Capital Region of Delhi. The study proposes post occupancy evaluation surveys and building performance simulation modeling to develop existing residential baseline data, and benchmarks sustainability indices of the study area. As such, the main focus is played on strengthening the case for performance gap modeling by exploring the distance between their actual performance and desired levels of target benchmarks. The findings of the research will be significant to identify critical areas needing more attention and scale up design strategies for retrofitting in a systematic manner to bridge the gaps.

Keywords: Retrofitting, sustainability indicators, occupant surveys, benchmarking, performance modeling

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1 INTRODUCTION

1.1 Urbanization and Sustainability

Most developing countries have witnessed major changes in urban landscapes in the last 20 years at a high expansion rate primarily due to demographic growth and a high rate of urbanization, thereby leading to irreversible dynamic change in urban structure at a rapid pace (Balachandra and Sudhakara Reddy 2013). As per report on Indian urban infrastructure and services by Ahluwalia et al. (2011), urban population in India is projected to be 600 million by 2031, (more than double compared to 2001), clearly shifting orbit of the focus of economic development onto towns and cities. The economic growth momentum can be sustained through the active role of urbanization in the structural transformation of existing economy. Cities and towns of India are visibly deficient in the quality of services provided, even to the existing population (Ahluwalia et al. 2011). The city infrastructure in terms of road networks, water supply, sanitation as well as housing supply has not kept up with the growth of urbanization and population flux, thus this has imposed an extra burden on existing infrastructure and causing serious environmental damages. There is an increased share of energy consumption per capita due to a better lifestyle, higher thermal comfort levels and more indoor living as well as higher affordability (Paula 2014). Additionally, in the absence of energy supply from the grid, use of diesel generator sets as an alternative means of power generation is causing serious environmental pollution. The ever deteriorating environmental conditions of cities have still not triggered the issue of sustainability as core of city development plans in the public realm in urban planning approach. The concept of sustainable development can play a central role in urban planning for balanced growth and for minimizing environmental impact. Sustainable development can be referred as the most widely accepted framework models for balanced development to sustain the city, using resources judiciously, without compromising future needs of society (World Commission on Environment and Development 1987). Sustainability implies “ability to be sustained” and refers to a process of using resources judiciously in a manner that the resource is not depleted terminally and at the same time, we are able to replenish resources at a rate faster than consumption as well as by reducing blatant consumption without exhausting natural resources or causing ecological damage (Burnett 2007; Hammer et al. 2011).

Sustainable development encompasses all three aspects, i.e., environmental in terms of minimizing the impact on...
the natural environment and choice of use of resources, social in terms of adding quality of life for people as well as economic in terms of enhancing the financial well-being, and recently it has included people or communities as a fourth dimension (Grierson and Moultrie 2011). Pearce (2006) has emphasized sustainable development as a process of ensuring increased quality per capita over time by building four types of capitals: man-made capital by buildings and roads, human resource by knowledge, natural capital by enriched environment and social capital (equity and cultural factors). The concept of sustainable development entails an integration of process for providing a healthy environment, sustainable economies and social welfare through concerted efforts made by active community. In view of major urban renewal initiatives undertaken by the Govt. of India such as developing 100 smart cities across the nation and Jawaharlal Nehru National Urban Renewal Mission (JNNURM), there is a shift onto inclusive and sustainable planning with major reforms in governance and citizen participation.

1.2 Sustainability and Built Environment

The availability of resources, their utilization and their impact on the economy, the environment and society are important considerations for any urban region. United Nations Environment Programme (2003) has observed in OECD (Organization for Economic Co-operation and Development) countries that 25 - 50% of total energy used is in the construction sector of buildings and about one-third of the end-use energy is consumed in HVAC, lighting, equipment and appliances. The common issues relating to urban energy use include transportation, building and housing, public health and safety, and an increase in the standard of living (Phdungsilp 2005). Rather, energy use per capita has been seen as development index. Increased energy use in the existing stock of buildings is a serious environmental concern around the world (Pearce 2006). Incorporating energy efficiency as a prime consideration in the development of existing stock can make a big difference to reduce the total use of energy and carbon emissions (Ahluwalia et al. 2011). Among the different sectors, where energy savings can be realized, the European action plan for energy efficiency of the European commission has identified the building sector as a top priority (Xavier et al. 2007).

Increased energy consumption in the construction of building and operating energy-used in air conditioning for thermal comfort has also led to an increase in the amount of emission of greenhouse gases, and caused serious damages to planet earth emanating from global warming, ozone depletion, acid rain, threats of biodiversity, soil erosion, and depletion of natural resources. Various steps have been taken at the global level since the United Nations Conference on Environment and Development (UNCED), which is also known as the Earth Summit in Rio de Janeiro in 1992 summit till date. India has also committed to reduce greenhouse gas emissions to 30% of its present use in the world summit in Paris.

Cities may not be just the aggregation of buildings and infrastructure or services, but they have multidimensional attributes in an ecosystem of ecological, cultural, technological, and spiritual and socioeconomic dimensions (Eames et al. 2013). Various attempts have been made in several countries to decode sustainable development paradigms, taking into account primarily environmental concerns; health and safety and transportation etc. Various terms like Sustainable urbanism, Eco-cities, Green Cities, Sustainable cities and Smart cities have been coined by several planners. Girardet (2008) in “Cities, People, Planet”, defines a “sustainable city” as one which enables all its citizens to meet their own needs and enhances their well-being without degrading the natural world or the lives of other people, now or in the future. India under the program on National Climate Change Action Plan has outlined eight National Missions out of which Ministry of Urban Development (2010) emphasizes sustainability by bringing codes for energy efficiency of buildings and integration of renewable energy (Ahluwalia et al. 2011).

There have been a number of models and rating systems adopted by various countries to address sustainability issues. However, the principles and models suitable for developed countries cannot be applied to Indian context due to different socio cultural patterns, technological and economic constraints, affordability of people, quantum of the cities and scale of urbanization. There are already important tools for evaluation of the sustainability of the built environment in developed countries, but there is a need for developing a framework for assessing sustainability in developing countries in a realistic manner, which is having a different local social and economic context (De Azevedo et al. 2010). Thus, there is a need to develop a different set of sustainable model frameworks by developing a set of indicators and benchmarks relevant to different regions, taking into account local context, climatic and socio cultural aspects of the region.

1.3 Sustainability and Residential Land Use

Built environment in cities including buildings and transportation contributes to 67% of total energy use (Pérez Lombard et al. 2008). Buildings alone play a significant role in consuming energy to the tune of 35% of the energy use (ECBC 2009). The major land use in any city comprises of residential land use as much as 35-40% of the total amount in large cities and metropolitan cities. 80% of the existing housing stocks in India is designed and constructed before 2001, when there was no code available and awareness to design buildings from sustainable planning principles (Jones Lang LaSalle 2014). National building codes in India has been revised recently to include sustainability as Part 11 addendum (Bureau of Indian Standards 2012). The focus of the Energy conservation building code ECBC, 2007 is on conditioned commercial buildings, which is also not mandatory in many states (ECBC 2009). Thus, there are no guidelines or codes for designing residential buildings specifically.
from a sustainability point of view. There have been very limited studies on understanding built fabric in residential land use. Recently, guidelines for the design of new residential buildings for energy efficiency only have been launched (Global Building Performance Network 2014; Bureau of Energy Efficiency 2014). Therefore, keeping in mind huge stock of existing residential buildings with their large footprint and continuous consumption of resources incessantly, it is important to understand issues concerning environmental and social impacts from the housing and take corrective actions by retrofitting them to resource consumption and enhance quality of life.

1.4 Retrofitting Existing Buildings

Based on a report on “Mitigation of Climate Change” published by United Nations’ Inter governmental Panel on Climate Change, it was expected that the largest energy and carbon savings potential in 2030 will be achieved by retrofitting and renovation of existing buildings (International Panel on Climate Change 2013). Given there is an already growing concern about quality and quantity of energy available in cities, the thrust is to reduce energy consumption by managing the demand side in existing buildings and also provide unprecedented opportunity to reduce CO₂ emission by 2050 (Architecture 2030 2014). Owing to the fact that by 2050, 70% of world’s population will have lived in cities, there is a dire need to reengineer systematically existing built environment on various scales (building, neighborhood, city-region) and domains (energy, water, use of resources) with regard to the climate change and resource constraints (Eames et al. 2013). Eames et al. (2013) have further envisaged “Retrofit 2050 Vision” for three different kinds of cities i.e. smart-networked city, the compact city and the self-reliant green city; each one is having variations in terms of indicators for energy, water, waste and resource use, land use, social values, economic growth and urban density. Seven European countries collaborated in the project such as the ENPER-EXIST that was for energy performance standardization and regulation (Xavier et al. 2007). Keeping in mind the largest footprint of residential buildings coupled with their highest share in energy consumption, this paper focuses on the retrofitting existing residential buildings from sustainability point of view. Most of the existing residential buildings stocks are characterized by low thermal comfort, poor indoor air quality, poor lighting conditions, acoustical problems etc (Indian Society of Heating, Refrigerating and Air Conditioning Engineers 2015). The retrofitting of existing buildings can lead to significant improvement of the indoor environmental conditions as well as increase in productivity and larger economic saving due to enhanced productivity (Xavier et al. 2007). Retrofitting residential buildings usually involves multiple benefits such as a significant reduction in energy consumption, and hence, cutting energy and maintenance bills, improving safety, quality, indoor comfort and aesthetic properties, extending life span of buildings, as well as boosting market value (Martinaitis et al. 2007; Užšilaityte and Martinaitis 2010). Therefore, retrofitting of residential blocks/clusters may not be just seen as technological issue of energy or water efficiency, but may be appreciated as an opportunity in a larger framework of integrated approach to improve neighborhood, considering urban aesthetics, safety, parking and landscaping issues, selection of materials from maintenance view point and as well as social and economic structure (Raslanas et al. 2011).

Residential buildings have significantly higher potential to harness passive low energy techniques to save energy, and as such the current building industry is advancing towards net zero carbon buildings or plus energy buildings with the aim of generating more energy than the buildings’ needs (Erhorn-Kluttig et al. 2015). The present study aims to develop residential baseline data for the segmentation of existing housing which uses higher energy and water, understanding their characteristics within socio cultural and economic context as well as people’s aspirations, assessing their performance through a set of sustainability key performance indicators, benchmarking their performance against national standards or rating systems, and finding out how much gaps are extant between their performance and desired levels. Thus, it involves two stage processes namely casting and scenario building (Eames et al. 2013). The “back casting” involves setting a future goal and then looking backwards from that future to the present in order to strategize and to plan how it could be achieved (Quist and Vergragt 2006). This study would help in analyzing based on the indicators whose areas are needed to be focused more, and determining what strategies and tools are needed to bridge the gaps for preparing sustainable development framework in order to retrofit the existing residential buildings.

1.5 Existing Residential Buildings Scenario

Many countries have already plans for retrofitting their existing residential buildings as their residential building account for one fourth of carbon emissions. Energy consumption pattern has the most tangible and direct impact on cutting greenhouse gases (Sustainable Energy Authority of Ireland 2014). In Ireland, roadmap has been worked out to set different trajectories to build five different levels or scenarios or phases of retrofitting existing stock and future housing stock. The baseline measures include phasing out inefficient lighting and setting minimum standards for boilers, the other scenarios like the “Low scenario aim” emphasizes on improving roof and cavity wall insulation, basic air sealing and heating system controls by 2020, and high energy scenario aims at integrating renewable energy supply by 2050 by building net positive houses. The Energy Performance of Buildings Directive sets a series of requirements specifically dedicated to existing buildings by ENPER-EXIST project on the basis of an application of minimum standards, providing general framework for calculating energy use intensity (EUI), and setting targets of EUI, and finally energy certification of existing
buildings as well as operation and maintenance of HVAC.

As per report of the Central Electricity Authority (2013), energy use in residential buildings in India has increased from 80 Twh in 2000 to 186 Twh in 2012. Global Building Performance Network (2014) in a study report titled “Residential Buildings in India: Energy Use Projections and Savings Potentials”, has projected scenarios indicating that electricity consumption is predicted to rise by more than eight times by 2050 under the business-as-usual scenario in 2014. There is a wide gap between high demand and limited supply of energy, leading to spiraling prices of energy and water - two major limited resources.

2 RESEARCH OBJECTIVES AND METHODOLOGY

The present paper seeks answer to define how a conceptual framework needs to be constructed so as to develop benchmarks and indicators for retrofitting existing housing stock. At the same time, how this framework can lead to enhanced understanding or analysis of gaps in current situation and targets to be achieved so as to develop design programs or strategy for combating barriers in the process? The goal of this research is to synthesize key benchmarks into indices of environmental, economic, and community sustainability, so that the progress towards the goal of sustainability can be measured holistically over a timeframe.

Thus, this paper aims at analyzing existing sustainability indices for retrofitting residential built stocks in National Capital Region of Delhi, India by taking stock of existing situation through studying their characteristics and benchmarking their performance to scale up design strategies in a systematic manner at different levels to bridge the gaps. The study has been conducted particularly in context of mid-rise apartments using mixed mode ventilation for thermal comfort as this segment is having the largest share in housing typology and contributing most to the energy consumption (Cushman & Wakefield 2015; Global Building Performance Network 2014). For meeting research objectives, this study endeavors to look for sustainable indicators applicable to existing buildings and housing schemes available in current green building rating systems in India. The study proposes qualitative and quantitative surveys by conducting post occupancy evaluation (POE) surveys and modeling the sustainability index of existing stock’s performance. A pilot survey of households have been conducted to construct and test hypothesis for detailed research required for identifying sustainability indicators and benchmarking standards and finally results can be used in building performance simulation software to identify retrofitting strategies.

3 SUSTAINABILITY BENCHMARKING

In wake of fast depleting limited resources and consequent effects of global warming, there is no other alternative except to turn to sustainable practices for future survival. For achieving sustainability goals, benchmarking is used as a tool in many sectors such as transportation, industrial and education etc. as well as buildings, as a tool to measure sustainability (Bantanur et al. 2012). Sustainability benchmarking is a most commonly used tool across the world to assess performance of a particular built fabric from sustainability parameters and improve projects to meet continually rising higher thresholds of sustainability (Sharma 2010). Benchmarking facilitates the identification of the gaps existed in the performance of the buildings, and retrofitting them to achieve sustainability goals by optimizing their functions in line with desired targets and thresholds (Grayson 2010). No two places which are in different climatic zones and cultural context within country or different countries are identical and need to be analyzed from different sustainability parameters (Reed et al. 2009). There is no room for universal indicators and indices in view of varying standards of adaptive thermal comfort, lighting and indoor air quality for different building typologies and for different climatic zones as well as socio cultural factors. Various sustainability indicators applicable to existing buildings have been analyzed in section 3.4, but there is a need to develop key performance indicators for benchmarking sustainability and enhancing performance for retrofitting existing housing stock consuming higher resources.

3.1 Role of Urban Sustainability Indicators

For sustainable development and sustainable urbanization, sustainability indicators play major role in measuring or benchmarking performance of a project at city level, neighbourhood level or building level (Soares and Ribeiro 2011). It is well said that what cannot be measured, cannot be managed (Hart 2014). Indicators are defined as a specific, observable and measurable characteristic to reflect the progress of process or impact of an action for achieving a specific outcome (Shen et al. 2011). Characteristics of good indicators include validity, reliability, precision and measurable (Heink and Kowarik 2010). Indicators along with their metrics can help to define various parameters of sustainability such as social, economic, environmental and governance, and they help you in understanding where you are, which way you are going to and how far you are from the target (Shen et al. 2011). Sustainability indicators must take into account carrying capacity of natural resources both renewable and non-renewable, ecosystems, diversity, community engagement, urban aesthetics in tune with nature, social capital and human capital (skill, health and education). Various researchers and international agencies have attempted to create inventory of indicators showing wide range of key performance indicators for benchmarking the projects or rating systems for projects ranging in scale from neighbourhoods to cities and metropolitan regions. Shen et al. (2011) have compared nine sustainability practices from developed and developing countries including India, and suggested a list of indicators called IUSIL - International Urban Sustainability Indicators.
List, listing 115 indicators in 37 categories. In developing countries particularly, sustainability indicators must take local context into account, and prioritize local needs, and foremost, they should lead to programs and policies in order to deliver at various levels by developing mechanisms and potential technological solutions (Chaudhary et al. 2012). Different frameworks or methods have been developed to organise a set of indicators for a sustainable community, combining multiple indicator variables in a single indicator variable called “Index” for reducing complexity of data analysis and presentation (Zimmerman 2002).

Different frameworks have been designed for different sustainability indicators with different intended purposes. They range from simple frameworks like “Category or List” for including checklist for easy understanding and identifying the problem areas; “Goal Indicator Matrix” measuring the goals of a community or deciding boundary conditions, targets and scoping; “The Driving Force State Response” framework showing measures of causes or driving forces for improving conditions and working out strategies for working out effective action plan to “The Endowments Framework Balance” among measures of auditing future reserves and taking stock or assessment of existing situation or baseline conditions (Hart 2014). Energy efficiency is recognised to play pivotal role in achieving sustainability goals by taking into account the resources limitations. Retrofitting existing stock from the view point of energy efficiency can be a significant step.

3.1.1 Environmental Dimensions of Sustainability Indicators for Housing

Meadows et al. (2004) have cited an environmental economist Herman Daly by suggesting three important principles of sustainability to be embedded in a relationship of housing to natural systems. These include equilibrium between the rate of use of renewable resources and their rate of regeneration; the rate of use of non-renewable resources needs to be less than or equal to the rate at which they can be replaced by sustainable renewable resources, and finally the rate of pollution emissions must be less than or equal to the rate at which they can be absorbed and processed by the environment. Based on the above definition, Sustainability Institute (2009) suggested indicators to be based on source and management of supply and demand of energy and water in households, building materials used in settlements and disposal and recycling of waste generated by households. Thus, the focus is on enhancing building performance in eco-efficient manner by taking the advantage of passive solar techniques, harnessing passive means such as wind towers, double skin facades and integration with renewable energy systems so as to minimize their impact on environment and yet at the same time promoting comfort and healthy living. There has been a greater thrust on environmental sustainability as sustainability issues have been driven by environmental concerns. However, in order to accomplish the sustainability goal, “triple bottom line” approach which consists of social equity, economic prosperity and environmental quality should be taken into consideration (Elkington 1997).

3.1.2 Social Dimensions

Social dimensions assume more significant role in the context of residential fabric. The concepts of physical as well as psychological security and social interaction or communication are inherently embedded in the ecosystem of housing (Hendler and Smeddle 2009). The features of social sustainability ascribed to good residential area include active community engagements, high degree of social interaction, equity with inclusive planning (mixed use neighbourhoods, mixing of different income groups, barrier free access to all areas, informal sector, safety and security, walk ability with good pedestrian spaces), good urban aesthetics, use of parks or green spaces, access to basic services and public transportation systems, social infrastructure such as schools, banking, retail, community halls, clubs etc. (Hartkopf and Loftness 1999; General Services Administration 2014). Thus social indicators such as equity, social interaction and presence of social infrastructure can be taken as constructs of benchmarking of neighbourhood design and can be helpful in enhancing quality of life in neighbourhoods. Additionally, inclusive city planning by creating universal spaces for physically disabled and mixed land use and crime free spaces by extending visibility, street lighting, surveillance, open parks and landscaping etc. serve as confidence building measures, and augments social capital of a place (National Crime Prevention Council 2003).

3.1.3 Economic Dimensions

Economic indicators in a housing estate are reflective index of how well the neighbourhood is performing in terms of social parameters and affordable for residents of the area. Thus, economic and social parameters are intertwined with one another in providing an affordable sustainable housing in which its denizens are enjoying quality of life. Hendler and Smeddle (2009) have underscored housing as an asset that is dependent on location, design and social security reflected by its market value, affordability of physically maintaining the assets by its denizens, and finally life cycle cost of the long-term economic value of the asset over the total financial, environmental and social liabilities.

Other economic indicators include housing shortage, equity of land, affordability of housing (income to price ratio) by different income groups, housing supply rate, housing stock being added every year, housing typologies, floor area per person in housing, lack of slums, housing-required major repairs, overcrowding in housing etc (Hart 2014). Various schemes have been launched by public and private agencies in partnership in India in the last 20 years to address housing shortage. A large stock of the housing needs repair due to poor operation and maintenance, affecting health and productivity of the occupants and energy consumption in buildings, thereby impacting national economy indirectly. Thus, total value of built environment may be seen in a perspective of national productivity, quality of life and energy consumption.
(Pearce 2003). Proliferation of poor or deteriorating built environment is already costing national economy, society as well as serious damages to the environment. Benefits of retrofitting existing housing stock can be ascertained directly by lifecycle-cost analysis of retrofitting measures and their payback period, but its role in improving health conditions of the occupants are not lessen. This will lead to better economic conditions of people and help in minimising the impact on the environment.

3.2 Role of Occupant Surveys

In order to understand characteristics of existing residential buildings within domains of sustainability framework i.e. environmental, socio-cultural and economic dimensions, findings on occupant surveys can act as the linchpin of the development of sustainability key performance indicators for a particular context considering the people’s aspirations and local specific context of study area. Post occupancy evaluation studies carried out under normal daily life routine of subjects, with their entire psycho-behavioural, environmental and social context, can serve as feedback and feed forward loop to continually evaluate and evolve relevant sustainability indicators (Kumar 2014b). Dahlan et al. (2008) suggested that subjective evaluation using occupant surveys is found to be more reliable in assessing sustainability. Post occupancy evaluation surveys are more helpful in addressing sustainability issues as they can best provide candid account of wider variations/diversity found in case of residential buildings in terms of occupant use, occupant age, built environment, psychological comfort and satisfaction as well as wide variations in energy use, even within buildings of similar built up area and building geometry within the same location (Preiser 1995). Findings on POE surveys can be useful to bridge the performance gaps, since invariably buildings are not found to perform as expected and enable the use of realistic parameters to produce realistic models for sustainability (Menezes et al. 2012; Hassanain and Mudhei 2006; Vischer 2002; Leaman 2003). As proposed in draft addendum No. 1 to National Building Code of India 2005 to incorporate a new part 11, Approach to sustainability, it is required to conduct occupant surveys annually for the first three years of building operation for obtaining feedback from users subsequent to commissioning and handover stage of building to the owner (Bureau of Indian Standards 2012). Field-based occupant surveys can play vital role in establishing sustainability indicators, benchmarking their performance against national standards or rating systems and finding out how much gap is extant between their performance and desired levels for mixed mode ventilation mid-rise apartments in National Capital Region of Delhi.

3.3 Analysis of Current Building Rating Systems

There is a vast repository of building software tools and green building rating systems across the globe for evaluating energy efficiency, renewable energy and sustainability within buildings. Criterion Planners (2014) in its report on Global Survey of Urban Sustainability Rating Tools, have listed 63 rating systems prevalent across the globe combined with major players among them namely BREEAM, LEED, CASBEE, GREEN STAR and HK-BEAM, SB TOOL, ARCHITECTURE 2030, ONE PLANET. The current building rating systems in India are GRIHA, IGBC, BEE, and they have developed criteria or credits and star rating systems for different levels of performances achieved by green buildings, but do not directly address sustainability parameters per se. They include well-defined environmental parameters as improvement over base-case, and accordingly allowing for credits to measure sustainability. The wide range of environmental performance design and assessment tools provide building design professionals and other project stakeholders with a choice of tools to aid the planning, design, evaluation and management of energy efficient buildings (Foliente and Tucker 2007).

Recently GRIHA has revised point systems more sternly, giving higher points of reward as you come closer to best practice target levels. Primarily benchmarking involves setting range from reference case i.e. “distance from reference case or base case” to “distance to target” i.e., and subsequently, best practice can be attained by intermediate levels of achievable targets (Burnett 2007). Use of the “whole building performance simulation” as a tool is a common practice to benchmark various key performance indicators at building level such as energy performance index or energy use intensity or at building systems level such as lighting power density or coefficient of performance of heating, ventilation and air conditioning (HVAC) systems. However, until now, thrust of performance standards is limited to environmental parameters with scant regard for other parameters i.e. social and economic dimensions of sustainability as indicators of these two parameters are largely inconspicuous by their absence. Commonly-used sustainability rating systems in India are discussed in the following section along with relevant sections for existing buildings for sustainability issues with their weights and underlying parameters.

3.3.1 GRIHA (Green Rating for Integrated Habitat Assessment)

GRIHA, designed as National Rating System and developed by the ministry of new and renewable energy and developed by TERI, The Energy & Resource Institute is in its inception since 2007. It has undergone major revisions in 2015 to reflect the current scenario and development in green buildings and revised its benchmarks for meeting sustainability goals better. It integrates all relevant Indian codes and standards such as National Building Code 2005, the Energy conservation building code 2007, environmental policies of India (MoEF) and local bye-laws. It also encourages the integration of traditional knowledge on architecture with present day technology. The GRIHA Version (2015) has
list 31 criteria in 9 categories as shown in Figure 1 with addition of two new sub-categories namely Socio-Economic Strategies with 6% weight; and Performance Monitoring and Validation with 8% weight as illustrated in Figure 1.

The parameters such as Criteria 12 Indoor air quality has been added to ensure healthy living conditions and entails monitoring of CO2, temperature and relative humidity at the occupied spaces as per national standards. The revised point weight break up is shown in Figure 1. Also, in order to achieve higher threshold, a new concept of non-linear point distribution for landscape water reduction has been introduced as shown in Table 1.

Table 1. Non-linear point distribution for rewarding sustainability measures (GRIHA Version 2015)

<table>
<thead>
<tr>
<th>Reduction in water requirement in design case versus base case</th>
<th>GRIHA V 2015</th>
<th>GRIHA V3</th>
</tr>
</thead>
<tbody>
<tr>
<td>30%</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>40%</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>50%</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

GRIHA LD (2015) has been recently put into practice that the total site area for large development should be greater than or equal to 50 hectares in housing townships or complexes by private builders or public sector agencies. The GRIHA LD emphasizes on qualitative aspects of development and concept of self-sufficiency in the energy, water and solid waste management. It also dovetails the concept of carbon foot print analysis with carrying capacity from ecological point of view and emphasis on low carbon life style. A minimum benchmark of EPI of 75 kwh/m²/yr (with 25% improvement over base case of 100 kwh/m²/yr) has been fixed in residential buildings in hot and dry or composite climates. The social and economic dimensions are addressed in much detail by introducing facilities for construction workers and service staff during operational stage of building, increasing environmental awareness, inclusive planning by taking care of EWS of society, space for informal sector and universal spaces, no smoking zones in public areas, social infrastructure facilities such as health centers and schools for lower income group as well as urban farming for fruit and vegetables.

3.3.2 IGBC Green Residential Societies Rating System

Indian Green Building Council (2015), IGBC Green Residential Societies rating system, has been recently launched in 2015, addressing existing multi-dwelling communities. Indian Green Building Council (IGBC) is a voluntary rating system, developed on lines of an international rating system, LEED ((Leadership in Energy and Environmental Design) for existing building developed by the US Green Building Council. The sustainability issues addressed in existing green residential societies are addressed towards achievable goals under various heads, as listed in Table 2. Some of social sustainability indicators have been given place in “Facility Management Section”.

IGBC has also developed special rating system for existing buildings “Green Existing Building O&M Rating System” in 2013 addressing sustainability parameters and benchmarking for existing buildings, focusing on site and facility management and O&M. For reducing carbon footprint, it has defined performance-based benchmarks for EPI, use of onsite and offsite Renewable Energy and energy metering. For health and comfort, it mandates occupant surveys to be conducted every 6 months after commissioning and handing over buildings and monitoring for Fresh Air ventilation, CO2, comfortable thermal environment at 26±20°C and 30-70% RH. It also spells out credits for providing facilities for differently abled People, thus advocating universal spaces.

3.3.3 National Building Code (NBC) Part 11: Approach to Sustainability

National Building code has been recently revised to add part 11 dealing with sustainability in a comprehensive manner. It underscores design parameters to be implemented above benchmarking standards given in the code in order to develop deeper understanding of performance of building as per climate zone, function and context, and imbibes on the traditional wisdom concepts of sustainability. It further emphasizes buildings’ long-term scenario by identifying optimum levels, and take decision-making process of measurable level for making judicious choices over lifecycle of the project (Bureau of Indian Standards 2012). It also
Table 2. Sustainability parameters for existing multi-dwelling societies rating (Indian Green Building Council 2015)

<table>
<thead>
<tr>
<th>Facility management</th>
<th>25 points</th>
</tr>
</thead>
<tbody>
<tr>
<td>FM Credit 2</td>
<td>Maintenance of facility</td>
</tr>
<tr>
<td>FM Credit 3</td>
<td>Access to basic amenities (Social infrastructure)</td>
</tr>
<tr>
<td>FM Credit 6</td>
<td>Heat island reduction roof 50%,75%</td>
</tr>
<tr>
<td>FM Credit 7</td>
<td>Covered external lighting fixtures : 50, 75, 95%</td>
</tr>
<tr>
<td>FM Credit 8</td>
<td>Design for differently Abled</td>
</tr>
<tr>
<td>FM Credit 9</td>
<td>Facilities for health &amp; wellbeing (recreational).</td>
</tr>
<tr>
<td>Sustainable water practices</td>
<td>29 points</td>
</tr>
<tr>
<td>SWP Credit 1</td>
<td>Rain water harvesting : 10, 20, ... 100%</td>
</tr>
<tr>
<td>SWP Credit 2</td>
<td>Landscape areas: 20, 25, ... 40%</td>
</tr>
<tr>
<td>SWP Credit 3</td>
<td>Water sub metering</td>
</tr>
<tr>
<td>SWP Credit 4</td>
<td>Water efficient fixtures : 40, 50, ... 90%</td>
</tr>
<tr>
<td>SWP Credit 5</td>
<td>On-site STP: 50, 75, 95%</td>
</tr>
<tr>
<td>SWP Credit 6</td>
<td>Automatic water level controllers</td>
</tr>
<tr>
<td>Energy conservation</td>
<td>22 points</td>
</tr>
<tr>
<td>EC Credit 1</td>
<td>CFC free appliances</td>
</tr>
<tr>
<td>EE Credit 2</td>
<td>Efficient lighting fixtures: 25, 50, 75, 95%</td>
</tr>
<tr>
<td>EE Credit 3</td>
<td>EC Credit 3 Solar power for street &amp; Common Area Lighting: 20, 30 ... 80%</td>
</tr>
<tr>
<td>EE Credit 4</td>
<td>Energy metering</td>
</tr>
<tr>
<td>EC Credit 5</td>
<td>Solar water heating systems: 20, 30, ... 70%</td>
</tr>
<tr>
<td>Waste management</td>
<td>10 points</td>
</tr>
<tr>
<td>WM Credit 1</td>
<td>Waste segregation</td>
</tr>
<tr>
<td>WM Credit 2</td>
<td>Organic waste management - 20, 40, 60, 80, 90%</td>
</tr>
<tr>
<td>WM Credit 3</td>
<td>E-waste management</td>
</tr>
<tr>
<td>Innovative practices</td>
<td>14 points</td>
</tr>
<tr>
<td>IP Credit 1.1</td>
<td>Water meters for dwelling units (50, 75, and 100%)</td>
</tr>
<tr>
<td>IP Credit 1.2</td>
<td>Reuse of treated waste water for landscaping</td>
</tr>
<tr>
<td>IP Credit 1.3</td>
<td>Fresh water treatment plant</td>
</tr>
<tr>
<td>IP Credit 1.4</td>
<td>Electric charging points for vehicles in common areas (2.5%, 5%)</td>
</tr>
<tr>
<td>IP Credit 1.5</td>
<td>LPG/CNG gas geyser for water heating (20, 40%)</td>
</tr>
<tr>
<td>IP Credit 1.6</td>
<td>Day-Light/Motion sensors in common areas</td>
</tr>
</tbody>
</table>

further focuses on balancing buildings’ envelope by eco-friendly materials and high technology end solutions, disaster preparedness, reduced embodied and operational energy, integrated water management and tracking operation and maintenance with the aid of occupant surveys. It also provides guidelines for integrated design approach, building orientation, shading, thermal massing, reduced footprint and reduced volume, building form, natural ventilation, optimum day lighting, building service life with life cycle analysis approach to be followed optionally. Section 13.4 of NBC, Building performance Tracking (Measurement and Verification) clearly spells out techniques of building performance assessment subsequent to commissioning and handover stage of building to the owner. Regular Monitoring of the performance shall be carried out, which will provide information whether set environmental performance and targets have been met or not.

3.3.4 Energy Conservation Building Code (ECBC)
The Energy Conservation Building Code ECBC (2009), launched by Bureau of energy efficiency in 2007 under the Energy Conservation Act, 2001, provides significant parameters for reducing energy consumption relating to building envelope, electrical and mechanical equipment, lighting and service hot water heating for various climate zones of the country. The code is applicable to building complexes having connected load of 100 kW or greater or a contract demand of 120 kVA or greater or having conditioned area of 1000 sqm and above. The code also applies to additions to multifamily dwelling existing units. Two approaches i.e. Prescriptive Approach setting benchmarks for individual components and option of trade-off between sub components and the other option “Whole building simulation approach” considering EPI and unmet hours showing total performance of system by enduser, are defined in ECBC for meeting benchmarking standards. Based on EPI of whole building simulation approach, Bureau of Energy Efficiency (BEE) awards star rating to energy efficient green buildings also in tune with the recognition of exemplary buildings.

3.4 Benchmarking Standards in Various Rating System
There have been major revisions and new categories introduced both within IGBC and GRIHA in 2015, pushing the sustainability boundaries and setting thresholds to higher levels and encouraging better practices in sustainability. IGBC has come up exclusively with rating systems for existing buildings O and M as well as for existing multifamily dwelling units. There is a strong tendency towards the environmental parameters such as energy and water in both rating systems. There is a great variation between baseline and top line value of all rating systems. Buildings with five-star rating in
Table 3. Comparison of sustainability parameters for different rating systems applicable to existing multi-dwelling societies

<table>
<thead>
<tr>
<th>Sustainability criteria</th>
<th>IGBC Green Residential Societies rating system</th>
<th>GRIHA LD</th>
<th>NBC Part 11: Approach to Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon footprint and carrying capacity</td>
<td>√</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Ecology</td>
<td>√</td>
<td>x</td>
<td>√</td>
</tr>
<tr>
<td>Site planning</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Facility management</td>
<td>√</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>IEQ</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Health and well being</td>
<td>√</td>
<td>√</td>
<td>x</td>
</tr>
<tr>
<td>Materials</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Renewable Technologies</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Energy</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Water and waste water</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Waste management</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Solid waste management</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Transport</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Pollution</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Social</td>
<td>x</td>
<td>√</td>
<td>x</td>
</tr>
<tr>
<td>Innovation</td>
<td>√</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

GRIHA and platinum rated in IGBC and BEE five-star rated are quite different in performance levels. GRIHA also takes into account social and economic indicators partly as shown in Table 3. ECBC is just a tool to assess performance of conditioned buildings, primarily applicable to commercial and institutional buildings, with star rating systems awarded by BEE.

Another major difference is baseline case for both rating systems followed by based-case modeling in ECBC and IGBC, whereas GRIHA prescribes absolute benchmarks for comparing proposed case and is easily understood. For example, EPI based-case is kept at 100 kwh/m²/year for residential buildings for three climate zones (composite, warm and humid, and hot & dry climates), even though GRIHA has more focus on passive building design by promoting low carbon architecture compared to high performance building design to save energy in air conditioning in IGBC. GRIHA LD has focus on both qualitative aspects as well as self-sufficiency in energy, water and waste. Renewable energy and recycled materials also find more attention in GRIHA and draft addendum to NBC, part 11 for sustainability as compared to IGBC practices (Kumar 2014a).

There is a greater thrust regarding the occupant surveys by explicitly earmarked credits for health and well-being in IGBC O and M for existing buildings endorsed by proposed framework through draft addendum of NBC for sustainability and GRIHA. Table 3 shows comparison of sustainability parameters for different rating systems applicable to existing multi-dwelling societies.

Thus GRIHA takes into account the passive solar design building techniques, renewable energy, occupant surveys and social indicators in large developments like housing complexes or townships. IGBC has set guidelines for rating of existing multifamily dwelling units, setting achievable goals for sustainability. ECBC does not consider existing residential buildings, and has inclination towards energy performance of buildings. No single rating system addresses core issues of sustainability, and hence there is a need to develop sustainability indicators for existing multifamily mid-rise residential apartments in a holistic manner.

3.5 Building Performance Evaluation Using Sustainability Indicators

Sustainability indicators are useful to quantify building performance, target setting and prepare roadmap for delineating strategies for taking corrective steps to address problems and achieve target benchmarks (Balachandra and Sudhakara Reddy 2013). Building performance simulation tools are widely used to understanding complex dynamic interaction systems of buildings and design high performance buildings by applying highest levels of design, construction, operation and maintenance principles (Hensen 2002). The US Department of Energy (Department of Energy 2014) has listed 416 building software tools along with a brief description of the salient feature of each tool including expertise required. Most codes and standards refer to the whole building performance simulation for evaluating various indicators and comparing effects of various parameters for making rational choices of appropriate building fabric and program in order to achieve sustainability.

National housing Bank, India developed IT based toolkit for energy-efficient residential buildings, known as “EnEFF: resBuild India” in collaboration with The Energy Resources Institute (TERI), Fraunhofer Institute for Building Physics (IBP), Germany and KfW Development Bank (KfW), Germany. It gathers information on various parameters such as weather or climate zone, housing unit type Break up of Conditioned and Unconditioned Floor plate, Total exposed and unexposed wall and roof area, Window Wall Ratio, Solar Heat Gain Coefficient factor of type of glass used
Table 4. Various parameters for US residential energy consumption survey (International Energy Agency 2014)

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Characteristics</th>
<th>Region &amp; Metropolitan Climate</th>
<th>Energy</th>
<th>End-uses</th>
<th>Appliances &amp; Electronics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of occupants</td>
<td>Year of construction</td>
<td>Urban vs. Rural</td>
<td>Energy by fuel type</td>
<td>Space heating</td>
<td>Count</td>
</tr>
<tr>
<td>Annual income</td>
<td>Floor area</td>
<td>Housing unit type</td>
<td>Energy by end-use</td>
<td>Space cooling</td>
<td>Age</td>
</tr>
<tr>
<td>Relation to poverty line</td>
<td>Ownership type</td>
<td>Water heating</td>
<td>Usage</td>
<td>Size</td>
<td></td>
</tr>
<tr>
<td>Energy payment method</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

and Local shading devices, Orientation and Thermal Conductance (U value) of materials used in apartments, Building services such as Lighting power density, Coefficient of Performance of Air conditioning systems installed and Solar water heater and Campus lighting. US Residential Energy Consumption Survey has listed indicators for tracking as shown in Table 4. In order to assess requirements of additional indicators, a field-based study will be taken for conducting post-occupancy evaluation surveys. IES VE Virtual Environment 2015, virtual environment software has been identified for simulating based-case and study area for its capability to carry naturally ventilated building or mixed mode buildings along with a lot of attributes and input options and lifecycle approach.

On the one hand, there is a need to develop baseline for existing residential societies in group housing, situated in National Capital Region of Delhi. POE surveys can provide valuable feedback on the design quality, functional aspects and thermal comfort. On the other hand, there is a need for objective and rigorous performance evaluation techniques and step by step process to provide systematic and easy to understand structure for measurement, evaluation and continuous improvement of buildings (Kumar 2014a). A pilot questionnaire survey and simulation of test modelling case can help to determine sample size and, finally develop a set of indicators proportionate to all three dimensions of sustainability for a specific case of retrofitting existing residential buildings in diverse climate. Comparison of various benchmarks achieved in the simulation output against design intent can be helpful in formulating strategies for high performing buildings in the near future (Grierson and Moultrie 2011). Selection of a well-designed existing residential complex for developing best case scenario, its POE surveys and then building performance simulation modelling, and finally its analysis, can serve as blueprint for setting achievable targets in various sustainability-related indicators. Thus analysis of baseline data of exemplars on extreme side of scale will help in understanding the concept of threshold values of indicators, and also help in bridging the gaps and fixing targets for retrofitting.

4 PERFORMANCE OF GAP MODELLING

Sustainability indicators for each of the dimensions of the existing housing study area are to be compared with base case developed using maximum and minimum threshold values of sustainability indicators. Maximum value of a particular sustainability indicator will be derived from best case scenario and worst value will be determined from worst case scenario (Balachandra and Sudhakara Reddy 2013). Mapping the standardised indicator values will be undertaken on the radar showing hypothetical best case scenario and proposed case or “as is” case as shown in Figure 2. The distance between two values will indicate the gap in the performance of a particular housing project under study. It will also reflect that which areas are needed more attention, and which areas of interventions needed special attention or no attention. The dimensions of the gap for the study area will also inform how far we are from achieving targets.

Retrofitting measures to be taken can be classified
into two or more than two scenarios. Immediate efforts can be undertaken for the easily achievable results i.e. low-hanging fruits. The other scenario can be built up using high hanging-fruit, but needing time and efforts, which can be done in phased manner. Remeasuring building performance after retrofitting can lead to better understanding of the subject and further innovations as indicators are means to achieve the objectives and are not an end in themselves. Thus the conceptual framework model identified for working out sustainability indicators for assessing sustainability of existing house, shall involve following steps:

1. Assess existing building rating systems from sustainability parameters and establish the missing indicators by expert interviews and other stakeholders;
2. Conduct Post-occupancy evaluation surveys to establish the indicators which are relatively important;
3. Develop residential baseline data for assessing the current performance of residential buildings or complexes. It may include standardized plan typologies, construction specifications, building envelope parameters, operational schedules, plug loads, energy and water audits and current environmental awareness programs and practices in use;
4. Identification and study of existing exemplar residential complex with best practices, to establish sustainability benchmarking and best case scenario;
5. Analysis of baseline data and POE surveys to develop sustainability indicators and formulate sustainability indices;
6. Building performance evaluation of the study area by calibrating building model in line with baseline data, performing building performance simulations and find out sustainability indices with respect to benchmarks;
7. Performance gap modelling of indices and to find out dimensions of gaps and identification of critical areas deserving more attention;
8. Identifying retrofitting measures and building’s scenario;
9. Compare remeasure performance with past performance or current practices i.e. self-referential benchmarking and best case scenario.

5 CONCLUSIONS

There is a need to retrofit huge existing housing stock consuming natural resources incessantly for reducing carbon emissions. Despite having largest footprint and high concerns of health and well-being of occupants, there are very limited studies on retrofitting of existing residential buildings. A conceptual framework model is proposed for developing sustainability indicators in a holistic manner to facilitate benchmarking of existing residential townships and campuses, that in turn, can help stakeholders to understand and apply retrofit measures for sustaining quality of life over life cycle of the project. The study concludes that a residential baseline data for assessing performance of existing mid-rise multi-storey housing stock needs to be developed by using post occupation evaluation surveys and expert interviews. The data obtained is to be compared with existing exemplar residential complex with best practices to establish best case scenario. After defining sustainability indicators for existing study area, it will be possible, based on the data of POE surveys and outputs of building performance simulation tools, to find out how much gap is extant between their performance and desired levels by process of back casting and scenario building. Accordingly, scenario building process will help in identifying different levels of scenarios and help in framing policy for taking corrective actions.

Thus this study would help in providing careful analyses through indicators that what areas are needed to be focused more, and what strategies and tools are needed to bridge the gaps for preparing sustainable development framework for retrofitting the existing residential buildings. The methodology used in this study can be helpful to incorporate key indices of sustainability into retrofitting existing housing stock to create vision plan with the aim of reducing carbon footprint, achieving social equity, quality of life and economic well-being.

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