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Sustainable Retrofit for Adaptive Building Reuse–A Facility Management Approach for Highlighting and Cataloguing Deficiencies for Retrofit Decision Making

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ABSTRACT:

Purpose–In India large businesses are beginning to adopt and report sustainability initiatives within their facilities and business processes. Facility managers are responsible for appraisal of the facilities to precisely pin point the areas requiring interventions of varying range of expertise and expenses. This paper aims to identify a methodology for facility managers for appraisal of their facilities with taking into consideration the occupants and changing requirements of the business, to categorize the areas of deficiency that are aligned with criteria of core sustainability for existing building operations, in-order to catalogue the range of potential improvements through retrofitting and measures to ensure sustainable reuse of the facility.

Methodology/approach–The study examined various existing building sustainability rating schemes–point and non-point based systems in India and abroad and brought out the interdependence of core service areas of facility management and the criteria for sustainability in existing buildings. The various systems specific to the core service areas of facility management are evaluated against a set of identified deficiency groups based on indicators from facility appraisal on energy use, water use, waste generation, occupant comfort, health and safety and ecological performance. To validate the approach, it is applied to three mechanically conditioned and ventilated office building facilities from 3 different geographical locations within India of two different types of occupancy- single and multitenant occupancy respectively. The application identified the various deficiency areas that were addressed and given priority to within different types of occupancy of varied facility management models.

Findings–Findings indicated that in most Indian office spaces, energy was the criterion given the most priority among the various sustainability categories. The paper proposed a generic template that consists of seven categories of possible deficiencies for assessment of the existing state of the building for identification of all areas requiring intervention from no cost through low to high-cost ranges under the various sustainability criteria.

Value–The paper provides the approach for deficiency identification from indicators to define the measures ranging from no cost to high capital investment sustainable retrofits of non-residential buildings, so as to sustain and improve the existing building systems and components addressing occupant health, safety and comfort, ecological protection, energy and water consumption and waste management. The approach, however, is not restricted to a specific region, and can be used anywhere as required.

KEYWORDS: Existing Building, Facilities, Retrofitting, Sustainability, Facility Management.

INTRODUCTION

The ever-growing population and the resultant increase in demand for buildings, materials and technologies has led to increased inventory on construction sites and new processes. A study conducted by the Material Consumption Patterns in India in 2016, a growing gap between the supply and demand of buildings and material has been identified. A significant part of the economic sector in OECD countries is represented by building activities, whose impact extends beyond the economic issues. The building activities and quality of construction have major impact on the social condition and environment of the building and its users. Buildings and construction projects are planned, designed and developed in accordance with the expectations of designers, clients, stakeholders, and the users. Also, the buildings are a daily use space and therefore must support ease of functioning and accessibility in addition to fulfilling the desired quality of built environment. An important aspect of achieving the quality is the construction materials and techniques that are used appropriately [1].

“Development that meets the needs of the present without compromising the ability of future generations to meet their own needs” - Brundtland Commission in 1987.

“Economic process that can be maintained long-term in line with earth's carrying capacity”. - World Council at the Earth Summit of the UN in Rio de Janeiro in 1992.

The JLL Report titled ‘Retrofitting India’s Central Business Districts (2011) states that CBDs can be identified as the most valuable business locations in an urban context or a city, having high property and land prices. Various factors influence the high demand for office locations in CBDs, which include accessibility to services, established business ecosystems, prestigious address and superior infrastructure. Constructing buildings that meet social and economic demands for longer periods of time can lead to reduction in usage of materials in the building sector, and consequently the generation of waste from construction and demolition processes. It can also help reduce the energy consumption in construction processes, transportation, loss of green areas, and reduce the demand for new construction and development in sub-urban areas, etc.

In order to make buildings meet these demands, it has to be operated and managed efficiently in a sustainable manner that can holistically satisfy its 3-dimensions, namely ecological, economic and socio-cultural. Businesses are increasingly considering the advantages available through sustainable refurbishment of their buildings and facilities, such as reduced operational costs, improved indoor air and environmental quality, enhanced public relations, improved productivity and demonstration of corporate environmental commitment. However, in India there is still more room for sustainability commitment to mature. The value and benefit from a building/ project can be maximized by standardization of processes, optimized designs and necessary materials; however, the peculiarities and constraints on site can compel the designers and project managers to adapt and modify as per requirements [2]. Further, it will also be beneficial for the decision makers and professionals to priorities their maintenance and management processes according to importance [3], availability of funds, etc.

Nevertheless, such inadequacies in existing construction techniques and processes, and the ever-increasing need for enhanced quality and speed of construction can provide opportunities for growth in research and development of newer, more detailed and optimised methodologies and processes [4]. The JLL report also highlights the significant potential and advantages in addition to main aspects of retrofitting. Some of the major characteristic highlighting the usefulness and justification of retrofit projects include – reducing costs, enhancing quality, expanding facility capacity, meeting environmental requirements, or incorporating a new technology.

According to Sanvido and Riggs, in their 1991 study, retrofit has been defined as: “A retrofit project is the modification or conversion (not a complete replacement) of an existing process, facility, or structure. Such modification may involve additions, deletions, rearrangements or not in-kind replacements of one or more parts of the facility. Changes may alter the kind, quantity, cost or quality of the products or services being produced by the facility.” In comparison to redevelopment, retrofitting is the preferred option, which also enhances the economic life and attractiveness of old buildings. The rising costs, the dwindling resources and the climate change has prompted facility owners and managers across the globe to incorporate sustainability through retrofit. Here lies the significance of examining the typology of buildings identified for retrofitting and implement the most appropriate processes to increase their real service lives according to their typology. “Strategies for the management and refurbishment of existing buildings play a significant role in the transition to a sustainable economy” [5]. To enable retrofitting of existing buildings to be sustainable, several strategies need to be adopted including sustainable principles and methods into the whole building operation. Building operation management, in other words, facility management comes into play in making the structures meet social and economic demands for longer durations. Facility performance improvement requires custom solutions depending on the characteristics and it is important to help owners and managers of buildings recognize the areas where renovation is appropriate. FM has only fleeting mention in the last forty years in developing nations.

There are 2 types of accepted definitions of FM globally. The first type is use in official national (UNI, BSI, DIN, etc.), global (ISO) and continental (Such as EN for Europe) norms and standards. The second type is the commercial norms and standards such as the ones from IFMA, RICS, etc. The International Facility Management Association (IFMA) defines FM as "a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, processes and technology." The European Committee for Standardization (CEN) defines FM as "(The) integration of processes within an organisation to maintain and develop the agreed services which support and improve the effectiveness of its primary activities."

The facility managers have a key role in identification of candidate buildings, legal and standards compliance, helping the decision-making body with selection and extent of retrofit to adopt, convincing the decision makers about the tangible and intangible benefits, and leveraging their knowledge relevant to current and post-implementation building performance. The extent of retrofit implementation however depends on factors such as alignment of changes with owners of core business areas, availability of capital renewal budget, associated risks, disruption to existing tenants and loss of revenue due to shut down, changes in process, facility management approach and operation styles among several others. To aid the facility manager in retrofit decision making, several Decision Support Tools exist. There are several decisions supports tools that have been made across different regions that cater to buildings of varied typologies, viz. offices, hotels, etc. However there exists limitations in them and also in adapting them for different regions other that those they were designed for.

McLaughlin (2004) points out the need for development of a strong business case in order to ensure better decision-making process. However, prior to considering the vast choices of available sustainable retrofit options and the costs in order to develop a strong business case it is of utmost importance to identify all the areas of a facility that have potential for improvement from their deficiencies. The challenges faced by facility managers are firstly, vast choices of energy-led refurbishment interventions, and secondly, inexperience in the specialised branch of refurbishment that can lead to unsuitable intervention sets being adopted. But it is found that the most challenging aspect in implementing sustainable retrofit improvements to existing buildings is the identification of the deficient areas within existing facilities needing varying range of interventions for improvement.

Thus, there is a need to identify the areas requiring retrofits towards sustainability within the different models of facility management, in order to identify the barriers and drivers to the adoption of sustainable retrofits within these models, their phasing during the life of the facility and the levels of intervention adopted. Facilities age and the need to be maintained and upgraded either to sustain or improve the function of the facility is unavoidable. This paper introduces an approach for facility managers to assess their facilities under consideration with respect to its business and occupants' changing requirements, to identify areas of deficiency aligned with criteria of core sustainability that are identified as important factors for existing building operations, in-order to classify the range of possible improvements from simple measures to high cost retrofit to enable sustainable reuse of the facility.

Rationalization for Choice of Cases for Analysis

The examples chosen for analysis are office buildings from three different states of India, with mechanically conditioned and ventilated interiors but of different occupancy types- single and multitenant occupancies. They were chosen so as to point out the barriers and drivers in achieving sustainability through retrofit refurbishments in business facilities that are operated under different models of facility management. The comparison helps to bring out the sustainability criteria given the most priority to for retrofitting office buildings across the region.

Scope

The scope of this paper is limited to existing business facilities, to understand the models of facilities management existing in them and the approach in each of the different types of business spaces. It is limited to understanding the various possible measures- no cost, low/medium, and high-cost measures, the system deficiencies that triggers these measures, and the phasing of the different levels of retrofitting during the course of operating the facility. The prime concern of this study is limited to office facilities- single occupancy and multi tenanted occupancy with FM models being based on control Building operated and Facility management consultancy operated. It is also limited to buildings having air-conditioned interiors. This includes building in which mechanical systems are the only means of achieving predetermined levels of interior comfort. Especially it does not consider buildings which largely depend on natural means for climate control within its interiors.

Literature Review

Significance of Sustainable FM by Elmualim, Czwakiel, C Valle, Ludlow, & Shah (2008) points out that Sustainable Facilities Management focus primarily on its contribution in the fight against climate change. An estimation by CIOB (2004) depicts that construction processes use only 5% of the generated energy, whereas power and operation of the buildings uses 45% of the energy. As highlighted by the Organisation for Economic Cooperation and Development (OECD, 2003), 32% of the world's resources are consumed by buildings, which includes 12% consumption of water. The resultant emissions of carbon dioxide due to such immense consumption of resources contribute significantly to global warming. However, such consumption patterns have to scope to be substantially reduced, thereby also reducing their detrimental effects on the environment.

Sustainable measures in FM are also important to be adopted to combat the problem of increase in fuel prices and uncertainty of supply due to intensive economic activities in the countries of India and China. In addition to the increased effect on climate change, the rising demands and pressure on resources can also cause 'fuel poverty' and insecurity in supply, thereby causing and exacerbating the associated social problems. The research 'Sustainability in Action: Identifying and measuring the key performance drivers' [6] indicates that the implementation of general as well as sustainable strategies requires the managers to understand the consequences of their actions and decisions for improvement in performance. A careful analysis of the key drivers of performance and a measure of the drivers and their linkages is necessary. Further, a clear understanding of the wide range of impacts caused by corporate activities is required, in addition to their impact on the stakeholders.

In order to examine the leading and lagging indicators of performance, a successful corporate strategy for social responsibility needs to be viewed over a long time horizon. The impacts of previous, pending and future corporate decisions, both on society and corporations has been highlighted in the framework devised by Epstein & Roy (2001). The framework can help in implementation of a sustainability strategy and connected actions that can enhance both financial as well as sustainability performance.

Existing Building projection for India

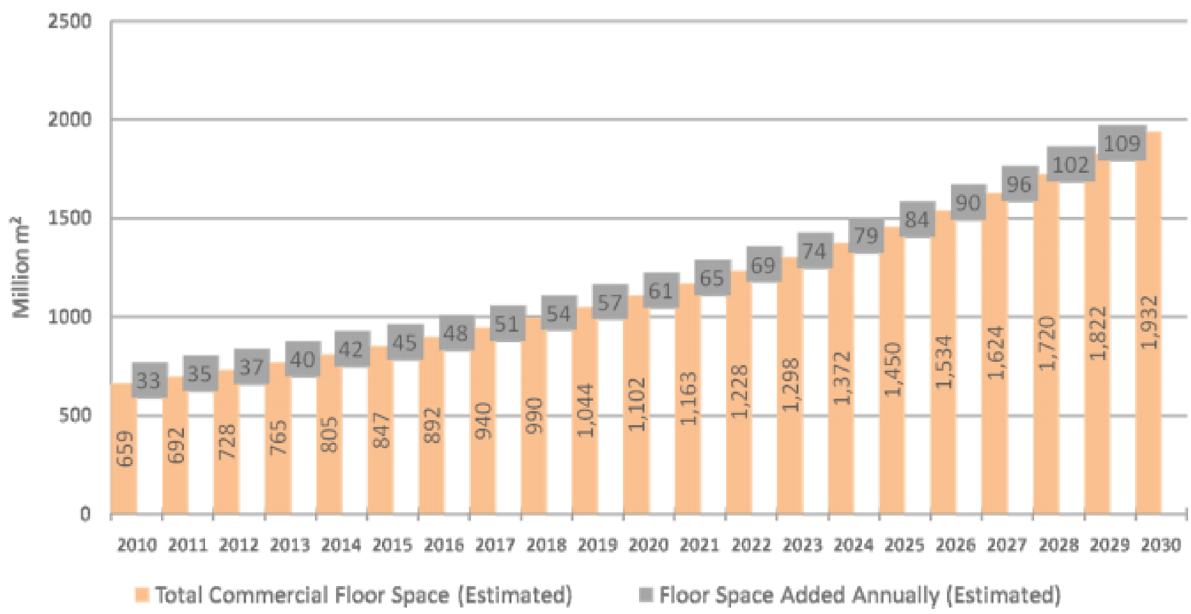

Figure 1: Commercial Floor Space Projection for India (Assuming 5-6% annual growth); Source: USAID ECO - III Project

Barriers and breakthroughs for multi-tenant developments [7]

The primary perceived hurdle in adopting high-performance building in the multi-tenant sector is the distribution of costs, benefits and responsibilities under current leasing practices. However, through industry education, integrated design approach, improved operational procedures, refined lease structures, and various other innovative practices, the multi-tenant leasing market is expected to become a mechanism, which supports the upcoming generations through a sustainable approach, while improving the triple bottom line. This transformation will be catalysed as owners, tenants and investors realise the full value of the benefits of high performance structures, with increase in worker productivity to decrease in operational costs. As reported by British Institute of Facilities Management (BIFM, 2007), while the profession of Facilities Management has been provided with an opportunity to make significant difference by driving forward the agendas of sustainability, however, currently it does not have ease of access to specialist tools and knowledge, and supporting case study data to make this a reality.From the papers it is evident that there are barriers in the implementation of sustainability through incorporation of retrofits in various facility management models. One such barrier that is highlighted is the lack of a comprehensive approach to evaluate the facility for sustainability improvements due to various deficiencies within the various models of facility management that exists in business facilities.

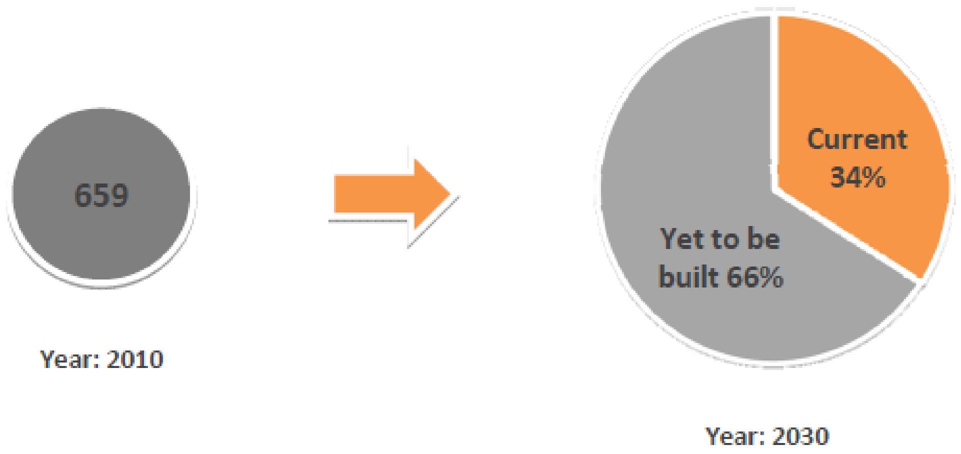

Figure 2: 66% building stock is yet to be constructed. Assuming 5-6% Annual Growth; Source: USAID ECO -III Project

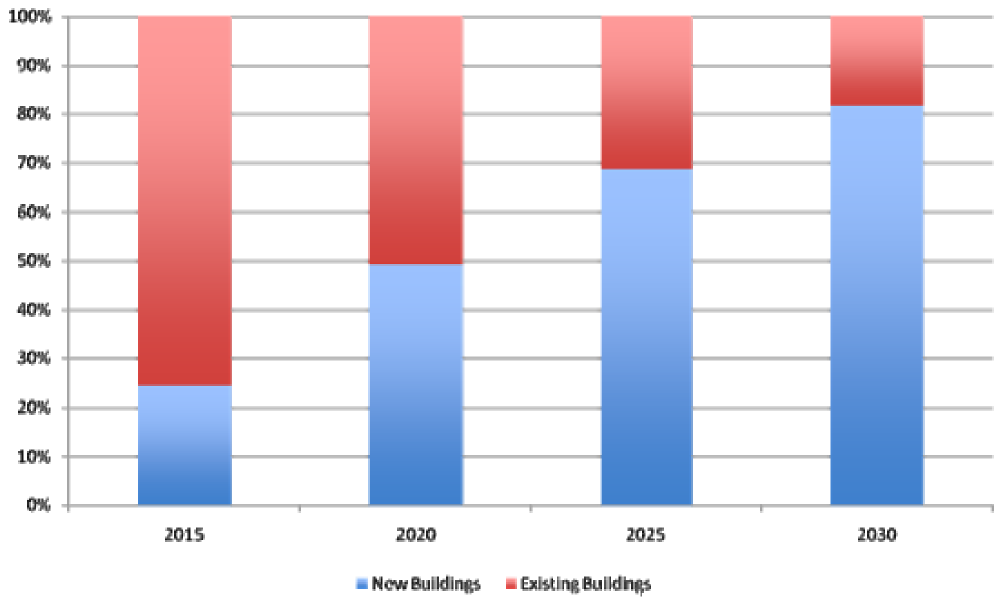

Figure 3: Annual Energy Consumption of New and Existing Buildings in India; Source: USAID ECO -III Project

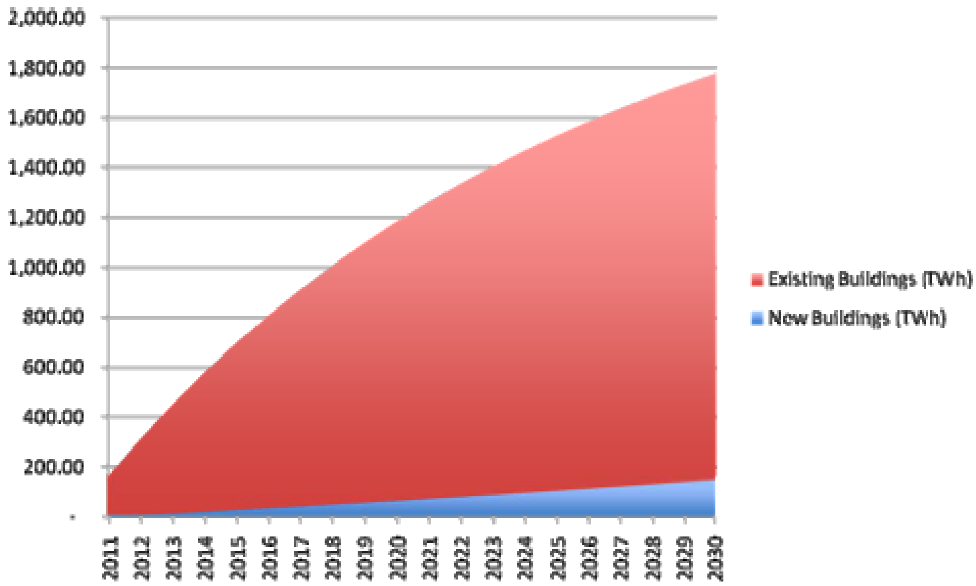

Figure 4: Cumulative Energy Consumption of New and Existing Buildings; Source: USAID ECO -III Project

Policies and Legislation, Codes, Standards, Programmes and Sustainability Assessment systems in India enforcing sustainability in existing buildings

Standards

India at present do not have any established standards laying down guideline in the form of ISO standards giving guidelines to energy, quality and environment management systems. However, few Indian Standards that prescribe guidelines related to sustainable measures exist.

Policies, Laws and Codes

The National Building Code Technical Committee in its amendment to NBC of India 2005 has incorporated a new Part 11: Approach to Sustainability. However, this provides guidelines to sustainability for new constructions and their operation and maintenance thereof and not for aging existing buildings that exist in Indian CBDs.

Table 1: Policies, Laws and Codes

Protection and Careful Management of Resource and Products	**Provisions under Indian Legislation**
Energy	Energy Conservation Act, 2001
Biodiversity	National Biological Diversity Act (2002) and Rules (2004)
Water	The Water (Prevention & Control of Pollution) Act, 1974
Air	The Air (Prevention & Control of Pollution) Act, 1981
Water	The Water (Prevention & Control of Pollution) Cess Act, 1977

Environment	The Environmental Protection Act 1986. Norms for General Standards for Discharge of Effluents, National Ambient Air Quality Standards, National Noise Ambient Air Quality Standards, and Noise Limit for Generator Sets Run with Diesel, and Ozone Depleting Substances
Hazardous chemicals	The Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989
Batteries management	The Batteries (Management & Handling) Rules, 2001
E-waste management	E- Waste (Management & Handling) Rules 2011

Programmes

United Nations Development Programme (UNDP) in India for Energy Efficiency in Commercial Buildings, under its fourth component aims to provide support to BEE for evaluation and recommendation of incentive options (such as financial and fiscal incentives) for the production, commercialisation and purchase of building materials that are energy efficient, and retrofitting and new construction of more energy efficient buildings. The proposed incentives must be compatible with the ECBC program and/or other programs for energy efficiency introduced by BEE. Additionally, it will help to introduce the tariff discount schemes and rebated in coordination with utilities and regulators for commercial buildings that implement the programs for energy efficiency, or for compliance with ECBC requirements. BEE has prescribed minimum efficiency performance standards, with the rating of appliances based on the energy efficiency indicated by suitable number of stars on the nameplate label. The number of stars range from 1 to 5. Higher number of stars indicate higher energy efficiency and more savings on energy bills for the consumers. Energy labelling program is mandatory from January 2010 for the following products viz. Room Air Conditioners, Frost-free Refrigerators, Distribution Transformers, and TFL among several others.

Sustainability Assessment Systems- point and non-point based

The point based, LEED India rating systems under IGBC (Indian Green Building Council) has been established, but they at present only consider (NC) new construction, (CS) core and shell and (CI) corporate interiors. They are voluntary systems and are not presently available for existing building sustainability assessment. The trend however is the voluntary use of LEED US established by USGBC for rating existing buildings in India, under the (EBOM) Existing Building: Operations and Maintenance rating scheme, also point based. Other point-based schemes include BREEAM- In Use which is UK based and has not been observed in use in existing building rating in India.

Non point based rating schemes widely in use is the BEE Star Rating system for Energy sustainability assessment of existing office and BPOs. This system however limits the ranking of the buildings against energy consumption benchmarks only and does not address aspects of water use, waste generation, environmental impact, etc. The present status and growth barriers and drivers in developing nations towards sustainability can be summarized as- the lack of mandatory codes for sustainability, presence of non-mandatory energy conservation codes for buildings, lack of government target policies to minimize sustainability impact due to existing buildings; with the UNDP programme to reduce energy consumption in existing and new commercial buildings in India serving as a push towards energy sustainability alone.

Facility Management in the Indian Context

Facility Management (FM) services involve the assistance of a third-party service provider to carry out part of the maintenance of the building facility, or outsourcing of the management of entire facility to an external organisation that conducts this process in a professional manner. This includes both hard services, such as building operation and maintenance, and soft services, such as energy management and support services. As highlighted by Frost and Sullivan (2011), hard services include electro-mechanical, electrical, mechanical, energy management and water management services. Soft services include security, housekeeping, catering, cleaning, horticulture, landscaping, transportation, and front office management, etc. While in developed markets FM services are integrated with other services such as lease management and rent collection, the same is not incorporated in the Indian market to provide complete property management solutions.

The FM services market in the Indian subcontinent is in the early stages of growth and is rapidly evolving, owed to the swift growth in the construction sector. This market is expected to reach the mature phase of growth, fuelled by the increased awareness levels among different vertical markets.

Table 2: Facility Management Sustainability and Its Relationship with Management of Core Service Areas

	Ecology	Energy	Water	Waste	Health	Comfort	Safety
HARD FM							
Electrical		✓					✓
HVAC		✓	✓	✓	✓	✓	✓
Plumbing	✓	✓	✓	✓	✓	✓	✓
SOFT FM							
House keeping		✓	✓	✓	✓	✓	✓
Security + Fire		✓	✓	✓			✓
Pantry & catering		✓	✓	✓	✓	✓	✓
Transportation		✓					✓
Landscape & horticulture	✓	✓	✓	✓	✓	✓	✓

Elements of Sustainable Facility Management

Table 3: Sustainability Impact of Existing Buildings

Land environment	Impact on natural drainage system
	Impact on surrounding land use compatibility
	Impact on the public infrastructure such as on roads, parking, public water supply and power supply and sewerage system
Biological environment	Impact on flora and fauna
Water environment	Impact due to ground water withdrawal
	Impact due to discharge of black water and grey water
	Impact due to discharge of water from swimming pools

Air environment	Impact during the operation stage – smoke from exhaust of Diesel generator, From energy consumption (off site), From transportation, Due to purchase and sale, Due to events, Due to processes and operations
Noise environment	Impact during the operation Facility activities
	Impact due to operation of D.G sets
Solid waste	Impact due to demolition waste
	Impact due to biodegradable and non-biodegradable, including plastic waste and e-waste
Natural resources	Consumption of power and water and the stress on the system

Table 4: Sustainability Assessment of the Key Criteria Identified - Ecology, Energy, Water, Waste, Health & Safety, Comfort

FACILITY DATA TO BE COLLECTED		
Resource use data	Source of data (consumption/ generation reading)	Information needed
Basic Building Information		
Building data	Physical survey of the building	Type of building Age of building Type of construction Dimensions Construction materials Orientation Fenestration systems Shading techniques
	Building Area	Total floor area Area on each floor Basements (if any)
	Inspection of Building Plans	
BUILDING SERVICES INFORMATION		
Types of systems	Mechanical System	Type Components Age of equipment Preliminary conversion systems
	Lighting systems	Fixture location Types

		Sizes Switching circuits Illumination levels Schedules of operation of space
	Plumbing systems	Fixture locations Types Passive measures
	Firefighting systems	Detection system fixture types, age and location Protection system fixtures, types, age and location Passive measures
Occupancy usage profile	Service areas of facility	Population and occupancy schedules Building utilization data (hrs. /day, days/week, weeks/year) Special conditions of usage
Operating practices-procedures	Equipment operating and schedule	HVAC systems Setback control systems Winter heating mode Summer cooling mode Maintenance practices Process loads
Equipment	HVAC- Plumbing Plant	Equipment inspection Controls
	Electrical Plant	Electrical wiring Distribution systems Lighting conditions for each area
Parking area	Parking (above and below grade)	Lighting condition Ventilation rates
WEATHER DATA	Hourly data	Outside air temperature (dry bulb) Wind speeds Humidity (wet bulb) Solar data
UTILITY DATA		
Energy from mains	Historical Invoices/ Energy bills, meter readings	Consumption- kWh or cubic meters
		Billing period
		Cost
		Contract demand

Energy (other sources)		
DG/ GG	Readings	Consumptions- kWh or cubic meters
		Cost
		Installed capacity
Fuel	Petrol Diesel Gas	Size of facility fleet Percent of occupants using private vehicles, public transport, cycle, etc.
Water	Invoices	Consumption- Cubic meter
WASTE		
Solid waste		Tonnes, kilograms, per waste container (size and density)
Paper		Number of sheets, reams or boxes
HEALTH, SAFETY & COMFORT		
Health & Safety	Questionnaire	Percent of employees/ tenants with each illness associated with indoor poor-quality environment, Percent of employees on sick leave Indoor monitored levels of CO2, Carbon monoxide, Ozone, Formaldehyde, Lead, Nitrogen dioxide, Sulphur dioxide, SPM, RSP, Benzene
Comfort	Post occupancy evaluation Questionnaire	Percent of employees/ tenants with each illness associated with indoor poor-quality environment, Percentage drop in productivity, Percentage reporting/ complaints of discomfort.

METHODOLOGY

Sustainable Retrofit Opportunity Identification

Table 5: Deficiency Indicators in Existing Facility Operations

INDICATORS	DEFICIENCY	LEVEL OF INTERVENTION
Servicing and Cleaning	Soft maintenance deficiencies	Existing component adjustments/part replace
Original defects at installation	Installation deficiencies	Additions on existing component

Wear and Tear	Maintenance- preventive, corrective, condition-based deficiencies	Component in kind replace/ renewal
Reduced efficiency due to primitive component	Functionally, operationally, efficiency wise deficiencies	Component upgrade to new kind
Reduced efficiency due to primitive system	Obsolescence- whole system deficiencies	Whole system design upgrade
Absence of systems for regulation of energy, water, health, comfort, safety and wastage	Technological deficiencies – energy, water, comfort, health, safety, wastage	New systems addition (energy- carbon, water, comfort, health, safety, waste)
Absence of monitoring systems for measurements and verification systems for control – incompatible existing building systems.	Control, tracking and monitoring technology deficiencies	Control & monitoring system addition

Table 6: Link between sustainable criteria and the Service Areas for Identification of Contributing Factors for Deficiencies

Sustainability criteria	Broad areas of improvement possible	Component/system with potential improvement through retrofit under the various criteria
Ecological sustainability	Site landscape	Hardscape, softscape
	Fabric	Façade, roof
Energy sustainability	Fabric	Wall, curtain wall, roof, window& door/ fenestration
	Systems	Hvac, plumbing, electric, fire, office equipment
	Transport	Vehicle use
	Alternative sources	Solar, wind, geothermal, energy from sewage
Water sustainability	Site	Envelope and roof
	Systems	HVAC, plumbing, irrigation
	Alternate sources	Grey, rain, condensate, sewage reclaim

Waste management	Bio degradable	Food, site surface litter
	Non-biodegradable	Packaging, defective parts
Health and safety sustainability	Particulate matter	Hvac
	Fire	Fire safety equipment
	Electric	Earthing, insulation, protection standards
	Harmful gases	Paints, materials
Comfort sustainability	Thermal	Equipment, lighting, discomfort sources
	Humidity	Moisture sources
	Visual	Indoor visual, fabric wall to glazing ratio
	Noise	Equipment, outside noise ingress- fabric

Table 7: Approach to Retrofit Positioning for FM

Deficiencies	**Soft maintenance deficiencies**	**Installation deficiencies**	**Maintenance- preventive, corrective,**	**Functionally, operationally, efficiency wise**	**Obsolescence- whole system deficiencies**	**Technological deficiencies – energy, water,**	**Control, tracking and monitoring technology deficiencies**
Cost Investment	Recurring (no cost- high)	Low	Low- medium	Medium- high	High	Medium- high	Medium- high
Retrofit appropriate Schedule (years)	0-5	0-5, at any time	5-10	>15	>25	Any point in life of building, compatible	When automation compatible systems exist
Levels of retrofit	Existing component adjustments/ part replace	Additions on existing component	Component in kind replace/ renewal	Component upgrade to new kind	Whole system design upgrade	New systems addition (energy- carbon, water, comfort, health, safety,	Control & monitoring system addition

Sustainability criteria
ECOLOGICAL SUSTAINABILITY
ENERGY SUSTAINABILITY
WATER SUSTAINABILITY
COMFORT
HEALTH & SAFETY – MATERIAL USE

RESULTS AND DISCUSSIONS

CASE STUDIES: Identification of areas of potential retrofit improvement when integrating sustainability criteria- ecology, energy, water, waste, health & safety and comfort with the deficiency groups by various contributing factors possible within facility management service areas

Table 8: The buildings chosen for assessment are as follows

	ITPC	**PAHARPUR BUSINESS CENTRE**	**EXPRESS TOWERS**
Location	Chennai, Tamil Nadu	Nehru Place, New Delhi	Nariman Point, Mumbai
Occupancy type	Multi-tenant	Single occupancy	Multi-tenant
	2007	1988	1972
Age	7 years age	25 years	40 years
Floors	B + G + 13 Floors	G + 6	25 (excluding Basement + Parking + Ground)
INFERENCES FROM COMPARISON			
Sustainability criteria considered for retrofit	Energy, Water, Waste, Comfort	Ecology, Energy, Water, Waste, Health, Safety and Comfort	Energy and Safety
Deficiencies	Maintenance, Operation, System, Technology and Control	Technology, Control, Operation, Obsolescence	Obsolescence, Technology and Control
Limitations	Approach helps to understand the limitations in the base builder to achieve total sustainability	Approach gives understanding that this model allows total control to base building in achieving sustainability up till the end user or the facility	Approach reveals the limitations of the base building to achieve total sustainability

Prerequisites	Strict guidelines for occupants and tenant regulatory rules in place.	There need to be guidelines for users and training of staff	Strict guidelines for occupants and tenant regulatory rules in place.
Coordination	Contract management and team work between facility management teams of base builder and the various tenants is important	Single in- house or outsourced facility team has a holistic control over the facility	Contract management and team work between facility management teams of base builder and the various tenants is important

Benefits and Limitations of framework

There are two scenarios possible that trigger need for retrofit, which can be identified from the model.

- Due to lack of maintenance:
  The lack of sufficient preventive maintenance and soft maintenance can be identified from the framework and this will indicate the areas of much needed retrofit improvement.
- Due to noticeable expenditure in operation and maintenance:
  The adopted maintenance and operation repairs, additions, refits and renewal can be identified from the framework; thus, bringing to notice the areas with the highest O&M costs. These areas can be prioritized for retrofit.

The model can be effective only under the following condition, which are not limited to:

- Presence of a strong sustainable policy for the operations of the facility.
- Presence of proper documentation and staff for the various maintenance activities.
- Presence of in place framework and designated role and responsibility within organization breakdown structure to cater to facility management sustainability.
- Presence of mandatory laws for limits and norms on energy, water, waste, comfort, health and safety within existing facility operations.
- Presence of strong communication between FM teams and contract management in case of multi tenanted facility.

The model does not provide exact costs but provides a framework to allow facility managers to identify deficiencies and excesses in terms of maintenance and expenditure respectively in order to decide priority of the areas requiring retrofit.

CONCLUSION

In case of facilities that are owner-occupied, the validation of integration of sustainable retrofits is easier due to the well-recognized soft and hard benefits (such as productivity gains, cost savings, improved occupant health, etc.) that are directly recovered by them. However, owners or developers of multi-tenant office buildings, on the other hand, encounter both real and perceived barriers that often prevent them from incorporation of sustainable retrofits for managing of energy, water and especially waste management within their facility. They owner cannot also ensure the health, safety and comfort within each tenanted area. This lies on the responsibility of the tenant company to incorporate the necessary measures to ensure health, safety and comfort for occupants. The base builder caters to all the common amenities viz. cooling, heating, electricity, plumbing, fire protection and leaves the end user requirements such as lighting, controls, ventilation rates and volume controls, etc. to the tenant companies' discretion. To ensure gain for the base builder and return from investment for the retrofitted measures, there should be strict guidelines for occupants and tenant regulatory rules in place. This however still restricts the extent of application of lighting, AHU variable volume capacity controls, etc. since each tenant has their own standard requirements for lighting and air volume and ventilation rates. This might hinder the achievement of returns to the base builder of the multi tenanted building compared to single owner-occupied facility, where implementation of policies and achievement of set objectives and targets are more feasible.

Future Scope: The research gives a generic model for use within office facilities to aid facility managers to identify deficiencies and excesses in terms of maintenance and expenditure respectively; in order to decide priority of the areas requiring retrofit. The model is apt for any business facility with comfort conditions provided using mechanical systems. The further scopes include: (a) Development of a visual identification system to identify the different deficiencies within system to allow for appropriate retrofit interventions; (b) The model can be further modified to suit various other building typologies viz. hospitals, industries, institutions, labs, etc.

REFERENCES

[1] G. Seshadhri and V. K. Paul, "Intervention Strategy for Enhanced User Satisfaction Based on User Requirement Related BPAs for Government Residential Buildings," in International Conference on Sustainable Infrastructure 2017, New York, 2017.

[2] V. K. Paul, S. Khursheed and R. Singh, "Comparative Study of Construction Technologies for Underground Metro Stations in India," International Journal of Research in Engineering and Technology, vol. 6, no. 3, pp. 55-63, 2017.

[3] G. Seshadhri and V. K. Paul, "Validation and ranking of user requirement related building performance attributes and sub attributes for government residential buildings," Facilities, 2018.

[4] V. K. Paul and V. Seth, "Benchmarking and Objective Selection of Technologies for Housing in India Using Quality Function Deployment," Journal of Construction in Developing Countries, vol. 22, no. 1, pp. 63-78, 2017.

[5] P. Appleby, Sustainable retrofit and facilities management, Abingdon: Routledge, 2013.

[6] M. J. Epstein and M.-J. Roy, "Sustainability in Action: Identifying and Measuring the Key Performance Drivers," Long Range Planning, vol. 34, p. 585–604, 2001.

[7] C. Carmichael, C. Fluhrer and E. Bonnett, Barriers and Breakthroughs for Multi-tenant Developments, 2008.