ISSN 2349-7475

Indian Buildings Congress

Volume Thirty Six
Number One
2026

Seminar on

SERVICES IN HIGH RISE BUILDINGS

July 25-26, 2026
Chandigarh

आधुनिक तकनीक सुरक्षित निर्माण

INDIAN BUILDINGS CONGRESS

PRELIMINARY PUBLICATION

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Mid-Term Session
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The views expressed in the publication are of the individual authors and do not necessarily reflect those of the Indian Buildings Congress. The IBC does not take any responsibility for the correctness of data given in papers by the authors.

Published by
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Kama Koti Marg, Sector-VI, R.K. Puram,
New Delhi – 110022
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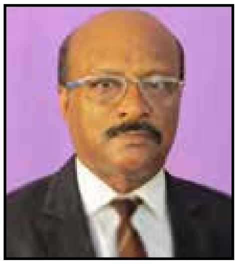
FOREWORD



The geographical spread of developmental projects across various sectors has led to the rapid expansion of existing urban areas and the emergence of new urban centres. As a result, our country is witnessing accelerated urbanization accompanied by a steadily growing urban population.

Such unprecedented expansion of the built environment and related infrastructure is inevitably accompanied by a host of challenges, including environmental concerns, climate change impacts, unsustainable development practices, and issues related to resource management such as water scarcity, sanitation, waste management, and transportation.

In recent years, significant emphasis has been placed on sustainable development by both public and private agencies. This has led to a series of innovations in the built environment, including the development of eco-friendly building materials and construction technologies, as well as the adoption of advanced tools such as Artificial Intelligence, Building Information Modelling (BIM), and digital documentation and process automation.

Innovation and sustainability are intrinsically intertwined. While innovation drives the development of solutions to address environmental and societal challenges, sustainability provides the framework for creating long-term value and ensuring a positive impact on future generations.

As we continue on the path of rapid development, it is imperative to place unwavering emphasis on sustainable practices, with innovation serving as the key driver. Equally important is the dissemination of these innovations among professionals associated with the built environment, thereby fostering greater awareness and facilitating large-scale adoption.

With this objective, the Indian Buildings Congress (IBC) is organizing a Seminar on "Services in High Rise Buildings" during its Mid-Term Session at Chandigarh on 25-26 July,2026 being hosted by IBC, Chandigarh State Centre & IBC, Haryana State Centre. The various aspects of this important subject will be deliberated upon in this one-day seminar. I am confident that the discussions and presentations will lead to valuable recommendations for consideration by the Government.

The Indian Buildings Congress (IBC), since its inception, has been at the forefront of knowledge-sharing, capacity building, and policy advocacy in the built environment sector. We recognize that timely completion, quality assurance, and the adoption of modern construction technologies are critical for realizing the vision of Viksit Bharat. Our emphasis must remain on sustainable materials, green buildings, smart urban planning, and integrated project management practices.

Equally important is the need to bridge regional and social disparities through infrastructure. Development must reach the remotest villages, ensuring housing for all, efficient transportation systems, renewable energy integration, and resilient public utilities. A truly developed India will be one where infrastructure empowers every citizen, regardless of geography or socio-economic background.

Capacity building of engineers, architects, planners, and project managers will play a defining role in this journey. IBC is committed to enhancing professional skills, disseminating best practices, and fostering collaborations with national and international institutions. By equipping our professionals with cutting-edge knowledge, we ensure that India's infrastructure stands as a model for the world.

During the programme, the preliminary proceedings containing of the articles selected for Seminar will be published.

I extend my sincere thanks to all the authors for rendering their valuable papers and making efforts for the publication.

(Er. C. Debnath)
President
Indian Building Congress (IBC) &
Fmr. President, IEI

PREFACE

Urbanization and land scarcity have made high-rise buildings a necessity in modern cities. To accommodate a large number of dwelling and commercial units on limited land, vertical growth has become the preferred solution.

However, this vertical expansion brings complex challenges for geotechnical engineers, planners, designers, supervisors, and service providers. The design, safety, execution, and maintenance requirements of high-rise buildings are far more demanding than conventional structures.

A major challenge lies in the integration and management of multiple building services. MEP services, vertical transportation, water supply and drainage, fire safety, and security systems must all function seamlessly. Their execution often faces issues of cost optimization, clashes with structural elements, and inter-service conflicts. Efficient integration is therefore critical for the safe and sustainable operation of high-rise buildings.

The construction industry is one of the largest contributors to the global economy, but it is also highly resource-intensive. For a developing country like India, the demand for infrastructure across all economic sections is huge, while natural resources remain limited. It is thus the need of the hour to adopt sustainable practices through innovation in construction techniques, equipment, and materials to ensure timely delivery of quality infrastructure.

In this context, architects, engineers, owners, and developers must address the exclusive service requirements of each high-rise project based on its specific usage.

Considering this significance, the theme selected for this year's Mid Term Seminar "Services in High Rise Buildings" is highly relevant and timely. The response from authors has been encouraging. A large number of papers were received, and after careful screening for relevance to the theme and originality, sixteen papers have been selected for publication and it will be presented by the authors during the seminar being held at Chandigarh.

It is expected that these presentations and the deliberations will lead to useful recommendations for the benefit of all stakeholders in the construction industry.

I express my sincere gratitude to Er. Satyanarayan Mendu, Co-chairman and all the members of Technical Committee for their valuable support in the screening and selection of papers.

I hope this seminar as well as publication will serve as an effective platform for knowledge sharing and for shaping future practices in high-rise building services.

R.K. Majumdar, IAS (Retd.)
Chairman, Technical Committee, IBC &
Former Director, Urban Development, Govt. of Tripura

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CONTENTS

IMPORTANT CONSIDERATIONS FOR SERVICES IN HIGH-RISE BUILDINGS

Dr. K. M. Soni*

Abstract

High-rise buildings have become the necessity in urban areas to solve the problem of land scarcity and to accommodate large number of dwelling units or commercial buildings in a limited land area. Since such buildings occupy more space in vertical direction, they pose a challenge to the geotechnical engineers, planners, designers, supervisors, and service providers due to their complex design, safety, services, and maintenance requirements. In addition, ultra-high-rise buildings have become a symbol of prosperity and luxury making them the centre of economic growth, attraction of investment, and tourism.

As the high-rise buildings have multiple services, execution and maintenance of services such as MEP services, vertical transportation services, water and drainage services, fire safety services and security services including their integration pose major challenges due to cost optimization requirements, their clashes with the structural components and possible clashes within themselves.

Inspite of the challenges, high-rise buildings offer numerous benefits as such have become highly attractive, whether residential, commercial, or institutional. Architects, engineers, owners, and developers have to cope-up with exclusive requirements of the services of a particular high-rise building based on its usage and plan them accordingly. Proper space planning and coordination, adoption of BIM, use of modular prefabricated components, use of durable construction materials requiring low maintenance, taking quality as a service, use of digital and AI services, adoption of reliable standby and automated services may be essential in all high-rise buildings in future.

SERVICES IN HIGH RISE BUILDINGS

High rise buildings have complex services than low rise buildings as they are taller, and if not properly designed, the maintenance of services becomes difficult. Also, if the services are not executed appropriately during construction, they may lead to permanent problems for the occupants during service life of the building. Therefore, planners and supervising engineers of the services have major role in success and quality of the high-rise buildings even though structural design and execution at height also pose a challenge.

For the quality services of a high-rise building, a consultant or owner must engage a good MEP consultant for the services. Also, to resolve the complexity of various services, use of BIM and CDE should be mandatory in high rise buildings as close coordination between various experts and timely decisions are very essential during various stages of planning and execution of high-rise buildings, also highly beneficial.

Considering gravity of CO_2 emissions, high rise buildings are to be designed with the concept of high-performance including sustainability, comforts, energy efficiency, water efficiency, aesthetics, safety, functionality, cost effectiveness for better productivity, maintainability, and accessibility.

Some important considerations in planning the services in high-rise buildings are discussed in the following:

GREEN BUILDING SERVICES WITH INTEGRATED SUSTAINABILITY

Sustainable buildings have to be green buildings with maximum extent of energy efficiency, water efficiency, material efficiency, indoor air quality, and cost efficiency. Apart from this, such buildings may be designed as net zero energy or net zero plus buildings however considering limited roof top space, it may be difficult. Therefore, aesthetic solar panels of high efficiency would be required in future. Further, the campus may be designed as net zero or net zero plus energy utilising open space in place of individual buildings.

Sustainability has become important criterion due to climate change and high carbon emissions. Therefore, integrated sustainability design clubbed with green building concept will be required

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thus campus qualifying for net zero energy, low-embodied-carbon materials, recycled materials, vertical greeneries, and advanced water-recycling and rain water harvesting systems.

Fig. 1: Requirements of High-Performance Buildings

High rise buildings have high energy requirements hence for sustainability and cost considerations, planning and execution have to include energy efficient equipment, HVAC system, electrical installations, vertical transportation system, and other electrical appliances provided in the buildings to minimise the energy demand.

Operational cost of mechanical, electrical and plumbing (MEP) services is going to be very high therefore, MEP systems in high rise buildings must meet sustainability goals while reducing operational costs by way of adoption of smart technology such as zoning of HVAC system, temperature controls, control of sun rays, lighting etc. to minimise the wastage. Integrated Building Management System (IBMS) and smart building automation have to be adopted for water conservation, MEP services, irrigation, and setting up comfort levels.

In India, most of the buildings are still constructed with AAC blocks and brickwork. Such materials were used as bricks and blocks were available in abundance and security was of the major concern being ungated structures. Now, high rise buildings are located in gated campuses hence engineers and architects need to switch over to light weight modular precast construction for infill walls which are energy efficient qualifying sustainability such as sandwich panels, stay in place panels, light gauge frame structural system.

Fig. 2: Stay in Place Panels for infill Walls

ACCESSIBILITY SERVICES TO DIVYANGJAN AND ELDERS

All the buildings, roads, transportation and other indoor and outdoor facilities, including housing and workplaces are to be planned and provided the barrier free accessibility in India. Equally important is to provide the information, communications and other services for them. Neglected attitude and lack of knowledge with the engineers and contractors executing the work related to accessibility, lower priority is accorded to the prescribed provisions compared to other services leading to discontinuity of the accessibility provisions during construction as well as during maintenance period. Therefore, all the service providers have to accord equal priority to accessibility norms and integrate them with other services.

Fig. 3: Low Priority to Tactiles Continuity

EXCLUSIVENESS AND PRIVACY SERVICES IN DESIGNING OPERATIONAL AREAS

Operational areas say in a residential unit are living room, dining room, bed rooms, and washrooms in addition to other service places as desired by the owner. These were traditionally designed with sharing concept. However, in the time to come, concept of “exclusiveness” and “privacy” will override the sharing concept. These operational areas may become service areas and each user may require exclusive area as the timings of rising, bathing, dining, and sleeping would vary from a family member to other family member and even may coincide. Exclusive services spaces such as bath, toilet, office working space, and kitchenet/pantry may be required to be designed separately for each member. For example, husband and wife may be having different eating habits and they may require two different kitchens one for cooking vegetarian meal and other for cooking non-vegetarian meal. Even if both are non-vegetarian, one may require separate kitchen for cooking different type of non-vegetarian meals.

The homes are to be designed additionally for the “work from home” office spaces having smart services in them adjoining to bed rooms. This may be essential even for school or college going children.

Fig. 4: Work from Home Setup

Due to availability of immense information, the urban areas particularly metropolitan cities are becoming hub for technological innovation, and these cities are rapidly embracing the transformative power of smart buildings and home automation. The homes are developing into residences plus office, and work places as office plus gym centres, yoga centres, bath places, resting places, and canteens. Hence, architects and NBC authorities have to revise their norms considering modern needs both in public and private high-rise buildings.

SMART SERVICES

High rise buildings include tall buildings some being constructed not only for living but for luxury and tourism. These buildings are designed with luxurious amenities hence cost is not the criterion. Living in them itself is a status symbol. These buildings are designed with modern amenities and smart services using smart technologies, high quality materials, rich specifications and modern services. However, users of other high-rise buildings also express their willingness of smart services. Therefore, all high-rise buildings should be designed with smart services.

Smart technologies and services in residential and commercial high-rise buildings are based on vertical transport and better people flow, destination dispatch, predictive maintenance, smart access, smart HVAC control, smart energy and smart HVAC management, smart and automated lighting, smart security, integrated face recognition-based access control, AI analytics etc.

Smart services in high-rise buildings utilize Internet of Things (IoT) sensors and will utilise Artificial Intelligence (AI) in near future to integrate the services including core systems like HVAC, lighting, security, elevators, natural light emissions, cleaning, sprinkler operations, alarming system, metering and bill payments etc. into a single digital infrastructure to optimize energy efficiency, minimizing maintenance, and for comfort to the users. Futuristic services may require operation of services through verbal command of the users, and AI based automated operations based on their living pattern behaviour. Thus, smart services will be of fixed and floating types, fixed being designed and provided in the building, and floating designed depending upon the user’s lifestyle.

PARKING SERVICES

Parking is already an essential part of the building design but parking norms need to be revised by the designers and NBC, as interior and luxury cars for every family member or for different purposes have become the status symbol. Parking norms in a high-rise building may start now from 2 onwards for a dwelling unit. This will pose a challenge if the designers do not adopt a new concept over existing concepts of stilt, podium or basement parking. Parking block itself may be required to be integrated in future with two or more residential blocks.

Further in future, owners will not have time to park and take out cars from their allotted parking spaces manually. They also would not like to share the keys to the parking drivers for the parking and taking out their vehicles. Hence, parking services in the time to come will have to be designed fully automated and robotic.

VERTICAL TRANSPORTATION, ELEVATOR AND SECURITY SERVICES

Vertical transportation in high-rise buildings encompasses the elevators, escalators, and service lifts that efficiently and safely move users up and down with minimum time of waiting and travel. Thus, high speed lift will be common relying on zoning, automated dispatch systems, and specialized high-speed traction technology. Energy generation through traction or similar technology may be integrated in the transportation system in future. These elevators have to be with almost zero defects, servicing on 24x7 basis, receiving consistent, reliable power, coordinating, and unifying distinct electrical components such as power sources, control systems, and machinery into a single, cohesive, and efficient network, merging process and power automation. Elevators will be fully integrated with MEP, and safety and security controls for safe and efficient operations.

ROOF DRAINAGE SERVICES

Roof drainage in high rise buildings is to be taken seriously in India as dust get accumulated on the roofs and the roofs are to be cleaned periodically. If roofs are not cleaned or inadequately cleaned due to neglected attitude towards the maintenance, water accumulated on roof results into damage of water proofing, and ponding conditions. When the cleaning of roof is done, water gushes into the pipes and damages the rain water pipes and fittings sometimes causing overflow into the rain water chambers and drains.

Another problem in the roof drain pipes is related to the pathetic attitude of construction and maintenance workers towards construction material spread or stored on roof, delayed cleaning, and work taken up during rains at their sweet will, leaving construction material for a long time in open on the roof. During rains, the material flows down automatically and few workers even deliberately throw waste and unused material into the rain water pipes so that the same is not to be collected and brought down. In such a case, construction material enters into the rain water pipes, resulting into chockage at the bottom, particularly if binder is mixed. Due to water accumulation into the rain water pipes at the bottom, the joints get opened and water starts leaking through the joints. In case, the rain water pipes are not accessible, it becomes very difficult to desilt them, and are to be broken. Drainage pipes should always be designed for additional capacity as actual area is likely to get reduced due to improper laying of water proofing, silting and rubbish choking the entry of rain water pipes.

Further, rain water pipes in high rise buildings should be avoided to be laid horizontally over a long distance for easy maintenance if they are laid on ground floor due to architectural design requirements. Even though rain water pipes maybe taken in the shafts, when run horizontally, any blockade in rain water pipes can create havoc during rains. Sometimes it becomes impossible to maintain them in case of chokage without breaking the floor. In case, they are essentially to be laid horizontally, adequate manholes should be provided on the floor for the maintenance.

PLUMBING AND WATER PRESSURE MANAGEMENT SERVICES

High rise buildings pose a challenge for ensuring water supply with uniform pressure to the users without damaging the pipes and fittings. Loss of pressure may arise in case water travels in vertical pipe without control on the upper floors while high pressure may damage water supply system in lower floors due to very high pressure in case of gravity flow. Pressure reducing valves at lower floors and sub risers to increase pressure at higher floors may be required appropriately. As the number of storeys goes up, challenges also increase. Hydro pneumatic pumping system is commonly used in high rise buildings. Stage pumping and gravity system is also followed. Therefore, water supply has to be designed appropriately by an expert considering the site conditions and the planned high-rise building. In high-rise buildings, it is also not feasible to replace the pipes and fittings easily hence selection of pipe material and fittings has to be compatible to the service life of the buildings.

For water saving, use of recycled water and rain water harvesting is part of the green building design and sustainability concept. However, local authorities and the governments should think over to make it mandatory to construct rain water storage tanks in open areas over which the greenery may be planned as ground water recharging is not successful at most of the places due to unattended maintenance.

HOUSEKEEPING AND SOLID WASTE MANAGEMENT SERVICES

Housekeeping in high rise buildings will be more and more robotic in future due to cost, timings of housekeeping, and safety considerations, particularly internal housekeeping of the dwelling units. Therefore, the floors are to be designed in such a way that they do not have level difference so that the robotic housekeeping becomes easy and practicable. The designers will have to design rooms in such a way that the housekeeping is easier for the robotic cleaning.

Solid waste management in high rise buildings is also to be designed considering local byelaws, and amount and composition of the waste by way of waste chutes, waste collection points, and their treatment and recycling in a way that maintenance and collection of waste is easy and efficient.

FIRE PROTECTION AND LIFE SAFETY SERVICES

Fire safety in high rise buildings is very crucial as such they have to behave as fire protection buildings at the first instant and thereafter, places of easy evacuation for the occupants by themselves and thereafter by firemen to minimize loss. Therefore, all fire safety norms have to be abided by the designers and builders in addition to those provisions made which are not included in the fire safety norms due to tall buildings being designed by the architects while fire authorities may not be equipped with the required facilities.

Another important consideration is abiding fire safety norms during life cycle of the building. Space in high rise building is money hence there is a temptation to make use of fire safety spaces such as refuge area, assembly areas, and fire escape staircases. Apart from this, fire tanks may be modified, smoke detectors and sprinklers covered for aesthetics and internal partitions, smoke exhausts closed or unattended, refuge areas covered, glass exits modified and so on. Such mindset has to be stopped altogether as the loss and casualties are very high in high-rise buildings.

SERVICE SHAFTS

As the space is very costly in high rise buildings, sometimes service shafts are miserly designed which are neither fit and safe for maintenance staff to work, nor having scope for future expansion of the services, and even not having enough space for changing the stacks and pipes. Sometimes, water supply and sewage pipes overlap due to insufficient space, creating undesired conditions. It has to be understood that number of services will ever increase during life of the building as such

Fig. 5: Refuge Area Covered Fig. 6: BIM of a Hospital

service shafts have to be planned with open mind by the architects, and concept of redundancy to be included in the design, and the codes.

BIM AND CDE SERVICES

Due to large services in high rise-buildings, higher possibility of clashes of multiple services and structural components, costly changes, information of cost and corrections of changes, and for timely decision-making during planning and execution stage, Building Information Modelling (BIM) and Common Data Environment (CDE) are to be used essentially during planning and execution of high-rise buildings.

NON-CONVENTIONAL ENERGY

Solar energy is going to be a main non-conventional energy source in India till the energy generated from some other environment friendly source is tapped economically. High rise building has limited area of rooftop, generally not enough for the requirement of solar panels hence area other than the rooftop is to be utilized. In future, solar panels are likely to be provided on façade also simultaneously high efficiency solar panels will be utilized to generate more power. Therefore, architects are to think for new ideas like providing solar trees in open areas, and solar panels on internal roads, boundary walls etc. to have more area.

FLEXIBILITY IN SERVICES

High rise buildings often evolve over decades and are to cater future requirements. As the technology is changing very fast, provision should be made for flexibility in space to include additional services like interiors, MEP systems, electric load and power point arrangements, security services, fire services, preferably modular systems to simplify replacements and expansions with adaptable lifestyle planning balances, cost optimization, and least maintainability.

CONCLUSION

Services in high-rise buildings are complex and need to be designed by the experts in a way that the buildings behave as high performance buildings through sustainable design. Services like accessibility services, exclusiveness and privacy services, parking services, smart utility services, roof drainage services, plumbing services, water management services, fire services, vertical transportation services, housekeeping services are to be designed considering future requirements using BIM and CDE with flexibility approach.

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SUSTAINABLE CONSTRUCTION THROUGH GREEN BUILDING PRACTICES TOWARDS ACHIEVING SUSTAINABLE DEVELOPMENT GOALS

Dr. Sunil Kumar Chaudhary*

Abstract

Greenhouse gas emissions are major environmental implications of the building sector. Buildings are responsible for at least 40 per cent of energy use, contributing to greenhouse gas emissions. IPCC estimated that by 2050, buildings are projected to emit 3,800 megatons of carbon. Hence it is crucial to promote green buildings in the construction industry as a way to tackle environmental issues and problems, achieve the social equity and reap the associated economic rewards. In green building, the many stakeholders collaborate to complete an integrated green design and construction process that fully achieves the goals of sustainability in design and construction. This paper explores the key principles and objectives of green building practices, including energy efficiency, resource conservation, water management, and indoor environmental quality. This paper critically analyses solutions and constraints to incorporating green construction into Sustainable development initiatives. The study goals are to identify green building adoption challenges, examine sustainable practices techniques and initiatives, evaluate their performance, and suggest ways to overcome them.

The comprehensive literature analysis synthesizes ideas from relevant research on incorporating green building practices and sustainable construction technologies into sustainable development projects across nations and regions. The investigation highlights economic, technological, social, and policy constraints. The paper summarises the key findings on challenges and ways for incorporating green building and sustainable construction into Sustainable development initiatives. The paper concludes with recommendations for policymakers, professionals, and stakeholders to further promote and integrate green building practices into the Indian construction industry, facilitating a more sustainable built environment.

INTRODUCTION

Buildings are responsible for at least 40 per cent of energy consumption in most countries, contributing to greenhouse gas emissions (World Council for Sustainable Development). IPCC estimated that by 2050, buildings are projected to emit 3,800 megatonnes of carbon. The United Nations Environment Programme says, as nearly one-third of the total greenhouse emissions come from buildings, "green buildings" are essential to any policies addressing climate change and environmental concerns. IPCC Report 1996 predicts that the real estate industry will consume 38 per cent of the global energy and emit 3,800 megatonnes of GHGs annually.

Being a rising economic power, India's energy demands are expected to overtake the energy demands of China by 2050. Commercial and residential buildings in India accounts for more than 30 per cent of the country's total electricity consumption. Buildings in India consume around 20 per cent of the total power and impact the environment and resources. The construction industry is growing by 10 per cent compared to the world average of 5.2 per cent. With the rapid boom in real estate, construction sectors and huge energy consumption, it is crucial to have more green buildings in the coming years. Thus, besides providing business opportunities, green building technology is the need of the hour.

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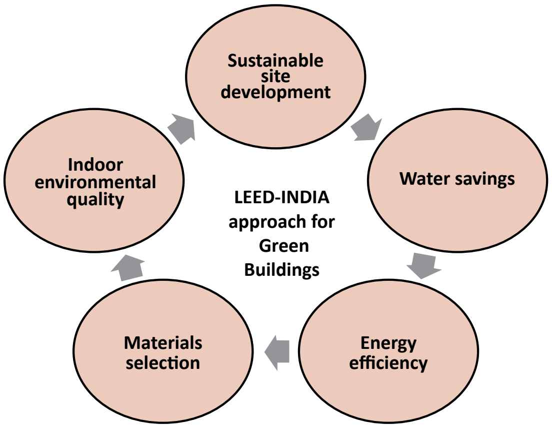
Green buildings offer one of the most cost-effective solutions to climate change and can lead to significant environmental, economic and social benefits around the world. Since the approach towards green buildings is holistic, it will address concerns other than a reduction in energy usage wherein they focus on the design right from the planning stage by envisioning sustainable features at the beginning and considering the whole supply chain - material sourcing, energy modelling, resource reuse, civic amenities, waste disposal. However, possibilities of using the local resources innovatively are left to the creativity of the concerned designer architect. Green building practices encompass various aspects, including design, construction, operation, and maintenance of buildings. Key objectives of the green building movement include:



Green buildings with their unique features of construction like economic use of resources, conservation of energy, support the Sustainable Development Goals in more than one way.

Source: World Green Building Council, https://www.worldgbc.org/green-building- **sustainable-development-goals**

Against this backdrop, the objective of this paper is to provide a systematic approach to Sustainable Construction through Green Building Practices towards Achieving Sustainable Development Goals.

GREEN BUILDING

Green building brings together many practices, methods, and skills to lessen and eliminate the building's impact on human health and environment the. The construction practices and technologies used in a green building are constantly developing. Even though the methods vary, the main principles persist. The figure below shows the CII Sohrabji Godrej Building in Hyderabad, the first platinum-rated green building in India. It is a 20,000 sq. ft. building created using innovative green building technologies and sustainable architecture. Green building design, practices, techniques, and skills lessen and eradicate the overall influence of the building on the surrounding natural environment by efficiently using energy, water, and other natural resources. It protects the occupants' health and well-being as well as improves employee productivity. Green buildings decrease waste generated, environmental pollution, and degradation.

GREEN BUILDING PROCESS

The essence of green building is to adopt an integrated process that provides a more holistic approach to building planning, design, construction and operation. Green building also needs an Integrated Construction Process (ICP) if it is to fully achieve the goals of green building. ICP facilitates the construction of a building that can attain the target green building performance. Here, all stakeholders are involved in aspects such as materials selection, system performance, decreasing construction waste, improving indoor air quality, sustainable site management, and safety, among others [9,15]. It is important to appreciate that in green building, delivering the building to the owner at the conclusion of construction is just the beginning of the building's life. Since a building consumes the majority of its energy and water during the operation phase, with significant generation of waste, it is very important that green building strategies continue to be implemented. The major green building processes during the operation phase are to optimize energy and water performance, procure green products, engage in green waste management, and maintain greenhouse functions, occupant comfort and environmental quality.

GREEN BUILDING STRATEGIES AND TECHNOLOGIES DURING THE CONSTRUCTION PHASE

During the construction phase of a building's lifecycle, careful attention must be devoted to both design strategies and construction opportunities for ensuring that a project is delivered in a sustainable fashion. To successfully implement green strategies and technologies during the construction phase, a range of green strategies and technologies can be deployed to achieve the goals of green building. Construction opportunities here include preconstruction services, minimizing site disturbance, erosion and sedimentation control, pollution prevention, sustainable site operation, construction waste management, indoor air quality management, green materials management, and commissioning, among others [9,15]. It is also important to fully document the processes implemented and the building's performance in order to earn an internationally recognized green building certification. Identifying green building strategies and technologies and stakeholders' roles and responsibility at the very beginning of the construction phase is the fundamental role of ICP in green building.

MODEL GREEN HOME

BENEFITS OF GREEN BUILDING

- Reduction in water and energy consumption. Energy savings may range from 20% to 30 % whereas water savings ranges from 30% to 50%.
- Enhanced air quality, excellent daylighting, health & well-being of the occupants
- Safety benefits and conservation of scarce national resources.
- Positive Environmental Benefits
- Lower Operating Costs

GREEN BUILDINGS - WHAT WORKS BEST?

- Design is Key
- Technology Matters
- Materials Count

GREEN BUILDING LIFE CYCLE ASSESSMENT

There are four stages during the lifecycle of a building –

- Material Manufacturing,
- Construction,
- Use & Maintenance
- End of Life (AIA Guide, 2010).

Maximum impact to the environment occurs during the first 2 stages. Sustainable manufacturing and construction practices if adopted can reduce the impact on the environment. The overall performance of buildings can be assessed by an extensive mechanism in five key areas, namely: energy efficiency, water efficiency, environmental protection, indoor environmental quality, and other green features and innovations (Belassi, W., Tukel, O.I., 1996).

GREEN BUILDING STATUS IN INDIA

As per the 2011 Census, almost 31 percent of India's current population lives in urban areas and contributes 63 percent of India's GDP. With increasing urbanization, by 2030, urban areas are expected to house 40 percent of India's population and contribute 75 percent of India's GDP (censusindia.gov.in, 2014). Comprehensive development of physical, institutional, social, and economic infrastructure is required to accommodate this growth. In India, the housing segment is growing quickly and is contributing enormously to the progress of the national economy. There is an immediate need to implement green concepts and methods in the housing sector, which can help growth in a sustainable way. National priorities addressed by a green building are water conservation, increased energy efficiency, reduction in the use of fossil fuels, efficient handling of household waste, reduced use of virgin materials, and the health and well-being of residents. In this direction, the Government of India has implemented smart cities, which requires that 80 percent of buildings constructed should be green.

It is interesting to note that India has the highest number of green buildings in the world and the outcome of a decade-old movement (CoreNet

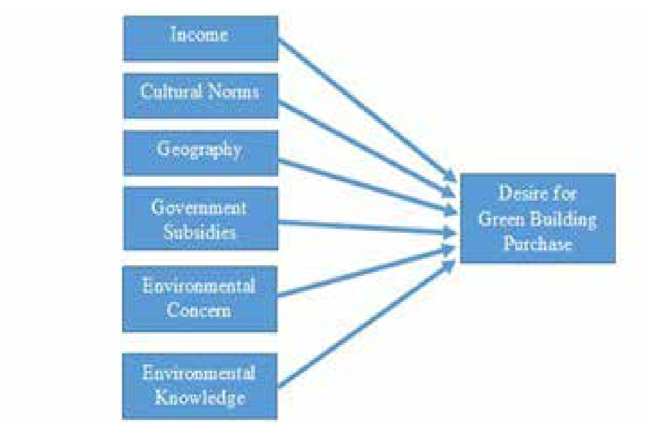
Global 2014). India was ranked second among the list of top ten countries in the world by the US Green Building Council (USGBC) for LEED outside of the US. It is estimated that by 2030, the Indian building stock would reach 100 billion square feet in comparison to the prevailing 25 billion square feet. The green building movement began in India with the establishment of the India Green Building Council (IGBC) in 2001, initiated by the Confederation of Indian Industries (CII) along with the World Green Building Council and the USGBC. The first green building in India, CII Sohrabji Godrej Green Business Centre was inaugurated on July 14, 2004, at Hyderabad. Currently, India has more than 2,030 registered green building projects and over 60 LEED platinum-certified constructions. Besides, India is leading the green building movement worldwide. The first green building was constructed around 2003-04. Currently, there are 2,204 green buildings, including hospitals, hotels, colleges and IT parks in the country and the number of green building is anticipated to grow from 2,204 at present across India, to about one lakh by 2027. Maharashtra has the highest number of green buildings and stands first in the country. Tamil Nadu holds third position and Karnataka stands fourth. Bangalore has some of the highest-rated buildings in India. Other cities, Chennai, Hyderabad, Pune and Mumbai are also promoting the green building movement in India. The Union Ministry of Housing and Poverty Alleviation plans to work in collaboration with all the stakeholders in promoting Green Affordable Housing and with the State Governments to map the needs and requirements for affordable housing. It is also proposed to make affordable housing a vital part of smart cities.

Though there is progress in green building construction in India still a major portion of constructions do not adopt green measures. So far there is no compulsion for all constructions to be green. Green buildings are costly and hence the demand is low for such buildings. But we cannot ignore the damage done to the environment due to construction of non-green buildings. Hence in order to generate more demand for green buildings it is necessary to increase more awareness among the consumers about the benefits of green buildings. It is also necessary to find out drivers which may stimulate the purchase of green buildings.

DIVERS FOR GREEN BUILDING PURCHASE

- Income
- Cultural Norms
- Geography
- Government Subsides
- Environmental Concern
- Environmental Knowledge

The Proposed Model



Challenges Facing Green Building Implementation

- Low awareness of incentive policies among industry players
- Lack of motivation, lack of economic incentives and weak enforcement of legislation
- Lack of expertise regarding the standards by local officials
- Lack of awareness among stakeholders, lack of technology in India
- Lack of skilled professionals and high renovation costs associated with existing buildings.

- Behavioural problems where developers tend to overestimate costs and occupants' lack of attention to energy efficiency
- The information asymmetry makes buyers hesitant about choosing green buildings, resulting in a cost-benefit mismatch for developers
- Energy pricing and contract structure hinder occupants from enjoying cost savings due to energy savings
- Information asymmetry between sellers and buyers about the environmental performance of green housing, where buyers are not fully aware of the operational benefits.
- Challenge for designers is to bring together the different sustainability requirements in innovative ways.
- Lack of technology, lack of awareness among stakeholders, high renovation costs associated with the existing buildings and lack of skilled professionals to carry out the process.

SUMMARY

- Given that, the construction industry is booming in India and is one of the largest economic activities growing at an average rate of 9.5 per cent as compared to the global average of 5 per cent, it is crucial to make the right decisions on sustainability.
- As 60 per cent of the infrastructure that India needs are yet to be constructed, and estimates are that by 2030, 10 billion square metres of construction will happen, it would be valuable to make their green buildings.
- There is a need for concern for the environment, commitment to social responsibility, and application of mind and passion to do something to conserve resources to help future generations.
- TERI estimates that if urban buildings were to be adopting green building concepts, savings could be up to 8,400 MW of power and enough to light 550,000 houses annually.
- It would be useful to focus and make this concept popular through small builders and should be adopted in smaller towns as well for extensive outreach and adaption.
- It would also be good to make the existing households/buildings resource-efficient.
- As highlighted by studies earlier, the general assumption among the masses is that green buildings are costlier compared to regular conventional buildings. This may be due to a lack of sufficient technical information regarding the concept of green buildings which is still in a budding stage in India.
- Added to this, immaturity of the market, lack of resources, long gestation period and lack of focus on lifetime return on investment (ROI) of these buildings are other reasons.
- It is important to create demand by providing various measures like tax incentives (tax rebates, etc), providing improved access to finance for the purchase of green buildings, through rewards systems, etc.
- There is less awareness about the benefits derived from green buildings.
- Currently, large scale capacity building programmes to promote the construction of green buildings are not adequate to meet the demands of the increased demand of the construction industry.
- Awareness creation through Training Programmes is important by making training programmes as a part of the syllabus and tie-up with the IGBC with the concerned departments in the Engineering Colleges.
- Innovative ideas should also be discussed to make them more adaptable across various levels of builders.
- Besides, there are lack of research studies at the micro-level on green buildings focusing on focusing on governance, awareness across the construction industry and the public, access to information to public, cost options and so on.
- Given these gaps, there is potential for further research on various aspects of green buildings and improving governance and initiating strategies so that public and private players can be committed to action and promote green buildings.

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RATIONALISING AND REDEFINING SERVICES IN HIGH RISE BUILDINGS-ISSUES & OPTIONS

Jit Kumar Gupta*

Abstract

Led by high cost & limited availability of land, rapid urbanization and prevailing high urban density , vertical expansion of cities has become the development norm. Accordingly, construction of high rise buildings, has emerged as the natural corollary for catering to rapid urban growth. Promoting high rise buildings has empowered cities, to meet demand for large built space, optimising land, redefining design of buildings, creating state of art services/infrastructures, adding value to the sky line and creating distinct identity for cities. Despite numerous advantages, high rise buildings are also known to create numerous challenges. Housing large population, high rise buildings invariably pose challenges in terms of structural safety, security of the people besides catering to rising temperature and issue related to parking/ vertical mobility. Requiring large variety/volume of services; high-rise buildings involve numerous challenges in terms of operational efficiency and sustainability. Looking at the complexity & challenges posed, high-rise buildings need to be planned, designed, constructed and operated rationally, for making them minimum consumers of energy/ resources, generating minimum waste and promoting safety and sustainability. For achieving the defined objectives, paper explores the options of; adopting innovative approach to planning & designing buildings; identifying services ; challenges faced in providing services ; rationally positioning/ planning service core/ducts, leveraging innovative technologies; optimizing cost of provisioning/operation/managing services, as the basic principles for making high rise buildings, sustainable, livable ,qualitative and operationally efficient.

INTRODUCTION

Buildings are critical for human living, growth and development. History of built environment is closely connected with the history of human living. Numbers, nature and volume of built environment have been increasing rapidly, with massive increase in human population and changing requirements of human living. Buildings have great role and relevance, because majority of human activities are performed within the buildings. With more than 80% life span spent within built environment, buildings are known to be major determinants of human health, happiness, growth and development. Buildings are central to human living, because they provide shelter, safety, and spaces for work, learning, and social interaction. Buildings also shape environmental sustainability through energy use and resource consumption. Their relevance extends beyond physical protection to influencing health, well-being, and ecological balance. If buildings are known for its positivity, they also showcase number of negativities. Buildings are known to be large consumers of energy, water and resources, besides generators of large waste. Built environment enormously impact environment because buildings are known to consume ;16% of world's fresh water withdrawal; 25% of wood harvested globally; 30% of consumption of raw material extracted from planet earth; consumption of 45% of global energy; 35% of world's CO_2 emission; 40% of Municipal solid waste and 50% of Ozone depleting CFC's still in use. In addition, 30% of residents suffering from sick building syndrome, is the outcome of people living in unhealthy buildings. (*Roodman and Lenssen, 1995*) Accordingly, buildings need to be planned, designed and constructed in a different and distinct manner, for removing all negativities besides promoting positivity.

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Looking at the entire context, it can be seen that buildings are never been static. Buildings have been evolving, devolving, never fixed and never finite, for the reasons, typologies of buildings remain closely connected with; available materials, innovative construction technology, changing needs of society, availability & pricing of land, rising population, increasing urbanisation, changing building bye-laws, increasing demand for large floor plate of built area. In order to meet these challenges , high rise buildings became a necessity. High-rise buildings are no longer just architectural landmark, in fact they are reflection of how modern cities are growing, adapting, and thriving in the era of globalization and liberalizations of economies . In rapidly evolving urbanisation, these vertical structures symbolize ambition, innovation, and optimisation of land utilization.

DEFINING HIGH -RISE BUILDINGS

Having genesis in USA, high-rise buildings have been defined differently and distinctly by different cities, states, countries, researchers, scholars and development agencies. as briefed below;

- A high-rise building is any multistoryed structure tall enough that elevators are required for vertical circulation, typically defined as having its highest occupied floor more than 75 feet (about 23 meters) above ground level internationally, or above 15 meters (around 5 floors) in India.
- High-rise building also called high-rise, multistoried building, tall enough to require the use of a system of mechanical vertical transportation such as elevators.(Minimol)
- Any building requiring mechanical vertical transport (elevators), usually above 75 feet (23 m)
- A highrise building is defined as any building with a height of 24 meters or more (NBCS 2026).
- Any building with an occupied floor or occupiable roof located more than 75 feet (≈23 meters) above the lowest level of fire department vehicle access (International Building Code -USA).

Looking at the above, despite variations in definitions, high rise buildings are Invariably characterised by its significant height and the use of elevators to access the upper levels of buildings. Architects and engineers play critical role in designing these buildings, by considering structural integrity, fire safety, efficient space planning and creating distinct architectural vocabulary. Construction materials used in high-rise buildings are required to meet stringent quality standards to ensure durability and strength, against external forces like wind and seismic events. Making provision of essential services also remain most valuable for these buildings, to ensure that they operate effectively and efficiently. Rising temperature and climate change has necessitated that these buildings are planned, designed, constructed and operated to be energy efficient, resource efficient and environmentally sustainable.

GENESIS OF HIGH RISE BUILDINGS

Globally, mega cities are spacing increasing number of new high rise buildings. In addition, large number of low rise buildings are making way for such buildings. It has been observed that high-rise buildings have genesis in; rapid urbanization, massive increase in urban population, increasing land scarcity, soaring property prices and widening gap between demand and supply of built up space for housing, offices, business and work. For catering to unsatiating demand for built space, mega cities like Mumbai, Delhi, Kolkata, Hyderabad, Pune, Chennai, Ahmedabad and Bangalore are undergoing rapid transformation in its skyline . High rise buildings are becoming the norm and most viable solution for accommodating growing population and meeting rising space demands. Prime reasons for increase demand for high rise buildings in India can be attributed to;

- **Limitation of Land :** Holding only 2.2% (32 lakh Sq kms)of the global land and housing 17.8% (1.47 billion) of global population, India remains most land stressed country among 195 nations. Limited availability of developed land coupled with high prevailing land prices and rising demand for built space in urban cores are pushing cities to expand vertically.
- **Rising Urbanization :** Led by large population base, ever rising urbanisation & urban population projected to exceed 800 million by year 2050, are pushing cities to create more cost-effective options for meeting rising demand for housing, institutional and commercial spaces in urban areas , calling for more high rise buildings. .
- **High Land Cost :** Rising property values, leveraged by increasing land speculation and land disposal policies , providing options of creating more units per square foot of land space, has made vertical construction more economical, cost- effective and efficient,
- **Supportive Legal Framework :** With building rules and zoning regulations, providing options for unlimited height and unlimited floor area ratio, high rise buildings are gaining currency in urban settings.
- **Rapid Economic growth :** Rising incomes and corporate demand for premium office spaces has led to ushering a culture of vertical development.

- **Supportive Technological :** Advent of steel and glass as the building materials, coupled with options of rapid vertical mobility through high-speed elevators have made tall buildings a distinct reality.
- **Creating Land marks :** In the race of creating distinct identity, cities are opting for taller and iconic buildings, so as to make global mark, promote tourism and making city a preferred investment destination.

SERVICES TO BE PROVIDED

Like all buildings, high rise buildings also require numerous services to make the built space operational and livable. These basic services include water supply, sewerage, sanitation, wastewater disposal, stormwater drainage, electricity, HVAC etc. However, due to complexity of structure , nature of buildings, height, density, large volume of built space, high rise buildings require additional and specialized services for the reason of safety, security, mobility, comfort, convenience and efficiency. For ensuring structural safety high rise buildings need structural systems made of reinforced concrete/ steel frame, designed to resist wind and seismic forces to make them safe against natural disasters like earthquake, cyclone etc. In case of manmade disasters like fire, high rise buildings need to be equipped with appropriate system of fire detection, warning, fire extinguishing besides options for ensuring safe exit of people out of buildings. For efficient and seamless vertical mobility of people , commodities and luggage, high rise buildings need to be equipped with appropriate elevators, escalators, and service lifts. For ensuring appropriate quality and quantity of water supply at desired pressure, high rise buildings require water supply pressurized pumping systems, overhead tanks, and booster pumps to maintain requisite flow of water at higher level. In addition, these buildings are required to be equipped to handle large volume of waste generated besides ensuring appropriate heating and ventilation options to have quality indoor living.

Looking at the context of high rise buildings in terms of height, intensity, density, and reliance on advanced systems, making provision of services in high rise buildings, is bound to be more complex, requiring high degree of planning. designing and technology besides skill, expertise, resources, knowledge and experience, when compared with low-rise structures. Besides structure, plumbing and water supply, other services to be provided in high rise buildings can be enumerated in terms of;

- **HVAC :** involving appropriate heating, ventilation, and air conditioning for achieving thermal comfort
- **Indoor Air Quality:** Ensuring appropriate quality of indoor air for making people happy and healthy
- **Lighting :** ensuring appropriate level of lighting for living, working& leisure
- **Energy management:** Minimsing energy consumption and creating options for using renewable energy integration.
- **Fire safety:** Making buildings safe against fire-hazards
- **Evacuation:** Creating effective & efficient systems for early/safe evacuation of occupants, in case of disaster.
- **Security:** for promoting safety of occupants against crime etc. through effective monitoring
- **Waste management:** ensuring safe collection and disposal of garbage
- **Telecommunication:** providing best of the services connected with Internet, telephone etc.
- **Power distribution:** ensuring uninterrupted quality supply of power

CHALLENGES IN PROVIDING SERVICES IN HIGH RISE BUILDINGS

When looking from outside, high-rise building from outside, may appear as a vertical tower, but for supporting that tower, there exists complex coordination of structural systems, MEP networks, safety mechanisms, and quality processes, all working together to create a safe , sustainable and functional built environment. Providing adequate, appropriate and qualitative services in high rise buildings have critical role, relevance and importance in making these buildings operationally efficient, cost-effective, sustainable and comfortable. However, despite distinct advantages offered by high rise buildings , providing services in such buildings remains difficult and challenging task, because providing , operating and maintaining such services are known to be cost-intensive and labour intensive, requiring high degree of skill, resources, technology and expertise. Providing services in high-rise buildings has been found to be far more demanding than low-rise structures Major issues and challenges involved in providing services in high rise buildings can be enumerated in terms of;

- ***Challenge of Power***: Power being the crux of efficient construction, operation, maintenance and safety of buildings, high rise buildings face major challenge of power outages; adequate/ uninterrupted quality ***power supply,***
- ***Challenge of Energy efficiency***: Recognised as large consumers of energy in vertical mobility, HVAC and lighting.
- ***Challenge of Water Supply***: Perpetual demand for assured supply in adequate quantity and quality at appropriate pressure to all the occupants, irrespective of their location,.
- ***Challenge of safety***: Using large number of electric appliances and inflammable materials, invariably create opportunities for fire hazards, posing greatest challenge of making buildings and human lives/ property, safe against fire related disasters. In addition, safety against human driven crimes in congested buildings also pose great challenge.
- ***Challenge of HVAC***: With large height , direct solar radiation, and high wind pressure, upper storeys of high rise buildings invariably face the challenge of appropriate heating, ventilation and mechanical cooling.
- ***Challenge of Vertical Mobility***: Catering effectively and efficiently to ensure hassle free vertical mobility of residents/users, for reaching destinations located at upper floors,
- ***Challenge of Indoor air quality*** : Providing appropriate quality of indoor air in buildings having sealed glass façade, has remained critical challenge in high rise buildings
- ***Challenge of Managing Waste***: Safe/ effectively collecting and managing disposal of large quantum of waste, generated in high rise buildings,
- ***Challenge of Maintenance***: Continued maintaining/upkeep of outer surfaces/ services invariably pose challenge in terms of; manpower, cost and system; in high rise buildings.
- **Service core design:** Integrating shafts for elevators, ducts, and utilities, without reducing usable floor space.

OPTIONS FOR PLANNING SERVICES IN HIGH RISE BUILDINGS

Considering the complexity, enormity and high cost, providing services *in high-rise buildings*, must be made cost-effective, operationally efficient, and easy-to-maintain .Best option to achieve the objective shall be ;

1. **Opting for Innovative Design Strategies :** by making services integral part of building's planning and designing & construction process, by optimising orientation, using natural resources, designing with nature and promoting natural ventilation for reducing reliance on mechanical systems. Innovative building design has been globally recognised/valued for role , relevance and importance, in providing services rationally and economically, in high rise buildings.
2. **Leveraging Integrated Approach:** Integrating services, in high-rise buildings by making them work together seamlessly, rather than treating them as an isolated system, remains the valuable and critical. Best approach would be, adopting a holistic, coordinated framework ,where structural, mechanical, electrical, and safety services are planned and designed, jointly and in harmony, as one unified system.
3. **Looking at Life Cycle Cost:** Marginalising limitation of initial cost, building services must be planned, designed and constructed on the basis of making high rise buildings, sustainable, cost-effective, durable and operationally efficient, over entire life cycle of building.
4. **Using principle of Clubbing and Sharing:** of services at individual floor level and cumulatively for entire building, have been valued as the best option for achieving economy, promoting operationally efficiency, ensuring easy planning, designing , operation and maintenanace of services.
5. **Opting for Centralized Service Core:** Creating centralized service core has been valued for its role, relevance and importance, in rationally planning/providing of services. Known as heart and soul of planning and providing vertical circulation along with other building services, centralized service core has to be planned,

positioned, designed and constructed carefully. Its location remains critical and fundamental to both planning, design, operation & combining services related to mobility , utilities, elevators, staircases; ducts, toilets etc. Service core also helps in reducing duplication and in economizing built space. In addition to service core, ducts are also needed to run horizontally/vertically for laying of services. While ducts act as the arteries, but along with service core, they jointly form the building's internal infrastructure, for providing services related to air, water, electricity, and communication.

6. **Opting for Mechanical Zoning:** Opting for mechanical zoning helps in efficient distribution of HVAC, water, and electrical systems, through intermediate mechanical floors, lowering vertical distribution costs.

7. **Using BIM Based Solutions:** invariably help in minimsing conflict and ensuring smooth integration of plumbing, electrical, and HVAC systems.

8. **Ensuring Daylight Harvesting:** have been recognised for making buildings sustainable, qualitative, energy efficient and cost- effective by minimsing use of artificial lighting and reducing rising energy cost.

9. **Optimising Water:** Creating options for multiple use of water, inducting water recycling, greywater reuse and rainwater harvesting into plumbing systems invariably help in, not only minimizing pumping, but also reducing use of energy and supply expenses involved in supplying fresh water.

10. **Leveraging Technology:** Considering valuable role and importance, inducting state of art technology in planning, designing and operating services in high rise buildings can help in making provision/ delivery of services, operationally more efficient and cost-effective by reducing/optimising manpower involved in providing/maintaining such services.

11. **Integrating Renewable Energy:** Solar panels and building-integrated photovoltaics cells can help in reducing dependency on grid electricity, reducing cost of electricity and ensuring uninterrupted supply of quality power.

12. **Making Services Intelligent:** Using IOT and sensors for monitoring elevators, pumps, and HVAC systems can help achieve operational efficiency, reduced maintenanace and avoid sudden disruption in service delivery.

13. **Opting for Centralized Waste Management:** For overcoming the challenges of waste and converting waste into wealth, providing system for automated garbage chutes and recycling systems connected to centralized recycling and composting facilities, can ensure effective and efficient waste management, with reduced manpower and reduced pollution.

14. **Opting for Distinct Heating Cooling:** Despite high initial investment, district heating and cooling is a futureready solution for high rise buildings. Based on the principle of combining efficiency, sustainability, and resilience, District heating and cooling (DHC) systems provide centralized energy for multiple buildings, offering major advantages in efficiency, cost savings, and sustainability. In India, where urban cooling demand is rising rapidly, DHC can cut electricity use by 30–50% and reduce greenhouse gas emissions by up to 40%, as showcased in gift city, Ahmedabad.

15. **Creating a Central Command Centre:** Considering complexity/variety of services provided, increasing demand for safety and security ; reducing use of resources; promoting occupants comfort and ensuring operational efficiency in services, calls for creating a **Central command system** ; in a highrise building . Acting as the **brain,** Command Centre integrate all mechanical, electrical, plumbing, fire safety, security services, along with IT, into one coordinated platform. Central command holds the enormous capacity and capability to transform a highrise structure into a smart, safe, and sustainable building, ensuring smooth operations and resilience against any possible disaster.

16. **Planning for Green Buildings:** Planning high rise buildings on the analogy of green buildings, will invariably help in rationalizing and optimisation/ economising provision of services in such buildings, for the reason that green buildings are known to reduce consumption of water(40%), economising energy(up to 50%), reducing consumption of resources(up to 30%), generating less waste(up to 70%), adopting principle of circular economy and ensuring best of indoor air

quality, to create win-win situation for users and owners of the high rise buildings.

CONCLUSION

Looking at the above narrative, high rise buildings are known for juxtaposing both positivity negativities. If these buildings are creating large built space, promoting optimum utilization of land, making cities compact, housing large population in limited land parcel, promoting economy in services, reducing mobility, helping overcome challenges of governance and rationalizing problem of traffic and transportation; then these building are also credited with creating large number of issues and offering numerous challenges; in terms of adversely impacting environment; promoting urban heat islands; consuming large resources, energy, water besides generating large volume of waste; creating large demand for services related to water and power. It needs to be understood and appreciated that Services, in high-rise buildings, play a critical role in ensuring safety, comfort, and sustainability. Integrating mechanical, electrical, plumbing (MEP), fire protection, and automation systems, invariably empower tall structures, to become functional, resilient, and livable. Without these services, high-rises cannot operate efficiently and efficiently. Accordingly, it will be appropriate that services in high rise buildings should be planned, designed, constructed and operated in such a manner that, these buildings overcome all prevailing negativities/ challenges and create options for leveraging available positivity, so as to make high-rise buildings great places to live and work.

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BUILDING SERVICES FOR GREEN BUILDINGS

Usha Batra*

Abstract

March 2026 was the fourth- warmest month globally according to the Copernicus Climate Change Service, with highest land and ocean temperatures, reflecting EI nino conditions later this year. It also recorded lowest sea ice extent indicating faster warming of polar regions than global average.

These conditions bring greater focus on sustainable and eco friendly buildings as buildings and construction sector is a major contributor to global climate change, responsible for approximately 37% to 40% of total global energy-related greenhouse gas (GHG) emissions.

Significance of green building services is that they reduce the environmental impact along with operational cost through various components like energy efficiency in lighting and HVAC, water conservation through better plumbing, reuse mechanisms and rainwater harvesting, better Indoor air quality by eliminating use of harmful chemicals, ensuring proper ventilation system, air purifiers and non toxic materials to provide safe and healthy environment using sustainable materials avoiding use of harmful substances, use of recycled materials, reducing embodied energy, ensuring structure and safety standards ensuring proper life of building along with safety during life span.

Advantages of green building services are that they reduce environmental impact and life cycle cost. These buildings have better market value and provide healthier living standards.

INTRODUCTION

Climate change impacts are already being observed after the first decades of the 21st century, with 2024 being the warmest on record at +1.60 °C since 1850. However additional warming will increase these impacts and can trigger melting of Greenland ice sheet so the nations collectively agreed to keep global warming well under 2 °C under the 2015 Paris agreement. The IPCC sixth assessment report (2021) included projections that by 2100 global warming is very likely to reach 1.0–1.8 °C under a scenario with very low emissions, 2.1–3.5 °C under intermediate emissions, and, 3.3–5.7 °C under very high emissions of greenhouse gases. Therefore, emission of green house gases is required to be controlled.

Around 30% of Earth's land area is largely unusable for humans because of glaciers and deserts etc., 26% is forests, 10% is shrub land and 34% is agriculture land. Deforestation due to population growth, infrastructure development and unauthorized felling of trees, leads to land use change as the re-forestation is hardly done. Thus land use change is the main contributor to global warming, as the destroyed trees release CO_2, and are never replaced by new trees, removing that carbon sink. Another main factor affecting climate change is air pollution in the form of aerosols.

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Climate change does not lead only to extreme weather conditions like intense storms, droughts, severe heat waves, coastal erosion, and increased flooding threatening to coastal cities and island nations but also leads to food & water scarcity along with threatening to human health hence impacts the survival itself and needs to be mitigated.

Climate change can be mitigated by stopping the emission of greenhouse gases which is not possible hence reducing the rate of emission of greenhouse gases is the only option. It is therefore decided globally to limit global warming to less than 2°C for which global greenhouse gas emissions needs to be net zero by 2070. This would be possible through systemic changes on an unprecedented scale in energy, land, transport, buildings, and industry. Generation of conventional energy today is directly related to carbon emissions hence energy generation from non-conventional sources and reducing energy demand are utmost important. Strategies to reduce energy demand vary by sector for which focus is needed on higher levels of energy efficiency in retrofitting and design and construction of sustainable and eco-friendly new buildings.

CORRELATION BETWEEN GREEN BUILDING AND CLIMATE CHANGE

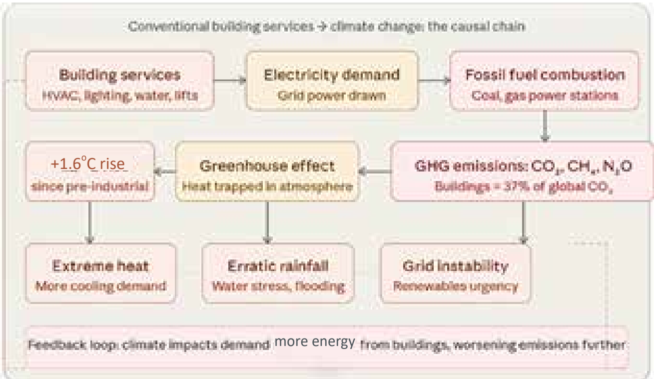

Fig. 1

Fig. 1 : shows the vicious cycle. Buildings consume energy → that energy mostly comes from fossil fuels → combustion emits CO_2 → the atmosphere warms → extreme heat forces buildings to consume even more energy.

Buildings globally account for around 37-40% of energy-related CO_2 emissions making them the single largest sectoral contributor to climate change.

A 2 °C rise in ambient temperatures is projected to increase cooling energy demand in Indian cities by 50–80% by 2050. Buildings designed only for today's climate will become increasingly expensive and carbon-intensive to operate.

Therefore reducing demand by high-performance envelope, efficient systems, and smart controls, decarbonizing supply by on-site solar, heat pumps, low-GWP refrigerants, and renewable energy procurement, and improving resilience through thermal storage, rainwater harvesting, and passive design can change the scenario and buildings function well even as the climate around it changes.

GREEN/ SUSTAINABLE V/S CONVENTIONAL BUILDINGS

Sustainability (Fig 2) is a process in which the design, planning and construction are done to minimize the total environmental impact throughout their lifecycle i.e. from planning / design to construction, operation, and even demolition while enhancing user comfort and productivity. These buildings aim to efficiently use energy, water, and materials while promoting a healthier living and working environment.

Fig. 2

Green and conventional buildings both serve the same fundamental purpose of providing shelter and functional spaces but conventional buildings are cost and functionality-driven, use natural materials e.g. clay bricks, concrete, steel, higher energy based standard systems, high VOC materials and standard insulation, involve high deforestation, produce waste, and pollution whereas green buildings use sustainability-focused, passive design, recycled, renewable materials, 25-30% less energy, minimal environment impact by eco preserving practices, low VOC materials and natural / recycled insulation

Important features of a green building are:

- **Smart Design and Layout:** By maximizing natural light and airflow, reducing dependence on artificial lighting and ventilation.
- **Energy Efficiency: They are** designed to use less energy through efficient lighting, HVAC systems, insulation, and additionally make use of renewable energy sources like solar or wind power.
- **Water Conservation: By** incorporating low-flow fixtures, rainwater harvesting systems, and waste water recycling to reduce overall water usage.
- **Sustainable Building Materials: They** use recycled, renewable, or locally sourced materials with a lower embodied energy and environmental impact, simultaneously saving resources.

- **Improved Indoor Air Quality: By using** Non-toxic paints, adhesives, and ventilation systems ensuring healthier indoor environments.
- **Efficient Waste Management: They** encourage waste reduction during construction and promote recycling and reuse of materials thereby saving environment.
- **Environmental Certification Compliance: They** meets criteria set by recognized green building rating systems like LEED (Leadership in Energy and Environmental Design), GRIHA, and continue to maintain the certification requirement.
- **Reduced Carbon Footprint: They** emphasize practices and technologies that significantly cut greenhouse gas emissions throughout the building's lifetime.

In brief green buildings influence everything from selection of materials and site planning to energy systems and waste management practices for resource optimization and reduced carbon footprint.

BUILDING SERVICES FOR HIGH-RISE BUILDINGS

A tall building is required to move people, air, water, power, and data across dozens of floors while managing the unique challenges of height - pressure, structural loading on risers, wind, fire evacuation, and the immense scale of plant required. There are nine major service systems:

There are nine major service systems:-

1. HVAC — Heating, Ventilation and Air Conditioning System:-Responsible for 40–50% of total electrical load.
2. Electrical Services including backup power System
3. Water Services System
4. Drainage System
5. Vertical Transport System
6. Building Management System
7. Fire Protection System
8. Gas Services
9. ICT and Communications includes: - Structured cabling, Wireless**:** Wi-Fi, Security systems: and PAVA (Public Address and Voice Alarm)

Services on serial nos 1-6 in green high-rises differ significantly from conventional buildings in design philosophy, equipment selection, and integration. Services on serial nos 7-8 are entirely safety in nature and must follow the provisions of various codes. Serial no 9 is a functional one but must follow the provisions of various codes.

Fire Protection System:-India reports approximately 7500 major building fires accidents annually i.e. 20-25 fires per day, resulting in more than 13000-15000 fatalities. Building fires often turn fatal due to systemic non-compliance with fire safety norms, leading to rapid spread of smoke, jammed exits, and delayed evacuations.

Flouted norms include- Emergency staircases are frequently used for storage, many Institutions / establishments operate without mandatory fire safety clearances or building bylaws compliance, premises often lack functional smoke detectors, fire alarms, sprinklers, and adequate fire extinguishers , Electrical overloading , use of inexpensive highly flammable materials (e.g., plywood or MDF for false ceilings) rapidly accelerates vertical fire spread. Hence we need to ensure that no norms are flouted.

Structural safety: - is not considered as service but recently several newly constructed buildings were declared unfit to live in, and the court has ordered them to be demolished and rebuilt. As per HT dtd 19.06.2026 The Centre is examining to make durability certification mandatory for buildings, citing recent court orders directing the demolition and reconstruction of structures declared unfit to live in as evidence of a quality crisis in construction. This is of great concern for environmental pollution, wastage of resources and finances, reducing building life from 60-100 years to 0-5 years, besides huge physical and mental discomfort to the buyers. Several roads and bridges have also collapsed during and immediately after construction.

Building envelope:-Green high-rises treat the building envelope as part of the services strategy because a well designed envelope itself can reduce the consumption of energy to an extent of 25% or more and is the permanent source of reduction. Building envelope i.e. façade and roof determine the entire baseline load that services must meet, and embodied carbon in construction materials is a significant one-time emission that no amount of operational efficiency can undo once the building is built.

The following services in green buildings differ from conventional buildings:

1. HVAC Systems

HVAC is where green buildings diverge most dramatically. Conventional buildings typically use centralized, oversized systems (chillers, boilers, VAV boxes) designed for peak loads with limited zone control whereas Green buildings employ:

- Variable refrigerant flow (VRF) systems for precise zone control
- Chilled beam or radiant cooling/heating systems and dedicated outdoor air systems (DOAS) with energy recovery ventilators, making it more energy efficient.
- Demand-controlled ventilation using CO_2 sensors
- Ground-source or air-source heat pumps.
- Thermal storage (ice or chilled water) to shift peak loads

2. Electrical Systems

Conventional approaches focus on meeting code minimums with standard transformers and distribution. Green buildings incorporate:

- Building-integrated photovoltaic (BIPV) on facades and rooftops
- Smart grid integration and on-site battery storage.
- High-efficiency LED lighting with daylight harvesting and occupancy sensors , Power factor correction and harmonic filtering
- Sub-metering at floor or tenant level for accountability and EV charging infrastructure in parking areas

3 & 4 Water and Drainage

Conventional systems use potable water throughout with standard fixtures.

Green buildings focus on water conservation, storm water management and micro-climate control. They manage surface water locally to avoid overloading municipal sewers.

- They use Rainwater harvesting to supplement municipal fresh water demand and grey water recycling for toilet flushing, irrigation and cooling tower make up tank and black water treatment on-site in some cases.
- Low-flow fixtures (faucets, showerheads, dual-flush toilets)
- Condensate recovery system from HVAC for cooling tower makeup.
- Leak detection and smart water metering.
- Solar thermal system to reduce gas demand for hot water.

5. Vertical Transport

Conventional vertical transport consumes higher levels of grid power; wastes energy as heat especially during braking, uses traditional "up/down" call buttons resulting in frequent stops and longer waits.

Green high-rises use

- Regenerative drives that return braking energy back to the electrical bus.
- Energy-efficient LED lighting and occupancy sensors.
- Destination Control Systems (DCS) and AI-driven algorithms group passengers by floor, reducing wait times and improving passenger flow.
- Double-deck lifts and sky lobbies are used in super tall towers (50+ floors) where conventional single-deck lifts would consume too many shaft spaces.

6. BMS Building Management System

Conventional BMS focuses on scheduling and basic alarms whereas Green buildings require a more sophisticated BMS that:

- Integrates HVAC, lighting, shading, and renewables into a single platform.
- Uses predictive algorithms and occupancy data to optimize energy use.
- Provides real-time dashboards for facility managers and supports continuous commissioning and fault detection.

7. Certification and Commissioning

Green buildings pursue certifications like LEED, IGBC which impose requirements on:

- Enhanced commissioning of all MEP systems, Metering and verification (M&V) protocols, Indoor air quality testing and ongoing monitoring

- Life-cycle cost analysis during design

8. Cost and Complexity Trade-offs

Conventional buildings have lower upfront cost, higher operational cost, need regular staff for maintenance and is dependent on grid for power supply whereas in green building upfront cost is 5-15 % higher but operational cost is 20-40% lower, requires trained staff and sensors for maintenance and has on-site generation and storage for power supply.

Though upfront cost of green building services is typically 5–15% higher, but lifecycle cost analysis (over 25–30 years) consistently shows it to be cheaper due to energy, water, and maintenance savings.

HOLISTIC PRINCIPLES WORTH HIGHLIGHTING FOR GREEN SERVICES

The nine services systems are deeply interdependent. The fire alarm controls HVAC smoke dampers, lift recall, and pressurization fan start-up. The BMS monitors the electrical, HVAC, water, and lift systems simultaneously. The water treatment plant feeds back treated water to the cooling towers. The CHP gas engine feeds both the electrical board and the hot water calorifiers. Designing each system in isolation consistently produces buildings that underperform against their design intent.

The systems are deeply interdependent. PV on the roof reduces grid dependency; BESS stores that solar output, VFDs on pumps reduce the electrical load that both PV and BESS need to serve. Better glazing reduces solar gain; reduced solar gain reduces chiller load; reduced chiller load lets you specify a smaller, cheaper chiller. The whole is far more than the sum of the parts. BMS ensures that everything else actually performs as intended. Every rupee spent on BMS and commissioning returns in a very big way through energy savings. Commissioning is not a one-time event. All the equipment above delivers its theoretical savings only if it is properly set up, verified, and re-verified over time.

CASE STUDIES

Case Study 1 — Indira Paryavaran Bhawan, New Delhi (Fig. 3)

India's first net-zero energy building, headquarters of the Ministry of Environment, Forest and Climate Change. Completed 2013, designed by CPWD.

- Energy conservation measures include architectural design with good ventilation, and courtyard, orientation, envelope insulation, trees and plantation, energy-efficient chilled beam system for AC, regenerative lifts, geothermal heat exchange system to reduce load on HVAC, and thin client computing system
- Annual energy consumption of 14.21 lakh kWh met with equivalent annual energy generation of 14.3 lakh kWh from Solar BIPV installed on-site on a tight urban site.
- 40% savings in energy; zero electricity billing; 55% savings in water; zero net discharge; largest rooftop solar power system in any multi-storeyed building at 930 kWp;
- Both GRIHA 5-Star rating and LEED Platinum certification achieved, making it one of the greenest buildings in India - a government office demonstrating the importance of sustainability

Fig. 3: Indira Paryavaran Bhawan, Delhi

Case Study 2 — Shanghai Tower, China (Fig. 4)

The world's third tallest building (632 m, 128 floors), and the largest LEED Platinum certified building from 2016 to 2025. Designed by Gensler.

- Energy consumption reduced by 21% and lifecycle energy costs by 45% — achieved through a cooling-focused atrium buffer zone, heat recovery systems, variable air volume air conditioning, demand-control ventilation, a geothermal system, wind turbines, an ice

Fig. 4: Shanghai Tower, China

storage system, a grey water system, and a combined heat and power system

- The design of the tower's glass façade completes a 120° twist as it rises, which reduces construction materials needed and wind loads on the building by %24. The double-glass façade reduces the building›s carbon footprint by 34,000 tonnes per year
- Smart control systems monitor electric consumption and generate savings of $556,000 each year in energy costs. Near the top of the building, 270 wind turbines provide the energy required to illuminate the exterior. A 2,130 kW natural gas-fired cogeneration system generates electricity and heating in the lower areas.
- A wind-turbine system generates 11,90,000 kWh of electricity every year; 25% grey water recycling used to flush toilets; energy-saving rate of 54% over the Chinese efficiency standard

Both the case studies confirm that combination of passive design (orientation, envelope, natural ventilation), efficient active systems (chilled beams, VRF, geothermal), on-site renewable generation (solar PV, wind), and intelligent controls (BMS, regenerative lifts) consistently delivers 40–70% energy reductions against conventional baselines, with reduced carbon footprint, water and cost savings that validate the investment within 3–10 years.

CONCLUSION

- Buildings globally account for around 37-40% of energy-related CO_2 emissions making them the single largest sector contributor to climate change.
- A 2°C rise in ambient temperatures is projected to increase cooling energy demand in Indian cities by 50–80% by 2050.
- Building envelope i.e. facade and roof can reduce the consumption of energy to an extent of 25% or more and is the permanent source of reduction and embodied carbon in construction materials is a significant one-time emission that no amount of operational efficiency can undo once the building is built.
- Services in green high-rises differ significantly from conventional buildings in design philosophy, equipment selection, and integration.
- Every rupee spent on BMS and commissioning returns in a very big way through energy savings.
- Green services consistently deliver 40–70% energy reductions against conventional baselines with reduced carbon footprint, water and cost savings that validate the investment within 3–10 years.

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INTEGRATED BUILDING SERVICES FOR HIGH-RISE BUILDINGS CHALLENGES, INNOVATIONS AND INDIGENOUS SOLUTIONS UNDER INDIAN CONDITIONS

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Abstract

High-rise buildings are rapidly reshaping India's urban skyline, driven by fast urbanisation, limited land and the Smart Cities Mission. As buildings grow taller and more complex, Mechanical, Electrical and Plumbing (MEP) services demand integrated, climate-responsive design. This paper presents a concise, practice-oriented review of building services in Indian high-rise structures under four linked themes: green-building requirements, innovative MEP, fire and life safety, and automation of maintenance. Special emphasis is placed on indigenous, low-cost and high Benefit-Cost Ratio (BCR) solutions suited to Indian climate zones, workforce realities and regulations. The discussion draws on NBC 2016, ECBC 2017 and draft NBC 2025 codes, rating systems (GRIHA, IGBC, GEM) and a documented case study: Infosys SDB-1, Pocharam, Hyderabad that demonstrates an achieved lifecycle BCR of approximately 4.2:1 at an incremental capital cost of 5–7 percent.

INTRODUCTION

India is in the middle of an unprecedented urban construction boom. Over 35 percent of the population is expected to live in cities by 2026, and land values in metropolitan areas make vertical growth the only economical option. The National Building Code defines a high-rise as a structure taller than 15 m, though in practice the term is used for buildings above 50 m [1]. The construction sector accounts for roughly 17 percent of national greenhouse-gas emissions and 33 percent of electricity consumption, so the design of building services is an economic as well as an ecological priority.

MEP services account for 25–45 percent of the capital cost and up to 70 percent of the life-cycle operating cost of a high-rise [11], [14]. In Indian practice they are still often inserted into frozen architectural layouts, causing costly retrofitting, inefficiency and at times compromised safety. This paper therefore argues for a shift from reactive MEP integration to proactive, integrated service design calibrated to India's climate zones, resource realities and evolving regulations, and concludes with a documented BCR case study.

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THE INDIAN CONTEXT

Before examining specific service strategies, it is useful to position them against distinctly Indian conditions. India spans five climatic zones: hot-dry, warm-humid, composite, temperate and cold, so a uniform MEP approach imported from temperate Western practice is unsuitable. Passive-first strategies such as shading, natural ventilation, evaporative cooling and night-flush ventilation can cut HVAC energy by 20–40 percent before any active system is optimised. Water stress, a variable grid and a shortage of skilled MEP trade labour further push design toward modular, factory-built and easily maintained systems.

The regulatory framework has matured. NBC 2016 sets the baseline across fire, electrical, plumbing and HVAC services [1]. ECBC 2017, administered by the Bureau of Energy Efficiency, sets performance standards for air-conditioned commercial buildings [2]. GRIHA (national), IGBC (32 formats) and GEM together offer voluntary yet increasingly incentivised green pathways [3], [4], [9], [17]. Several states offer FAR bonuses and property-tax rebates for green-certified projects. The draft NBC 2025 proposes stricter fire mandates, including addressable detection in all buildings above 15 m and IoT-enabled alarm connectivity with municipal services [5]. The India IBMS market, valued at USD 8.57 billion in 2024, is projected to grow at over 24 percent CAGR to 2034 [6], [7]. With this context set, we now turn to the four service themes in sequence.

GREEN BUILDING SERVICES

Energy and water performance form the foundation on which all other services rest. India's green-building framework is layered: GRIHA, adopted as the national system by MNRE in 2007, evaluates buildings against 34 criteria covering site, resource, well-being and innovation; IGBC offers 32 rating formats; GEM, launched by ASSOCHAM in 2017, addresses the full life cycle [3], [4], [9], [17]. The highest-BCR interventions for Indian high-rises are summarised below:

- Indigenous solar shading (jaali screens, perforated terracotta panels, projection overhangs) re-engineered with modern materials: up to 50 percent solar heat-gain reduction.
- Indian-made VRF / VRV HVAC (Blue Star, Voltas, Daikin India): 25–40 percent energy saving over constant-volume systems.
- LED lighting with DALI daylight harvesting (Havells, Wipro, Crompton): 60–70 percent lighting-energy reduction.
- Rooftop solar PV with net metering under PM Surya Ghar Muft Bijli Yojana: 15–30 percent offset of base electrical load.
- Dual-pipe plumbing, MBR-based STPs (Pureflow, Thermax, Suez India) and rainwater harvesting: 30–40 percent reduction in potable water use; 25–35 percent more savings from WELS-rated low-flow fixtures (Jaquar, Parryware, Hindware).
- Low-GWP refrigerants (R-32, R-410A under India's HCFC Phase-Out Plan) and fly-ash service shafts: 15–25 percent lower embodied MEP carbon.

INNOVATIVE MEP SERVICES

With the green baseline in place, MEP innovations address the vertical complexity of high-rises stack effect, variable solar gain across orientation, wind-induced infiltration and long distribution runs [11], [14].

- HVAC. Zoned chilled-water circuits with intermediate plate heat exchangers for buildings above 60 m (to manage static pressure); Underfloor Air Distribution (UFAD) saving 20–30 percent over overhead systems; Phase Change Material (PCM) thermal storage shifting peak load under time-of-day tariffs; hybrid natural-plus-mechanical ventilation for transition seasons (annual HVAC energy ↓ 15–20 percent).
- Plumbing. Hydro-pneumatic pressure zones every 10–12 floors replace intermediate gravity tanks, freeing floor area and cutting contamination risk; vacuum drainage reduces pipe diameter by up to 40 percent and is ideal for retrofit; DRDO-derived biodigester grease interceptors (BCR > 3:1) treat F&B waste and generate biogas.
- Electrical. 11 kV distribution to mini-substations every 15–20 floors reduces cable mass, space and losses; AMI-compatible smart meters (IS 15959, IS 16444) from HPL, Secure and L&T curb non-technical loss; regenerative destination-dispatch elevators (Otis, Schindler, KONE India) recover 20–35 percent of braking energy; rooftop and BIPV facade PV from Waaree, Adani Solar and Vikram Solar offset common-area loads.

Modular prefabricated MEP—factory-assembled pipe, duct and electrical modules delivered to site as units cuts on-site installation time by 40–60 percent and reports BCRs of 1.8–2.5:1 over conventional installation [12], [13]. BIM-based clash detection, mandated under the MoHUA BIM Policy for public projects over INR 100 crore, consistently saves 10–15 percent of MEP installation cost by resolving conflicts in the design office rather than on site [8], [12]. With these innovations in view, we now turn to the life-safety systems that must be tightly coordinated with them.

FIRE AND LIFE-SAFETY SERVICES

Life safety is the most critical service layer because a failure here cannot be compensated by any downstream efficiency gain. Delhi alone reported a 10 percent rise in fire incidents in 2025, disproportionately in residential high-rises [10]. Well-designed protection systems reduce both the probability and consequences of fires by orders of magnitude, and the BCR of comprehensive fire-safety investment, measured against asset protection, liability and insurance-premium savings consistently exceeds 5:1 over the building life cycle.

Part 4 of NBC 2016 provides the baseline: automatic sprinklers mandatory above 15 m, staircase pressurisation (25–30 Pa) and lift-shaft pressurisation (50 Pa), 2-hour fire compartments up to 750 m² (+50 percent if sprinklered), wet risers at ≥ 3.5 kg/cm² at the remotest point, refuge areas above 60 m, and a staffed fire command centre [1]. The draft NBC 2025 goes further: mandatory addressable detection in all buildings above 15 m, IoT-linked alarms that auto-notify municipal fire services, mid-level buffer water tanks above 45 m, and a two-stage permitting process with periodic renewal certificates [5].

- Addressable analogue detection and multi-sensor units (optical smoke + thermal + CO) from Siemens India, Honeywell India and Bosch India reduce nuisance alarms and provide pre-alarm signals.
- Aspirating smoke detection (VESDA) for data centres, server rooms and heritage spaces; AI-powered video fire detection for atria, lobbies and car parks.
- High-pressure water mist (80–90 percent less water than sprinklers) and Compressed Air Foam Systems (CAFS) for mixed-occupancy towers; engineered passive fire protection from Promat, Hilti and Rockwool India.
- Voice Evacuation Systems with floor-specific messaging, phased evacuation strategies and photoluminescent wayfinding (zero-energy, zero-maintenance), all now available indigenously.

These life-safety services rely on continuous monitoring and rapid response, which leads naturally to the role of automation and control.

AUTOMATION AND CONTROL

A modern Building Management System (BMS) is the central nervous system that integrates HVAC, electrical, lighting, plumbing, fire, security and vertical transportation onto a single supervisory platform. Documented benefits for Indian high-rises include 30–50 percent reduction in HVAC energy, 20–40 percent reduction in operating cost and up to 11.8 percent property-value uplift per square foot [6], [15]. IoT-based wireless BMS further reduces deployment cost by up to 30 percent versus wired systems, and is especially suited to retrofit in occupied buildings [15], [16]. Indian providers such as Build Track (Aegis Graham Bell Award 2025 for IoT innovation; Mohali Smart Automation Experience Centre opened February 2025), 75F (demonstrating up to 50 percent HVAC saving through ML-based predictive control) and NETIX.AI offer world-class, indigenously developed or India-adapted solutions [16]. Digital Twin platforms, now offered by Honeywell, Johnson Controls and several Indian firms, enable real-time simulation, predictive failure analysis and portfolio-level command. Predictive maintenance, per EESL studies, cuts maintenance opex by 20–35 percent and extends equipment life by 20–30 percent. AI-powered facial-recognition access control (Staqu, Uncanny Vision, Techno Art India) integrated with the BMS enables intelligent responses such as automatic unlocking of fire doors on alarm. Robust cybersecurity, network segmentation between OT and IT, encrypted channels and role-based access control is essential as smart-building connectivity grows.

INTEGRATED SERVICE DESIGN AND BCR

The highest BCR outcomes come from integrated design across all four themes, not from optimising individual systems in isolation. The recommended protocol is: Stage 1 (pre-design) climate and passive-load analysis with MEP engaged beside the architect; Stage 2 (concept) residual-load based active sizing and BIM initiation; Stage 3 (developed) full BIM clash detection, ECBC-compliant energy modelling and GRIHA/IGBC registration; Stage 4 (construction) prefabrication and parallel BMS programming; Stage 5 (post-occupancy) IPMVP measurement and verification feeding predictive maintenance. Table 1 summarises indicative BCR for key innovations (25-yr life; benefits = energy, water, maintenance, asset-value and insurance savings; cost = incremental capital + opex premium).

Table 1: Indicative BCR for high-rise building-service innovations (25-year life cycle).

Service innovation	Primary benefit	Indicative BCR	Indigenous avail.
High-performance facade shading (jaali / terracotta)	HVAC load reduction 30–50%	3.5–5:1	High
VRF / VRV HVAC (Indian manufactured)	Energy saving 25–40%	2.5–4:1	High
Rooftop solar PV + net metering	Electricity offset 15–30%	3–5:1	Very High
LED + DALI daylight harvesting	Lighting energy saving 60–70%	4–6:1	High

Service innovation	Primary benefit	Indicative BCR	Indigenous avail.
Dual-pipe plumbing + MBR STP	Potable water reduction 30–40%	2–3:1	High
Modular prefabricated MEP	Labour saving 40–60%, shorter schedule	1.8–2.5:1	Growing
Addressable fire detection + IoT alarm	False-alarm reduction; life safety	5–8:1	High
Pressurisation + phased evacuation	Orderly evacuation; life safety	6–10:1	Moderate
IoT-based BMS (wireless retrofit)	Energy + maintenance saving 30–50%	3–5:1	Very High
Predictive maintenance platform	Opex saving 20–35%; life +25%	3–4:1	Mod–High
Regenerative elevators	Energy recovery 20–35%	2–3:1	High
Biodigester grease interceptors	Biogas + wastewater treatment	3–4:1	High

DOCUMENTED CASE STUDY: INFOSYS SDB-1, POCHARAM, HYDERABAD

To illustrate the actual BCR achievable under Indian conditions, consider the Infosys Software Development Block-1 (SDB-1) at the Pocharam campus, Hyderabad, one of India's most extensively monitored commercial buildings, developed as part of the Infosys "radical energy efficiency" programme. Although SDB-1 is a multi-storey office block rather than a slender residential tower, its service-integration lessons translate directly to high-rise practice. The project is benchmarked against a business-as-usual (BAU) Infosys building of comparable vintage and floor area [3], [4]. Key outcomes are summarised in Table 2.

Table 2: Infosys SDB-1, Pocharam — documented performance and achieved BCR (values compiled from published Infosys, GRIHA and IGBC case-study disclosures).

Parameter	Documented outcome
Built-up area	Approximately 2.5 lakh sq.ft., fully air-conditioned
Climate zone	Composite (Hyderabad)
Certifications	LEED Platinum (USGBC) and GRIHA 5-star equivalent performance
Renewable energy installed on site	44 KWp
EPI	51.85 kWh/m^2/year
Energy reduction	56 percent
Water reduction	56 percent (dual-pipe + STP reuse + low-flow fixtures)
Capital-cost premium	~ 5–7 percent over BAU
Simple payback period	~ 5–6 years
25-year NPV (indicative)	Lifetime savings ≈ 3.5–4.5× incremental capital
Achieved BCR (25-yr life)	~ 4.2 : 1

The key service-design decisions that drove this result, and that translate directly to high-rise practice, were:

- Radiant slab cooling with dedicated outdoor air systems (DOAS) in place of conventional overhead VAV, cutting fan power by more than 60 percent.
- High-performance glazing with orientation-tuned external shading, reducing solar heat gain by about 40 percent.
- Variable-speed chillers with integrated thermal storage, shifting peak electrical load off the grid.
- Dual-pipe plumbing with on-site MBR STP supplying flush, HVAC make-up and landscape irrigation water.
- LED lighting with daylight and occupancy sensing on a DALI network, holding lighting power density to 4–5 W/m^2.

- A full-coverage BMS with real-time sub-metering feeding an IPMVP Option D measurement-and-verification protocol.

The pattern is consistent: an incremental capital investment of 5 to 7 percent, strategically allocated to the highest-leverage service interventions, delivers lifetime BCRs in the range of 3.5:1 to 4.5:1 under Indian climatic and tariff conditions [11], [14]. Scaled to a 30– to 50-storey tower, where MEP services form a larger share of capex, the absolute value of these savings grows substantially.

RECOMMENDATIONS

Building on the analysis above and the documented case-study evidence, the following recommendations are offered for practitioners, developers, policymakers and the Indian Buildings Congress:

1. Mandate integrated MEP design from the pre-design stage in all high-rise projects, ending the practice of post-architectural MEP insertion.
2. Make GRIHA or IGBC certification a prerequisite for building-permit approval in all Smart City and urban-agglomeration projects.
3. Adopt draft NBC 2025 fire-safety provisions particularly addressable detection and IoT-linked alarms as voluntary enhanced standards now, ahead of mandatory enactment.
4. Publish national BIM standards for high-rise MEP coordination under the MoHUA BIM Policy, enabling standardised digital deliverables.
5. Support domestic manufacturing of smart-building technologies through targeted PLI-scheme incentives for BMS, IoT sensors and MEP equipment.
6. Require post-occupancy measurement and verification (M&V) as a condition of occupancy-certificate issuance, building a national performance database.
7. Incorporate cybersecurity standards for building OT systems into the next NBC revision.
8. Revise ITI and polytechnic curricula to develop trade skills in modular MEP prefabrication, BIM coordination and smart-building maintenance.

CONCLUSION

High-rise buildings are self-contained vertical cities with complex, interdependent service ecosystems. In India, the challenge of designing, constructing and operating these services is compounded by climate diversity, resource constraints, skills gaps and an evolving regulatory environment, yet those very constraints are also the crucible of innovation. The centuries-old jaali is a sophisticated solar-control device; the DRDO biodigester is urban waste infrastructure; GRIHA is a more relevant benchmark than any imported framework. With indigenous MEP, smart-building automation, solar PV and AI-powered fire detection all now maturing domestically, India is positioned to produce high-rise service solutions that are not merely adapted from international practice but genuinely world-leading. The Indian Buildings Congress can lead this transition through codification, knowledge dissemination and policy advocacy. The time for incremental improvement is over; the time for transformative, integrated service design is now.

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BUILDING SERVICES IN HIGH RISE BUILDINGS DURING WAR EMERGENCY AND POST-WAR SITUATION: LEARNING EXPERIENCE

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Abstract

High-rise buildings are resilient against many natural and man-made disasters through adopting advanced technologies, innovative structural systems, engineering materials, etc. but the same is always vulnerable due to vertical structure, high density, interconnected building services, etc. Therefore, critical building services must be accurately planned, designed, operated and maintained under normal conditions to ensure their effective functioning during emergency situation. The learning experiences of both case studies of "UK's Post-war Rebuilding Programs" and "Israel's integration of Protected Spaces (i.e. Mamad, Mamak, Mamam and Miklat) in Residential and Public Buildings" into reconstruction efforts, demonstrate the vital role of building services in enhancing the safety, resilience and functionality of the built environment, as well as protecting building occupants. Advanced building services reflect the economic prosperity and technological advance, but during war emergency, their resilience becomes important, as they support critical functions, enhance occupant survivability and maintain the operational functions of high-rise buildings.

INTRODUCTION

Building services are mounted in buildings for efficient operation of built environment. If such services are placed in position particularly in high-rise buildings (height exceeding 24 mt. as per NBCS 2026), they need integration with building design. Building services related to mechanical, electrical, plumbing, communication, safety, etc. occupy a significant physical space and therefore, architectural design is prepared for service shafts, mechanical floors, lift cores, refuge floors, utility corridors, etc. with accessibility, functionality and safety. Further, both architectural design and structural design integrate building services for efficient space utilization, ease of maintenance, fire compartment, energy efficiency, disaster resilience, etc.

In high-rise buildings, building services are operated and managed by an Intelligent Building Management System (IBMS). IBMS is a centralized digital platform that monitors and controls various building services in real time. In other words, architectural design, structural engineering and building services need to be integrated through an IBMS. During war emergency, these services in high-rise buildings shifted to emergency mode of operation with priorities of fire safety, structural integrity, occupant survival, emergency escape, etc.

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BUILDING SERVICES DURING WAR EMERGENCY

As per local emergency management/civil defense regulations of the United States of America, the definition of war emergency is as follows:

"War emergency means and includes any disaster occurring anywhere within the township as the result of enemy attack or the imminent danger thereof."

In context of disaster management and civil defense principles, the definition of war emergency is as follows:

"War emergency may arise due to aerial bombardment, drone/missile attacks, military operations, terrorist attacks on critical infrastructure, etc."

In other words:

"War emergency as a state of affairs arising from confrontation, external aggression, etc. may cause or likely to cause loss of life, damage to infrastructure, interruption of essential services, etc. which require emergency response and civil defense measures (i.e. non-combat actions to protect civilians, property and essential infrastructure from hostile attacks)."

In context of high-rise buildings, war emergency may involve disruption of building services due to structural damage of water tanks, electric stations, leakages of gas pipelines, obstruction of entry/ exit points, fire outbreaks, failure of power & communication systems, etc. As soon as, emergency is detected through:

-Blast or vibration sensors,

-Fire detectors (smoke, heat, flame),

-Gas leak detectors,

-Structural health monitoring sensors,

-Security systems & CCTV analytics,

-Manual emergency activation, etc.

then IBMS automatically activates a 'Pre-defined Emergency Mode Sequence'. Table 1 describes the various provisions of building services during both normal operation and emergency operation.

Table 1: Operation of Building Services in Normal Situation and War Emergency

S.N.	Building Services	Normal Operation	Emergency Operation
i.	Fire Safety	Fire Suppression is done by sprinklers, hydrants, hose reels, extinguishers, etc.	During war emergency, fire risks increase significantly due to explosions, missile attacks, fuel fires, etc. Fire suppression system with protected water storage and backup pumping arrangements is needed. Apart from Fire detectors, blast sensors, gas leak sensors and emergency monitoring system are also required. Firefighting water system with firewater tanks, hydrant systems, automatic sprinkler systems, fire pumps & jockey pumps must be in place and these must remain operational even during power failures.
ii.	Electric System	Run on grid electricity.	During war emergency, it is shifted to emergency power. Automatic Transfer Switch (ATS) starts standby generators and critical services remain in operation without interruption. Non-essential loads are also disconnected.
iii.	Structural Integrity	Follow Standard high-rise design to bear gravity loads, environmental loads service loads, etc.	War emergency exerts extraordinary loads/pressures due to bomb blasts, missile strikes, drone attacks, etc. that are generally not considered in ordinary building design. Blast Resistance through RCC walls, blast resistance glazing, etc. and 'Progressive Collapse Prevention' through structural redundancy, strong column–weak beam theory, etc. need to be incorporated in structural design.
iv.	Water Supply	Municipal supply, storage tanks and pumping facilities.	Water supply system shifts from routine service to emergency support. High-rise buildings should maintain underground emergency reservoirs, overhead storage tanks, dedicated firefighting water tanks along with backup power for water pumps.
v.	Refuge Areas	Refuge areas (refuse floors) are used as temporary shelters/ assemble points but remain unoccupied in normal conditions.	During war emergency, it is used as staging/assembly area for evacuation & rescue operations, assistance point for medical/first-aid facilities, focal point for communication & coordination. Provisions of emergency electrical supply, water supply, fire protection, active fire suppression, smoke control, pressurized & smoke-free air supply, etc. need to be planned during normal situation for emergency uses. *(Pressurization is the process of supplying fresh air mechanically into refuse areas. The supplied air creates a higher air pressure inside these areas than in adjacent areas. When a door is opened, air flows outward from the pressurized area rather than allowing smoke to flow inward. This difference in pressure prevents smoke and toxic gases from entering in refuse areas.)*

Source: Compiled from multiple sources and thus represents appropriate information

CRITICAL BUILDING SERVICES DURING WAR EMERGENCY

During war emergency, some of the building services which contribute to life safety, emergency response, occupant survival, continuity of emergency operations for escape, etc. are classified as critical building services. In most of the cases, high-rise buildings are resilient against most of the disasters by adopting advanced engineering technology and smart materials but the same is always vulnerable due to vertical structure, high density, interconnected building services system, etc.

During war emergency, critical building services such as lighting (emergency), water supply (reserved), electricity (heavy-duty backup generators/batteries), emergency stairways (pressurized), specialized communication systems, etc. are required. Table 2 describes critical building services need to be planned, designed and maintained in normal conditions so that the same can be utilized in emergency conditions.

Table 2: Critical Building Services during War Emergency

S.N.	Critical Building Services	Description	Provisions for War Emergency
i.	Emergency Fire Protection System	High-rise building requires combination of both active and passive fire protection systems. During war emergency, fire protection systems is required to extinguish fires caused by explosions, missile strikes, falling of debris, fuel spillover, electrical failures, etc.	Automatic Fire Detection and Alarm System provide early warning of fire and smoke to the occupants for moving to refuge areas. Automatic Sprinkler System reduces fire spread followed by explosions. Apart from electric fire pumps/diesel-engine-driven fire pumps, Jockey pumps are also required to maintain water pressure for hydrants and sprinklers. (A jockey pump is a small-capacity pump used in a fire protection system to maintain pressure in the fire sprinkler and hydrant-piping network. It prevents unnecessary starting of 'main fire pump' due to minor pressure losses in the system).
ii.	Emergency Electrical Power	Redundant and resilient emergency power system.	Electric grid power fails due to attack, bombing, etc. then emergency power automatically starts and supplies power to critical loads such as fire pumps, emergency lighting, security system, etc. Emergency lighting system such as battery-backed emergency luminaires, exit signs, staircase lighting, refuge floor lighting, etc. is required to illumination for safe evacuation and rescue operations. Dedicated Life-Safety Electrical Circuits as 'emergency circuits' should be separated from normal electrical circuits to take load of fire alarms, fire pumps, smoke extraction fans, staircase pressurization fans, etc. during emergency.
iii.	Emergency Water Supply	Operation of water system from normal utility service to critical life-support infrastructure, which must sustain building occupants during wartime disruptions.	Provisions for dedicated firewater storage separated from domestic water tank, emergency potable water storage for occupants and distribution networks, etc. are required.

S.N.	Critical Building Services	Description	Provisions for War Emergency
iv.	Emergency Communication System	During war emergency, communication system becomes one the critical building services as it coordinates for evacuation and rescue operation, broadcasting of emergency instructions, etc.	Three layered emergency communication system for war-resilient high-rise buildings are required: 1st layer: PA/Voice Alarm System 2nd layer: Intercom and Radio communication 3rd layer: Satellite communication, emergency telephones, cellular/mobile networks (4G/5G), Emergency Position Indicating Radio Beacons (EPIRB), etc. It enhances occupant safety and emergency response even if one or more systems fail during war emergency.
v.	Vertical Transportation	Vertical transportation system such as elevators, firefighting lifts, evacuation elevators, emergency fire staircases, etc. provide emergency access in rescue operation.	During war emergency: IBMS automatically redirects conventional passenger elevators to a designated safe floor (i.e. ground floor/ refuge floor). Firefighter lifts enable firefighters and rescue teams to reach affected floors for rescue operation' Such lofts are protected against fire and smoke ingress. Evacuation elevators assist in the controlled evacuation of occupants, such as persons with disabilities, elderly individuals, injured occupants, etc. Such elevators are designed with enhanced fire protection, emergency power backup and communication system to ensure safe operation during emergency.

Source: Compiled from multiple sources and thus represents appropriate information

The critical building services are also essential in 'refuge floor /temporary shelter area' amidst power failure and structural damage. Such critical building services assume vital role in life-support functions such as emergency power, firefighting capability, pressurized smoke-free environments, etc. The uninterrupted operation of these services is crucial to safeguard occupants and enhance emergency response during wartime situation. It is important to maintain safe and habitable conditions within refuge areas in normal situation so that the same can be used during prolonged emergency.

BUILDING SERVICES DURING POST-WAR SITUATION: LEARNING EXPERIENCE

After the war, towns and cities faced different challenges such as large-scale destruction of housing stocks, damages of infrastructure, shortages of building materials, financial constraints, etc. The post-war building services

Fig. 1: Damaged Apartment Building in Residential Neighborhood at Kramatorsk, Donetsk Region (Ukraine) dated Feb. 8, 2026.

Source: Iryna Rybakova/Ukraine's 93rd Mechanized Brigade/AP

Fig. 2: Emergency Services Personnel work to extinguish fire in Kyiv (Ukraine) dated 7th September, 2025.

Source: Efrem Lukatsky/AP

initiate from basic utility facilities to integrated systems to support large-scale reconstruction and rehabilitation. Generally, standardized/modular designs and prefabricated components are widely used in housing construction to fulfill housing requirements in short span of time. Similarly, expansion of utility lines such as electricity, water, sewer, etc. and improved sanitation are given priority in reconstruction and better living conditions of the residents.

Case Study I: Post-War Building Studies (UK, 1944 onward)

The Post-War Building Studies was a series of technical reports commissioned by the Govt. in the United Kingdom during and immediate after World War II. It established technical guidance for:

-Reconstruction of war-damaged cities,

-Promotion of standardized construction techniques,

-Promotion of electrical wiring practices,

-Development & Restoration of building-service systems, etc.

for better and fast development during post-war situation.

Construction Components and Building Services

-Standardization of construction methods
(speed up reconstruction and upgradation of the works).

-Regulation on electrical installations and wiring practices
(maintain fast and uniform building services).

-New plumbing, heating, ventilation and sanitation systems
(New Mass Housing Construction & Projects).

-Prefabrication and Modular Construction
(Rebuild damaged cities and supply housing stocks in shorter span of time).

-Development of Design Standards
(Useful for further new construction and development)

Learning Experience

It is observed that 'Post-War Building Studies (UK, 1944 Onwards)' is a foundational reference for standardized wiring and construction methods used to rebuild cities after large-scale destruction. Post-war reconstruction prominences on progress of building services from traditional methods to post-war upgradations including rapid restoration and broad modernization of building services. The use of prefabricated-modular systems to restore essential building services is considered very effective during post-war situation.

Fig. 3: Hundreds of thousands of Prefab Houses were erected in Estates across the UK following World War II, providing housing to those left homeless from bombing raids.

Source: Getty Images

Case Study – II: Infrastructure Rehabilitation Plan (2023–2024), Israel

The State of Israel launched 'Infrastructure Rehabilitation Plan' in late 2023 and early

2024 (just after Operation Swords of Iron on 7th October, 2023) particularly in the Gaza-border Region, later designated as Revival District (Tekuma Region). It was for rehabilitation and development of communities affected by the war and the plan consisted of rebuilding housing, public infrastructure, energy system and community resilience. The government approved multi-year rehabilitation budgets and established dedicated authorities to coordinate reconstruction efforts (Source:www.trade.gov/market-intelligence). Post-war reconstruction strategy reinstated prominence of the protected spaces within buildings as described in Table 3.

Table 3: Protected Spaces and Services within Buildings in Israel

S.N.	Protected Space	Descriptions	Construction Components
i.	Mamad	It is known as 'Apartment Protected Space' or 'Residential Protected Room'. It is a reinforced safe room built inside an individual apartment or house in Israel to protect occupants from attacks, explosions, blast, etc. During war emergency, residents can move into the Mamad instead of traveling to a public shelter.	Specification: Floor Area: Minimum 9.00 square meters of internal space. Ceiling Height: Between 2.5 meters and 2.8 meters. Wall Thickness: Thickness of outer concrete walls=30 cm -40 cm Thickness of internal concrete walls = 20 cm (minimum) Door Dimensions: Steel doors having typically 80 cm wide by 200 cm high and designed to withstand high blast. Window: Steel shutter with inner impact-resistant glass and openable inward. Ventilation: Ventilation pipe (20 cm dia.) connected to chemical, biological, radiological and nuclear air filtration system.
ii.	Mamak	It is known as 'Floor Protected Space'. Infact, it is shared protected space on a building floor also known as 'Floor-Level Protected Room'. In other words: It is a reinforced protected area located on a floor of a multi-stored building and is shared by several apartments or occupants on that floor, rather than being part of an individual dwelling like Mamad.	The key features of Mamak are same as Mamad but it is located within easy & quick reach of the occupants on the floor. It is used as an emergency shelter during attacks and strikes.
iii.	Mamam	It is known as 'Institutional Protected Space'. In fact, it is a protected area within public buildings such as schools, hospitals, community facilities, Govt. buildings, etc. In other words: It is a reinforced shelter area built within public and institutional buildings to protect occupants during rocket attacks, missile strikes, explosions and other security emergencies.	The key features of Mamam are same as Mamak but it is designed to accommodate a larger number of people than residential protected spaces.

S.N.	Protected Space	Descriptions	Construction Components
iv.	Miklat	It is known as 'Public Bomb Shelter'. Miklat is a dedicated subterranean or ground-level bomb shelter designed for larger communal groups or public gatherings. These structures are found in the basements or courtyards of older apartment blocks built before the 1970s, as well as standalone municipal facilities on city streets, public parks, and beach promenades.	It is located in underground or at ground level and originated in old apartment buildings, streets, public areas, etc. It is open during attacks for nearby civilians. It is identifiable by high-visibility yellow or red sign displaying the word "Public Shelter."

Source: Compiled from multiple sources and thus represents appropriate information

Provisions of Building Services

Building services are required in Mamad, Mamak, Mamam and Miklat. These protected spaces are designed as 'Modern Safe Spaces' with separate water and sewage connections to maintain basic hygiene during extended stays. Protected spaces are equipped with dedicated air-filtration system including chemical/ biological filters, electrical outlets, communications ports, protected lighting, etc.

Learning Experience

It is learnt that Israeli civil-defense system has identified 'Mamad' and 'Mamak' as preferred protective spaces during rocket and missile attacks. Therefore, provision of these protected spaces in both new construction and post-conflict rehabilitation projects are well incorporated. Further, apart from Mamad and Mamak facilities in residential buildings, Mamam spaces are considered important for ensuring the continuity of essential public services such as education, healthcare, etc. during emergency period.

Fig. 4: Types of Protected Spaces in Residential and Public Buildings in Israel

Source: www.israeltraveladvisor.org

CONCLUSION

i. The scale of high-rise buildings and high density of occupants make vulnerable target during war. It is important that building services should be remain functional and resilient otherwise damage to a single core service can disable the entire building. It is understood that many high-rise buildings are not designed to endure the extreme heat or impact of modern explosives, leading to total collapse in some combat zones. Therefore, designing of high-rise buildings should resist explosive threats to provide physical security of building services.

ii. Building services have significance during both war emergency and in post-war recovery & reconstruction phase. During emergency, building services help to maintain necessary operations for safeguarding & rescuing the lives. Further, during post-war situation, building services support reconstruction by restoring infrastructure, enabling speedy housing construction, etc. The learning experiences of both case studies of "UK's Post-war Rebuilding Programs" and "Israel's integration of Protected Spaces (i.e. Mamad, Mamak, Mamam and Miklat) in Buildings" into reconstruction efforts, demonstrate vitality of building services to ensure safety and resilience of the built environment as well as occupants of the buildings.

iii. During war emergency, it is understood that building services in the form of basic utility provisions are strategic components of safety and sustainability. In fact, less damage to building services contribute to victory in the war as fast post-war repair depresses reconstruction cost, quicker re-occurrence of housing, transport, etc. shortens the post-war recovery time and budget.

iv. The function of critical infrastructure such as hospitals, emergency shelters, etc. during war emergency depend on availability of building services such as electricity for medical treatment, water for consumption, ventilation for safe shelters, etc. which reduce casualties and human losses and provide social stability. Urban areas/cities with minimal damage to building services during war are better able to sustain governance, recover quickly and maintain spirit of resilience for longer period. Advanced building services reflect the economic prosperity and technological progress but during war emergency, their resilience becomes equally important, as they support critical functions, enhance survivability and operational capacity of high-rise buildings.

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SOLAR POWER AND SMALL-SCALE WIND ENERGY INTEGRATION IN HIGH-RISE BUILDINGS: ECONOMIC ANALYSIS AND POLICY FRAMEWORK FOR INDIA

Dr. Subhranshu Sekhar Swain* and Dukhabandhu Behera**

Abstract

Rapid urbanization and increasing vertical development in Indian cities have substantially increased the energy demand of high-rise buildings. Building services such as heating, ventilation and air conditioning (HVAC), electrical installations, water supply systems, firefighting systems, vertical transportation and building automation systems constitute a major share of operational energy consumption in such buildings. Green building concepts aim to reduce this environmental impact through energy-efficient design, renewable energy integration, sustainable resource management and intelligent operational systems. This paper examines the role of building services in high-rise green buildings with particular emphasis on rooftop solar photovoltaic systems and small-scale wind turbines. A typical economic analysis has been presented for a medium-scale high-rise building in Odisha to assess the annual energy generation, pecuniary savings, payback period and carbon emission reduction potential. The paper further discusses Indian regulatory provisions including the Energy Conservation Building Code (ECBC), National Building Code (NBC) 2016, IGBC and GRIHA frameworks along with Odisha-specific renewable energy initiatives and urban sustainability measures.

INTRODUCTION

India is presently witnessing rapid urban expansion accompanied by increased construction of high-rise residential, commercial and mixed-use buildings. Such developments have become essential due to increasing population density, scarcity of urban land and rising commercial activity. However, high-rise buildings are also associated with substantial energy consumption owing to continuous operation of HVAC systems, pumping systems, lifts, lighting networks and other utility services. Studies indicate that buildings contribute approximately 30–35 percent of total electrical energy consumption in India. Consequently, improving the energy performance of buildings has become a critical component of national sustainability goals.

Green building practices have emerged as an effective strategy for minimizing energy consumption while improving occupant comfort, environmental quality and long-term economic sustainability. In high-rise structures, building services play a decisive role in determining overall energy efficiency and operational performance. Proper integration of renewable energy systems such as rooftop solar photovoltaic panels and small-scale wind turbines can substantially offset grid energy demand while reducing greenhouse gas emissions.

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The Bureau of Energy Efficiency (BEE) under the Ministry of Power has issued the Energy Conservation Building Code (ECBC) for improving energy efficiency in commercial buildings. Similarly, the National Building Code (NBC) 2016 incorporates sustainability provisions relating to energy conservation, water efficiency and environmental protection. Green rating systems such as IGBC and GRIHA further encourage adoption of sustainable building technologies across India.

GREEN BUILDING REQUIREMENTS FOR BUILDING SERVICES

Building services in high-rise structures constitute the operational backbone of the building and directly influence the energy footprint of the facility. Among these services, HVAC systems generally account for nearly 40–60 percent of total electrical consumption. Green building design therefore emphasizes the adoption of energy-efficient HVAC systems such as Variable Refrigerant Flow (VRF) systems, high coefficient of performance chillers, demand-controlled ventilation systems and heat recovery mechanisms. The incorporation of thermal insulation, double-glazed façades and cool roofing materials further reduces cooling load requirements. A Conceptual view of a green high-rise building integrating rooftop solar photovoltaic panels, vertical axis wind turbines and BIPV Curtain Walls is presented at Figure 1 for reference.

Lighting systems also contribute significantly to

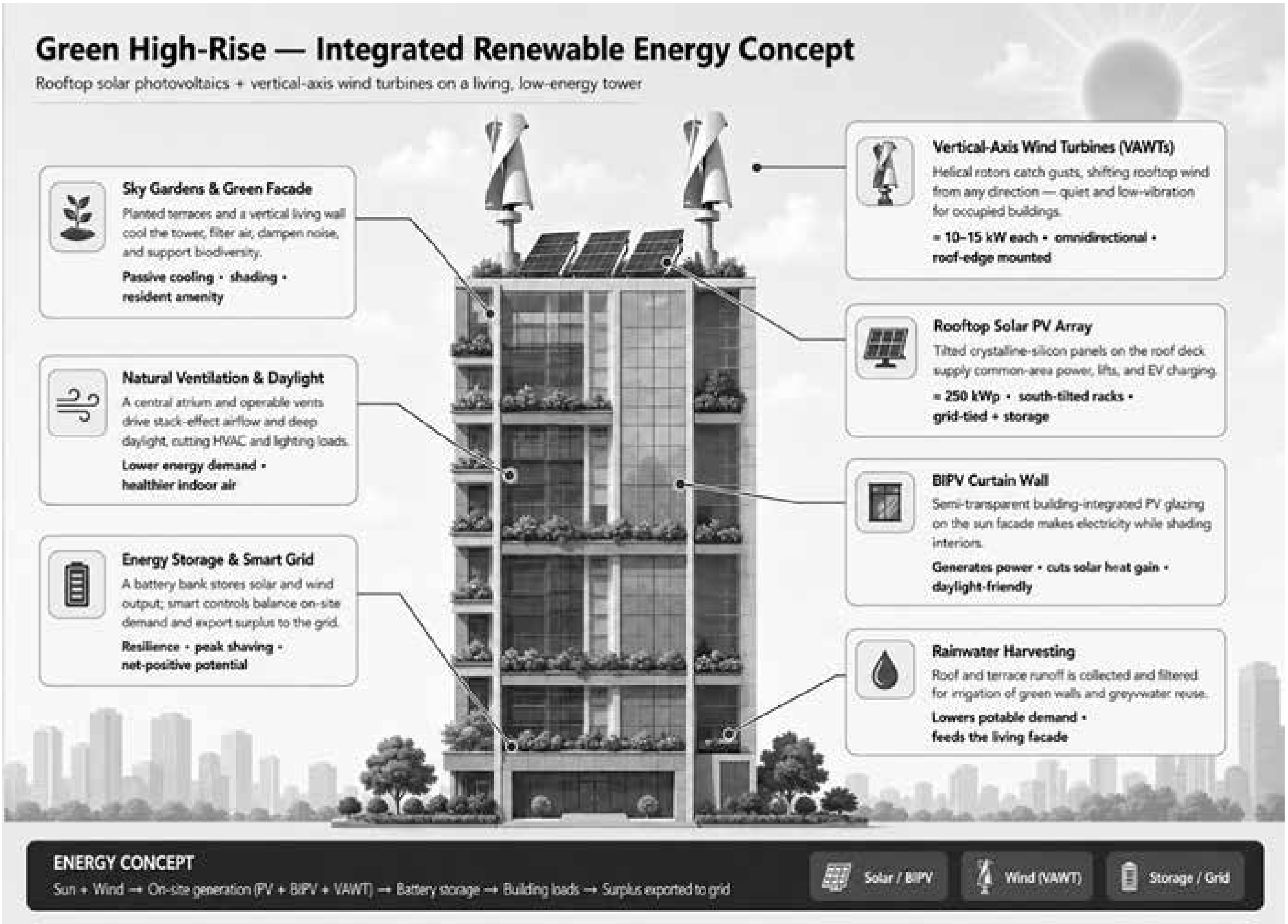

Fig. 1: Conceptual view of a Green High-Rise Building Integrating Rooftop Solar Photovoltaic Panels and Vertical Axis Wind Turbines

electrical consumption in high-rise buildings. Green buildings therefore prioritize LED lighting systems, daylight integration, occupancy sensors and automated dimming controls to optimize electricity usage. ECBC provisions mandate automatic lighting controls and prescribe limits on lighting power density to improve overall efficiency.

Water supply and plumbing systems are another important component of green building services. Sustainable high-rise buildings incorporate low-flow fixtures, greywater recycling systems, sewage treatment plants, rainwater harvesting systems and dual plumbing arrangements to reduce freshwater demand. NBC 2016 and IGBC guidelines encourage water conservation and reuse practices in urban buildings.

Vertical transportation systems such as elevators and escalators also play a major role in energy consumption in tall buildings. Modern green

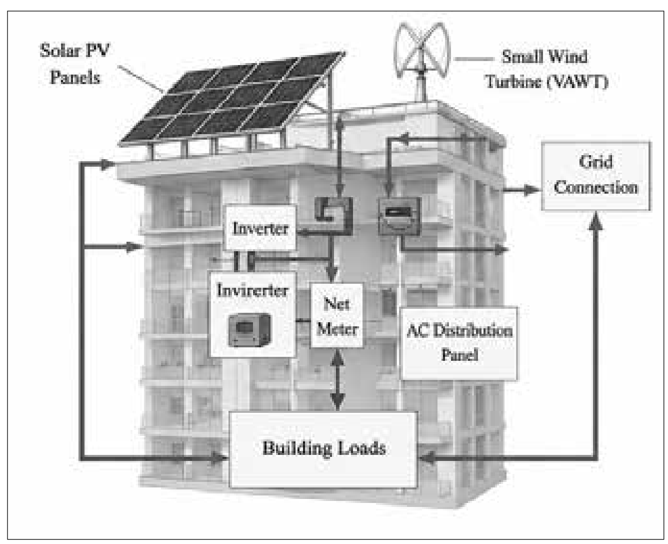

Fig. 2: Typical Energy Flow Diagram showing Renewable Energy Integration with HVAC, Lighting and Building Services

buildings utilize regenerative elevators, variable voltage variable frequency (VVVF) drives and destination control systems to improve operational efficiency and reduce energy demand. A typical energy flow diagram showing renewable energy integration with HVAC, lighting and building services is presented at Fig. 2 for reference.

In addition to these systems, Building Management Systems (BMS) are increasingly used for intelligent monitoring and control of lighting, HVAC, water supply and energy systems. Such systems facilitate real-time optimization and improve lifecycle performance of the building. A schematic representation of smart Building Management System (BMS) integrated with renewable energy monitoring is presented at Fig. 3 for reference.

RENEWABLE ENERGY INTEGRATION IN HIGH-RISE BUILDINGS

Renewable energy integration has become an essential component of modern green buildings. Rooftop solar photovoltaic systems are presently the most widely adopted renewable technology for urban buildings due to their modularity, reliability and declining installation costs. ECBC 2020 recommends allocation of Renewable Energy Generating Zones (REGZ) in commercial buildings for future renewable energy installations.

A typical rooftop solar system comprises photovoltaic panels, grid-tied inverters, mounting structures, metering systems and optional battery storage. The electricity generated by the system can either be consumed within the building or exported to the grid through net metering arrangements. The integration of rooftop solar systems significantly reduces dependence on conventional grid electricity while lowering operational costs.

In high-rise buildings, rooftop wind energy systems can also supplement solar power generation. Due to increased wind velocity at higher elevations, rooftop locations on tall buildings may provide suitable conditions for small-scale wind turbines. Vertical Axis Wind Turbines (VAWT) are generally preferred in urban environments because they perform better under turbulent wind conditions and generate comparatively lower noise levels.

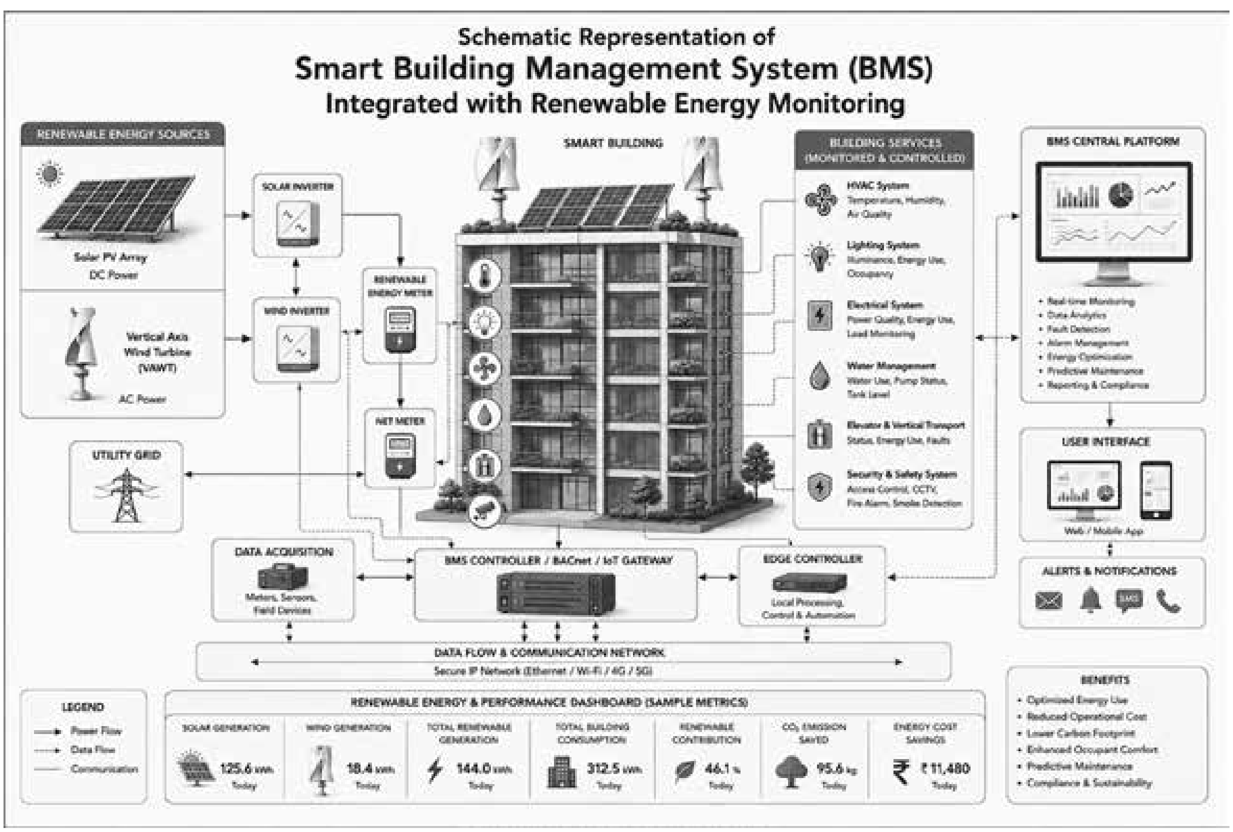

Fig. 3: Schematic representation of smart Building Management System (BMS) integrated with renewable energy monitoring

The installation of rooftop wind turbines requires detailed structural assessment, vibration control measures and wind load analysis in accordance with IS 875 (Part 3). Adequate safety measures are necessary to prevent structural fatigue and ensure occupant comfort.

TYPICAL ECONOMIC ANALYSIS FOR RENEWABLE ENERGY INTEGRATION

For the purpose of this study, a hypothetical fifteen-storey mixed-use high-rise building located in Odisha has been considered. The building is assumed to have a roof area of approximately 1,200 square metres, of which nearly 60 percent is available for renewable energy installations.

A rooftop solar photovoltaic system of 100 kW capacity is considered for the building. Assuming an average daily solar generation potential of 4.5 kWh per kW and a system performance ratio of 0.8, the annual electricity generation from the solar system may be estimated as follows:

$E = P \times H \times PR$

Where:

E = Annual Energy Generated P = Installed Capacity H = Equivalent Annual Solar Radiation Hours PR = Performance Ratio

Accordingly:

$E = 100 \times 4.5 \times 365 \times 0.8$

$E \approx 131{,}400$ kWh per annum

Additionally, a small rooftop wind turbine system of 10 kW capacity is assumed. Considering an average rooftop wind speed of approximately 5–6 m/s, the wind turbine system may generate nearly 48,000 kWh annually.

Therefore, the total annual renewable energy generation from the combined solar-wind system may be estimated as:

131,400 + 48,000 = 179,400 kWh per annum

Assuming an average electricity tariff of ₹8 per kWh, the annual monetary savings achieved through renewable integration may be estimated as:

Annual Savings = 179,400 × 8

Annual Savings ≈ ₹14,35,200

The approximate installation cost of the 100-kW solar photovoltaic system may vary between ₹45–50 lakh depending upon panel technology, inverter configuration and structural requirements. The 10-kW wind turbine installation may require an additional investment of approximately ₹12–15 lakh. Including structural modifications, electrical integration and control systems, the total project cost may be estimated at approximately ₹70 lakh.

Accordingly, the simple payback period may be estimated as:

Payback Period = Total Cost / Annual Savings

≈ 70,00,000 / 14,35,200

≈ 4.9 years

The analysis therefore indicates that renewable energy integration in high-rise buildings is economically viable and can recover the initial investment within approximately five years while continuing to generate operational savings over a service life exceeding twenty years. A comparative graph showing annual energy savings and payback period is presented (Figure 4) for reference.

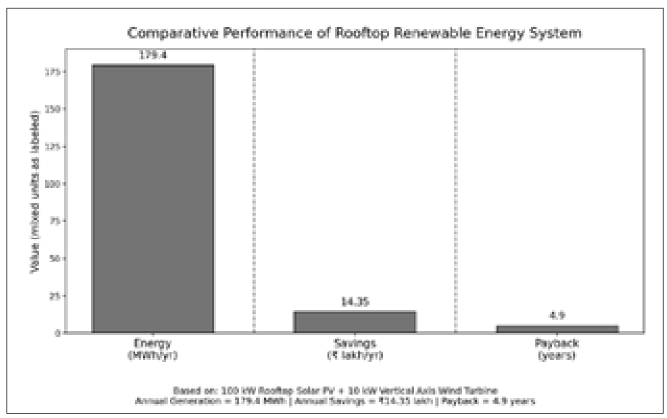

Fig. 4: Comparative graph showing annual energy savings and payback period for rooftop renewable systems.

IGBC AND GRIHA RATING SYSTEMS

Green building rating systems provide structured frameworks for evaluating sustainability performance of buildings. In India, the Indian Green Building Council (IGBC) and Green Rating for Integrated Habitat Assessment (GRIHA) are among the most widely adopted systems.

These frameworks assess multiple sustainability parameters including energy efficiency, water conservation, indoor environmental quality, sustainable materials, waste management and renewable energy integration. Buildings achieving higher ratings often experience improved market value, lower operating costs and enhanced environmental performance.

GRIHA has been recognized by the Ministry of New and Renewable Energy (MNRE) as India's national green building rating system. IGBC rating systems specifically address commercial buildings, residential complexes and high-rise developments.

CHALLENGES AND LIMITATIONS

Despite the significant benefits associated with green building technologies, several implementation challenges continue to exist in the Indian context. One of the major barriers is the relatively high initial capital investment required for renewable energy systems and advanced building services. Developers often prioritize short-term financial considerations over lifecycle savings.

High-rise buildings also face structural limitations with respect to rooftop wind turbine installations. Urban turbulence, noise generation and vibration control require careful engineering analysis. In densely populated urban areas, limited rooftop space may further constrain renewable energy installations.

Additionally, lack of awareness among stakeholders, shortage of trained technical personnel and inadequate maintenance practices often affect long-term performance of green building systems.

FUTURE SCOPE AND WAY FORWARD

Future urban development in India must increasingly adopt sustainable and energy-efficient practices to address climate change and energy security concerns. Mandatory implementation of ECBC provisions for all major urban developments may substantially improve building energy performance.

Government agencies may consider providing additional Floor Area Ratio (FAR) incentives and tax benefits for certified green buildings. Wider adoption of net-zero energy buildings, smart energy management systems and AI-based building automation technologies may further improve efficiency.

Odisha possesses significant potential for expanding renewable energy integration in urban infrastructure. Municipal bye-laws may incorporate mandatory rooftop renewable energy provisions for high-rise buildings. Public awareness programmes, professional training and financial incentives may also accelerate adoption of sustainable building technologies.

CONCLUSION

Green building services are fundamental to achieving sustainable high-rise development in India. Efficient HVAC systems, intelligent lighting networks, water conservation measures, building automation systems and renewable energy integration collectively contribute towards reducing operational energy demand and improving environmental sustainability.

The present analysis demonstrates that rooftop solar photovoltaic systems combined with small-scale wind turbines can substantially reduce electricity consumption and operational expenditure in high-rise buildings. A typical medium-scale high-rise building in Odisha may achieve annual savings exceeding ₹14 lakh with a payback period of less than five years.

The coordinated implementation of ECBC, NBC 2016, IGBC and GRIHA provisions can significantly enhance the sustainability performance of urban infrastructure in India. Odisha, with its growing urban centres and increasing renewable energy initiatives, is well positioned to adopt green high-rise building practices on a larger scale.

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ELEVATING ENERGY-EFFICIENCY THROUGH CONFLUENCE OF NATURAL FACTORS WITH MECHANICAL SYSTEMS: HIGH-RISE BUILDINGS IN THE GREEN FRAMEWORK

V. SHOBHANA*

Abstract

With rapid urbanization giving momentum, mixed-use high rise buildings have become the perceptible icons of a rapidly progressing India. But with climate volatility and an ongoing global crisis altering energy equations, Indian high rise building industry finds itself at a crossroads. Cutting-edge technology has now to be balanced with increased environmental responsibility in the way MEP systems for them are conceptualized, provisioned and operated. With energy security, sustainability, public health and productivity envisaged as the emerging spectrum of HVAC services, the 'vertical' challenge is widened to address indoor air quality, life cycle energy-efficiency and resilience.

While rapid advancements in technology are enabling efficient high-performance HVAC systems in varying Indian operating conditions, the standpoint of a 'systems integration' approach to effect long-term savings in energy consumption and operational costs of high-rise buildings is gaining ground. Complementary interventions at the initial stage of building design can offset high upfront costs of technology-driven mechanical systems. Thus a strong case emerges for visualizing high-rise HVAC systems in the green building framework, harnessing natural environmental factors for sustained energy efficiency and resilient performance.

This paper aims to look at such augmentative strategies that would contribute to optimizing the scale of HVAC systems and subsequently life-cycle costs.

INTRODUCTION

Dominating the skyline in every city and once symbols of resource intensive urbanization, high rise buildings strive today to balance architectural form and structural design with environmental responsibility as a core concern rather than an afterthought. Global warming due to carbon emissions and climate change have not only affected how tall buildings are designed but also the building services. One of the critical components of these services is the HVAC system which ensures comfortable indoor environment even while consuming a significant portion of the building's energy.

Mitigation of climate change and reduction of GHG and GWP emissions have become the cornerstone of sustainable development in a world of depleting resources. Environmental and climate change projections for 2050-2100 indicate a potential increase in warm discomfort hours by upto 70%. Contemporary high rise buildings have to be envisaged as energy-efficient, comfortable and healthy spaces. There is a pressing need for solutions that enhance indoor comfort while supporting the goal of environmental sustainability – and thus an ingrained compatibility with green building principles.

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THE GREEN OBJECTIVE

The 'green' principles pertinent to a building's HVAC systems are

- To create healthy indoor atmosphere directly affecting comfort, health and productivity of occupants
- Ensuring energy-efficiency and reducing operational costs
- To create sustainable environment to enhance environmental responsibility

Integrating above goals seamlessly with advanced HVAC technologies, sustainable HVAC systems contributing to reduced environmental footprint and advanced adaptability to climate change can be arrived at.

HVAC IN HIGH-RISE – COMPLEXITY AND CHALLENGES

High-rise buildings are complex integrated systems involving several components – elements sharing a building's space physically, binding harmoniously

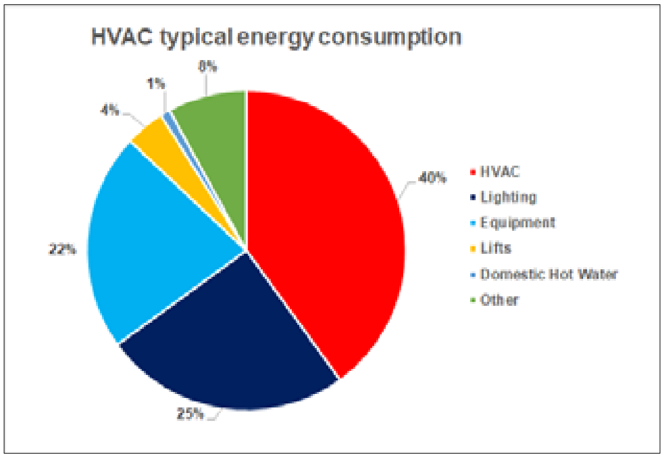

Fig. 1: Energy Consumption by HVAC System

Source : *Analyzing energy efficient design strategies in high buildings with reference to HVAC system - Mohammad Arif Kamal, Ehtisham Ahmed*

visually and functioning in a coordinated manner so as to effect energy savings.

To render high-rise buildings sustainable, its various interconnected systems need to be synchronized to operate well and use less energy during operation. This integration if started at the first stage of an energy conscious design process itself leads to long-term economy in terms of life-cycle costs.

High-rise buildings are characterized by their high energy consumption as they rely intensively on mechanical HVAC systems for occupant comfort due to the extreme weather conditions associated with increase in height. HVAC systems account for nearly 40 to 50 percent of the energy used in high-rise buildings in India. With rising energy concerns, reliable and efficient HVAC in high rise buildings is no longer optional – it is a core necessity.

At the other end, HVAC technology has evolved to meet the challenge of energy usage and environmental effects. Modern systems use cutting edge designs, and materials to minimize adverse environmental impact. Air conditioning technology advancements have been made to address energy efficiency, environmental issues and occupant comfort.

Modern HVAC systems have to respond to varying climate demands throughout the building. Relationship between building height and energy consumption and weather conditions associated with increase in height become a significant design issue.

The critical challenges affecting design and efficiency of HVAC in high-rise can technically be expressed as

- Pressure differential and Stack effect – causing pressure difference between lower and upper floors – further complicated by magnitude of wind pressure and buoyancy.
- Temperature variation and air distribution – Temperature and wind conditions vary dramatically between lower and upper floors.
- Scale and equipment limitations – equipment location and static pressure problems

Since these can directly impact and amplify HVAC requirements, the case for looking at strategic options for introducing natural elements of design in high-rise buildings gains ground.

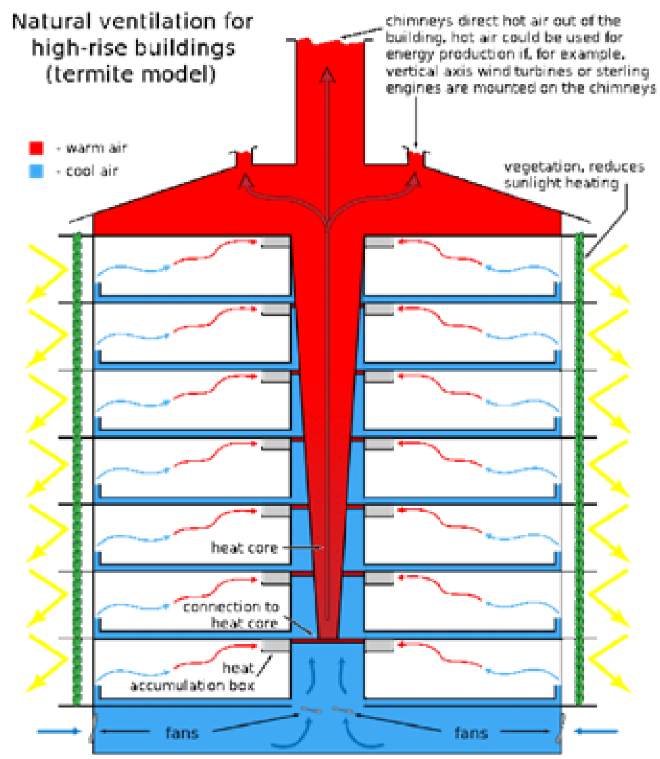

Fig 2. Natural Ventilation in High-Rise Building

Source: Back to basics – Natural Ventilation and its use in different contexts – Dima Stouhi

HVAC IN HIGH-RISE – ENERGY CONSUMPTION AND INFLUENCING FACTORS

High-rise structures typically require substantial energy for daily operations and are now embracing innovative strategies to minimize energy consumption, enhance comfort, and reduce environmental impact. Climate plays an important role in high-rise building energy consumption. High-rise buildings are exposed to various micro-climatic conditions that change gradually with the increase of the building height above sea level. While wind speed varies, high-rise buildings receive both direct and indirect solar radiation– thus creating different patterns of energy consumption as height increases.

To turn high consumption buildings into high-performance buildings with significantly lower carbon footprint and operational costs an approach blending passive and active design interventions emerges as a rational approach. Harnessing natural ventilation and lighting for many spaces and integrating renewable energy can even enhance operational efficiency in addition to energy savings. Even a perfunctory glance reveals great potential for reducing energy consumption of high rises by enhancing envelope design parameters (upto 79%), optimizing plan layout (upto 17%) and utilizing natural ventilation (upto 45%).

The most influential design parameters of high rises regarding energy consumption are

1. Thermal Comfort

2. Ventilation

Thermal comfort is affected by factors such as air temperature, air velocity and relative humidity, to create a spaces that are comfortable to occupy and work in.

Air is a free, natural, renewable and healthy resource. Ventilation is bringing in outdoor fresh air and distributing it into a space and may also to improve its air-quality.

Daylighting is harnessing the light of the sun effectively to reduce reliance on lighting equipments thus reducing heating loads.

Adopting passive measures is to facilitate these natural elements optimally into the design of a building. With technological tools available to quantify the effects of these, it is being established that these interventions go towards augmenting the energy-efficiency and economy aspects of HVAC systems in high-rise buildings.

In high-rise buildings the chimney effect is used for effecting thermal comfort. Opened areas in the building's centre or towers help air to rise and circulate throughout the indoor environment through roof, clerestory, zenithal openings or wind exhausts.

Elevated air movement through cross ventilation increases convective heat transfer and evaporative cooling.

Wind tower, perforated facades and screens, sky gardens, green roof and green facade for shading and ventilation are some passive techniques in practice.

PASSIVE DESIGN APPROACHES IN HIGH-RISE – CONSOLIDATING ACTIVE SYSTEMS

(a) Architectural Design Parameters

Passive design as pertaining to energy-efficient architecture, leveraging natural forces such as sunlight, wind and the thermal mass of concrete buildings to regulate temperature, air movement and heat gain act in high-rise buildings. substantially lowering a building's energy-use. These design strategies which rely on natural environmental interaction rather than artificial intervention can in tandem with efficient active HVAC systems can considerably lower a building's energy use.

Integrating the physical systems for environment friendly high-rise buildings is important. Connections between each important physical system and subsystems of a high-rise building is to be done from the start of design process. The earlier design integration is conceptualized, higher can be the energy savings effected. The first interventions concern the architectural design parameters – that form the skin of the building outside and the spatial arrangements to disperse the advantages inside.

(i) Building Orientation

The way a building has been placed on a site with respect to the solar and wind direction is an important factor in determining the airflow and illumination available in a building. Having the spaces that need more natural light oriented towards the north direction in the northern hemisphere leads to a decrease in the energy consumption required to shift the thermal load from the artificial lighting. A good spatial design can be harnessed advantageously and optimally to reduce the load of HVAC system.

(ii) Building Shape

Different building geometry has affects on their solar exposure as some shapes receive more solar radiation than others resulting in higher cooling loads inside the building. In addition, some shapes improve the natural daylight and ventilation flow inside the building that will decrease the thermal and ventilation load inside it.

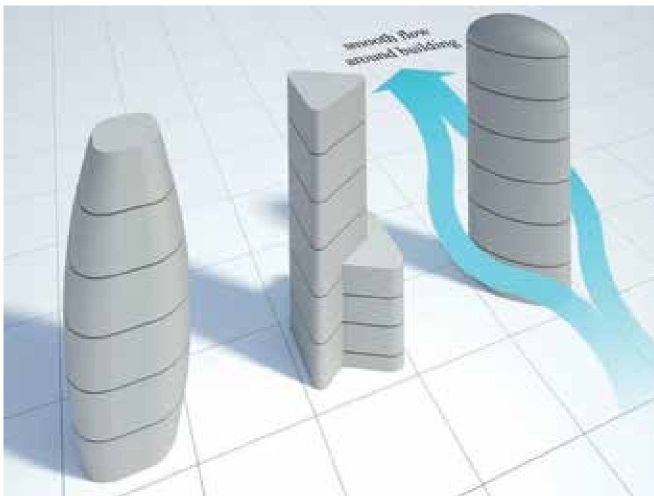

Fig. 3: Building Shape and Energy Consumption

Source: Energy efficient tall building strategies – a holistic approach – Hazem Halotefy, Khaled SS Abdel Majid

(iii) Building Envelope

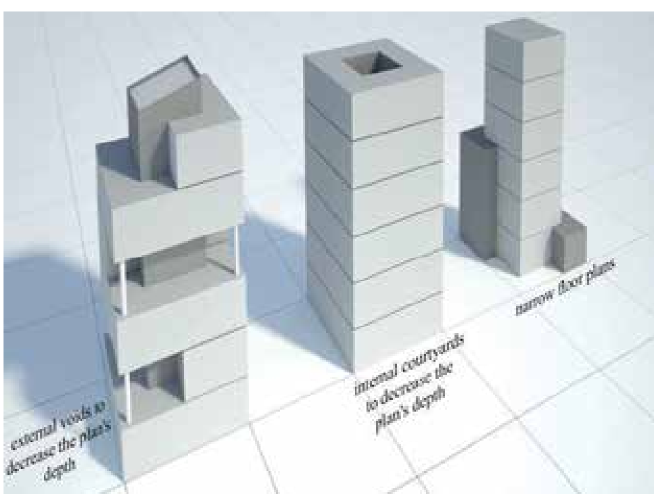

Fig. 4: Building Elements and Energy Consumption

Source: Energy efficient tall building strategies – a holistic approach – Hazem Halotefy, Khaled SS Abdel Majid

Building envelope controls the internal environment of the building against the external climatic conditions such as the amount of solar radiation, temperature, humidity and wind entering the building. The envelope materials with their different thermal properties such as solar insulation, thermal mass and heat transfer have a great impact on the energy consumption inside the building.

High-performance glazing and advanced insulation further enhance energy efficiency by minimizing heat transfer. Integrating shading devices like louvers or vertical fins in warm climates reduces solar radiation on façades, lessening the need for air conditioning. Advanced façade applications that are appropriately linked with cutting-edge HVAC systems lead to significant energy savings and enhance indoor air quality as a byproduct.

(iv) Building height

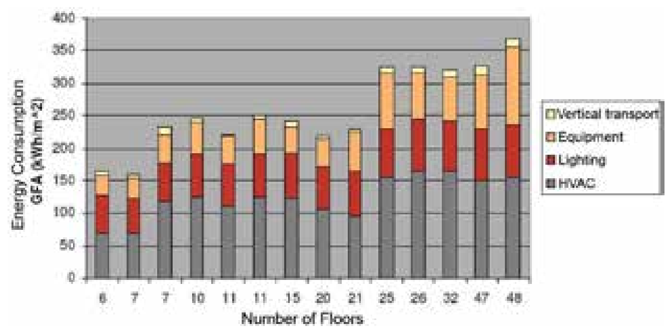

Fig. 5: Number of floors and energy consumption

Source : *Analyzing energy efficient design strategies in high buildings with reference to HVAC system - Mohammad Arif Kamal, Ehtisham Ahmed*

Tall buildings are usually higher and isolated from the urban pattern of the surrounding built environment. This results in increasing the energy use for mechanical heating and cooling while combating higher wind speeds.

(b) Renewable Energy Integration

On-site renewable energy generation has become a key feature of high-performance high-rise buildings, helping reduce reliance on non-renewable sources such as fossil fuels. Integrating renewable energy is a critical component of HVAC solutions for high-rise buildings. By switching to renewable energy, the carbon impact of outdoor cooling is drastically reduced while operational costs drop significantly.

(i) *Solar energy* is an abundant resource. PV panels or building-integrated photovoltaics (BIPV) can be installed on rooftops or façades to harness sunlight and produce clean energy. These advanced PV systems blend with architectural design, turning façades into functional and aesthetic energy generators.

There are two categories of solar energy: passive and active. Passive solar energy is put into practice as a design strategy to accomplish direct or indirect space heating and daylighting. Active solar energy is implemented through technical installations such as solar collectors and photovoltaic (PV) panels.

(ii) *Wind energy* - Wind is a renewable energy source which can be advantageously tapped at the higher altitudes of high-rise buildings where wind speed is considerably high. High-rise buildings can be shaped to funnel wind into a zone containing wind turbines without having negative effects on the structure, its surroundings and the occupants. By such profiling of the structure, wind speed can be amplified and used to produce more energy.

(iii) *Geothermal energy* – Geothermal systems taking advantage of stable temperature beneath the ground level offer a stable and renewable heating and cooling source. This is particularly valuable in regions with extreme climate shifts.

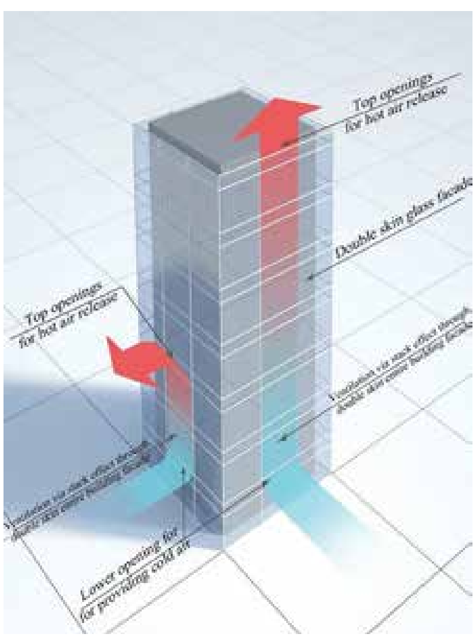

Fig 6 Façade and openings – passive elements

Source: Energy efficient tall building strategies – a holistic approach – Hazem Halotefy, Khaled SS Abdel Majid

(c) Façade Technology

Daylighting and shading are usually the key aspects to façade design for typical green buildings. The façade covers over 90-95% of the external building surface area in a tall building, leaving the roof area almost insignificant compared to façade areas. Thus, the energy gain or loss for a tall building depends very much upon the materials and technology employed in the façade treatment. Being a part of building envelope, besides architectural aesthetics, it can also be advantageously used to control the internal conditions of the building.

The latest trend is the use of double skin or triple skin walls, façade with ventilation system, double glazing with argon-filled cavities, triple glass and glass coatings can reduce heat gain within high-rise buildings.

(d) Green Roofs and Vertical Gardens

Green roofs and vertical gardens add aesthetic value and enhance energy efficiency by enhancing insulation. These features help maintain stable indoor temperatures by absorbing heat during the day and releasing it at night, reducing the need for mechanical heating and cooling. They also mitigate the urban heat island effect and contribute to a building's energy performance by adding a natural, insulating layer to its structure.

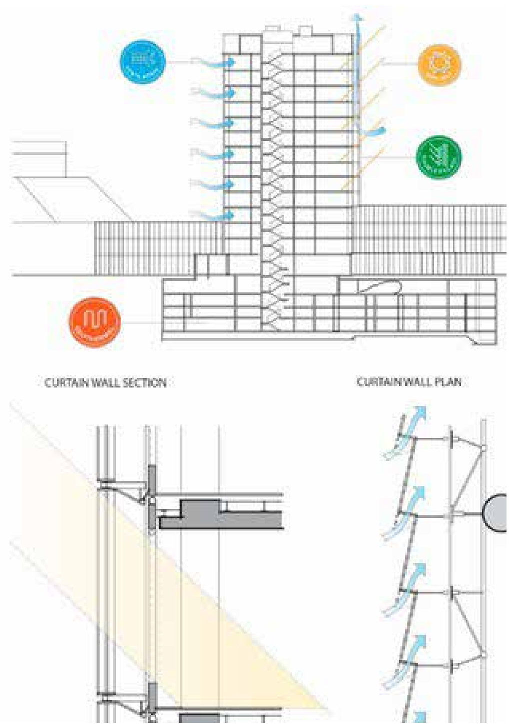

Fig. 7: Double layered Wind-Pressured

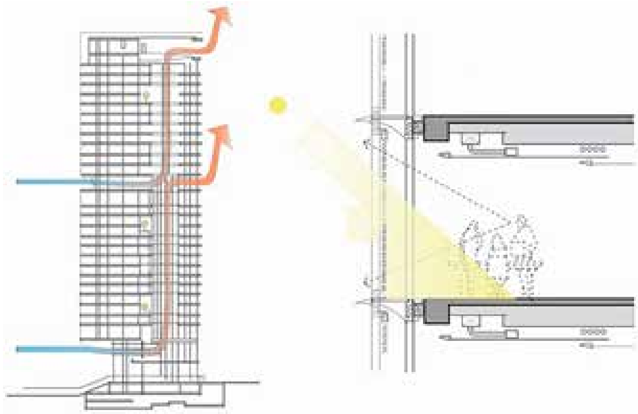

Fig. 8: Double Skinned Façade and Atrium Facades

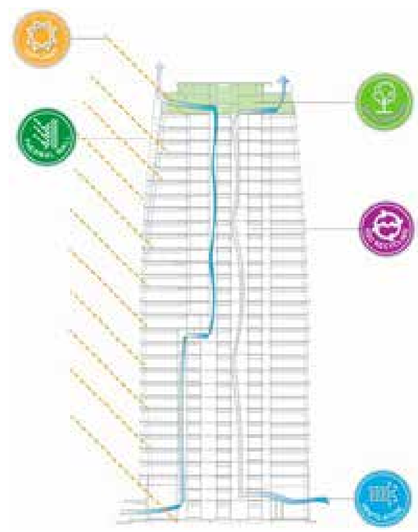

Fig. 9: High-Performance Thermal Façade and Shading

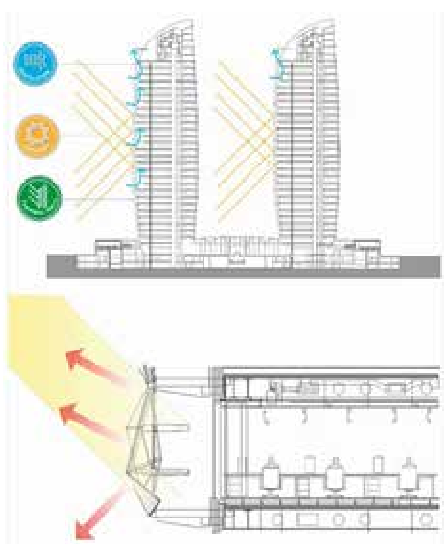

Fig. 10: Sun-Responsive Screen – Skin Element

Source: Sustainable tall buildings - Summary of energy-efficient design -Kheir Al-Kodmany, Mir M Ali, Paul Armstrong

GREEN BUILDING STANDARDS AND HIGH-RISE BUILDINGS – VALIDATION

The National Building Code, ISHRAE standards, ECBC Norms, ECO Niwas Samhita along with ASHRAE guidelines provide the technical backbone of the green framework of HVAC in high-rise buildings. Outputs from adherence to green building standards in high-rise buildings can be summarized in terms of:

- Energy Efficiency: As evident, high-rise buildings have significant energy demands for heating, cooling, and lighting. Green building standards promote energy-efficient design and technologies, reducing operational costs and environmental impact.
- Resource Conservation: Green building standards emphasize optimization of naturally available sources helping high-rise buildings minimize resource consumption to generate comfort conditions.
- Indoor Environmental Quality: High-rise buildings can benefit from improved indoor air quality, daylighting, and thermal comfort through green building practices, enhancing occupant health, productivity, and satisfaction.

CONCLUSION

Energy crunch notwithstanding, volatile weather conditions, rising air pollution, climate change and global warming have thrown new challenges to provisioning and maintaining HVAC systems in the ever rising number of high-rise buildings in India. The call is for resilient, efficient and dynamic HVAC systems strictly complying with national and international standards – but cutting-edge options result in increased upfront costs and stringent operation. On the plus side, there is historical evidence and thus scope for harnessing the elements of nature to create comfortable living spaces, which can augment mechanical systems in buildings – that in modern parlance, can be called as 'green building' interventions. Integration of naturally inducible passive systems with technologically bolstered active systems at the conceptual stage itself is an emergent solution to economical, energy-efficient and resilient HVAC systems in high-rise buildings.

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RETROFITTING OF FIRE FIGHTING SYSTEMS IN HIGH RISE BUILDINGS: TWO CASE STUDIES

Sidhant Das* and Bijoy Chandra Tripathy**

Abstract

This paper reviews the need for retrofitting fire-fighting systems in older high-rise buildings through two case studies (Fortune Tower and IDCO Tower in Bhubaneswar, Odisha). Major fire incidents in India since the 1970s are outlined first and the strong linkage between electrical hazards and fire safety[1][2]. Then how India's National Building Code (NBC) fire-safety provisions have evolved (editions in 1970, 1983, 2005, 2016)[3] are summarized. A comparison of key fire-fighting requirements in NBC-2005 versus NBC-2016 is presented (Table 1). The case studies describe the specific retrofits carried out (new pumps, sprinkler/hydrant piping, alarms, etc.), noting challenges and timelines. The conclusions are given with lessons learned: aging buildings often fail to meet current NBC standards (e.g. higher pump pressures, dedicated tanks, fire-rated structures), making retrofits essential. Retrofitting improves safety and code compliance, as underscored by recent Odisha fire tragedies (e.g. a 2026 hospital ICU fire that killed 10 patients[4]) and the prevalence of electrical-origin fires[1][2].

INTRODUCTION

High-rise buildings demand robust fire-fighting systems (standpipe hydrants, sprinklers, pumps, alarms) designed per the National Building Code (NBC). Over time, codes have been consistently dynamic in updating fire fighting systems in buildings in line with technology, complexity and occupancy. The NBC was first published in 1970 and revised in 1983, 2005, and 2016[3]. Many older buildings were built with earlier, less stringent rules. Meanwhile, India has suffered numerous catastrophic fires, underscoring the stakes in renew, reassessment and restoration of fire safety provisions in them. For instance, a 1986 fire at Delhi's nine-storey Siddharth Continental Hotel killed 37 people[5]_and Upahar cinema hall fire (Delhi) in year 1997 killed 59. More recently (2026), a trauma ICU fire at SCB Medical College (Cuttack, Odisha) killed 10 patients[4]. A Feb 2026 blaze in a four-storey Bhubaneswar market destroyed property worth lakhs[6]. The analysis of fire accidents highlight systemic failures like inadequate fire safety provisions, blocked exits, overloaded wiring, insufficient alarms implying the critical need for undertaking up-to-date fire safety measures. Retrofitting ensures that active systems (sprinklers, alarms) and passive systems (fire doors, refuge areas) are integrated to protect human life during the critical evacuation window.

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Fire safety is closely tied to electrical safety. Short circuits and overloaded circuits are a leading fire cause[1]. Studies note that roughly 60% of building fires in India originate from electrical faults (overloads, nonstandard wiring, lack of inspection)[1]. In Odisha, electrical faults were cited in over 40% of fatal fire accidents in 2023[7]. Given this link, fire retrofits often require parallel upgrades to electrical distribution (e.g. dedicated fire pumps on emergency power, proper earthing, insulation).

NBC 2016 (Part 4) codifies prescriptive fire requirements (travel distances, zoning, alarms, extinguishers, pumps, hydrants) and reflects lessons from past fires[3]. Retrofitting old buildings bridges the gap between their "as-built" systems and today's standards. In the case studies below, two such projects are examined:

- **Case Study 1: Fortune Tower, Bhubaneswar** – an IDCO office tower where additional pumps, sprinklers, hydrants and controls were installed.
- **Case Study 2: IDCO Tower, Bhubaneswar** – a government high-rise where a comprehensive fire-protection system was added.

Before these cases, key fire-protection changes of NBC-2005 vs NBC-2016 are compared (Table 1). This Table highlights new retrofitting requirements (e.g. higher pump pressures, dedicated systems) that motivated the projects.

FIRE HAZARDS SINCE 1970: HISTORIC INCIDENTS

Since the 1970s, several high-profile fires have driven fire-safety reforms. In 1986, Delhi's Hotel Siddharth Continental (nine storeys) caught fire, killing 37 and injuring 46[5]. The major 1997 Uphaar Cinema fire (Delhi) killed 59 and led to stricter cinema hall norms. Odisha itself has seen deadly fires: in March 2026, a Cuttack hospital ICU fire due to a suspected short circuit killed 10 patients[4]. In early 2026, a massive fire in a Bhubaneswar market building (multi-storey commercial complex) burned out hundreds of shops over 12 hours, though miraculously without casualties[6]. These and other fires reveal common hazards: poor egress, lack of sprinklers/alarms, combustible storage, and electrical failures. Inadequate maintenance compounds these risks.

ELECTRICAL AND FIRE SAFETY

Modern buildings often operate closer to electrical capacity; overloading or degradation can spark fires. An Indian construction industry analysis notes that "*approximately 60% [of] fires originate from electric causes*" such as overloading, short circuits, and substandard wiring[1]. State fire records confirm this: Odisha had the highest number of fire fatalities in 2023, many due to electrical short circuits[7]. Strict electrical safety (proper wiring, earthing, load buffers) is therefore integral to fire prevention. NBC Part 4 itself mandates that emergency power supports all fire-life safety systems, and that fire pumps be on fire-resistant circuits[8][9].Modern retrofitting recognizes this link by mandating the isolation of electrical shafts with fire-rated materials and the installation of direct suppression systems over vulnerable electrical infrastructure, such as Automatic Fire Detection Suppression Systems for Electric Panels.

NBC FIRE-SAFETY PROVISIONS (1970–2016)

India's National Building Code (NBC) was first issued in 1970. Subsequent editions (1983, 2005, 2016) incorporate lessons from tragedies and new technology[3]. NBC 2016 (Part 4) now requires, for example, full-coverage sprinklers in high-rises, fire-rated shafts, pressurized stairwells, fire command centres, and automatic detection systems. Earlier, NBC 2005 had more modest requirements. The progression reflects a growing emphasis on *prevention*, *life safety*, and *fire protection systems* (the three core NBC fire safety principles[10]). Each update tightened criteria for exit routes, building occupancy classifications, fire pump sizing, and materials.

Because many buildings predate these codes, retrofitting is often needed to meet current standards for fire and life safety and sustainability of the building considering functional and economic value. The next section compares select 2005 vs 2016 requirements (fire-fighting related) to illustrate what retrofits address.

Table 1: Comparison: NBC-2005 vs NBC-2016 Fire-Fighting Requirements

Feature	**NBC 2005** (Fire & Life Safety)	**NBC 2016** (Fire & Life Safety)
Hydrant/sprinkler pump pressure	~2.5 kg/cm² (terrace tank option)[11]	3.5 kg/cm² at the remotest hose connection[12]
Underground/terrace water tanks	Separate fire water tank (no domestic use)[11]	Combined domestic+fire tank allowed (with isolation)
Fire pump motor start	DOL start (no code mandate)	Soft starters or VFD required on fire pumps
Fire pump location	No specific restriction; often basement	Fire pump room on or above ground floor (max 2nd basement)[13]
Fire-rated electrical shafts	1-hour rating for conduits	2-hour rating for electrical shafts[14]
Refuse chute enclosures	No specific enclosure requirement	Must have 120-min fire-rated enclosure (noncombustible)[15]
Fire command centre	Not specified	Mandatory on entrance floor, 120-min rated walls/door[16]

Feature	NBC 2005 (Fire & Life Safety)	NBC 2016 (Fire & Life Safety)
Sprinkler zoning	ICVs or control valves per zone	Max 4,500 m² per automatic sprinkler control valve[17]
Travel distance (fully sprinklered)	Standard values per Table-22	Travel distance may be increased by up to 50% if fully sprinklered (subject to conditions)[18]
Refuge areas	General provisions without extensive detailing.	Must feature 75mm signage, ventilation, first aid, public address speakers, fireman talk-back, drinking water, and full sprinkler coverage, fire command centres and automatic detection system.
Other (annex changes)	Annexes A–E	Annexes A–D (e.g. drills, fire resistance as annexed material)[19]

Table 1: Selected changes in fire-fighting provisions (NBC 2005 → 2016).
Sources: NBC code and commentary[11][12][14][15][16].

The table shows, for example, that NBC 2016 raised minimum hose pressure to 3.5 kg/cm² (vs. 2.5 kg/cm² under NBC 2005)[12][11]. It also permits combining domestic and fire tanks (though fire volume must remain dedicated)[11]. These upgrades improve hazard control but require retrofitting: older systems often lack sufficient pump head, storage capacity, or rated structures.

CASE STUDY 1: FORTUNE TOWER, BHUBANESWAR

Building: Fortune Tower is a multi-storey commercial tower in Bhubaneswar. Originally built in the year 2003 with basic fire protection as per NBC-1983, it required upgrades to meet current NBC-2016 norms for fire and life safety and retain high value tenants.

Information Box-1

S. No	Description	Response
1	Location	Fortune Towers, PS- Maitri Vihar, Chandrasekharpur, Bhubaneswar-751023
2	Year Built	1999-2003
3	Area (approx)	33,228 sqm
4	Height (approx)	36 metres (B1+GF+7)
5	Occupancy (approx)	1500 persons/day (commercial; IT and other offices)
6	Urgency for retrofitting	To adhere to the NBC-2016 guidelines as a matter of life safety, as per the demand received from tenants for fire and life safety and compliance to the Odisha fire department

Information Box-2

S. No	Earlier provisions	Retrofitting provisions
1	No terrace tank (only hydrant pipe till top with 2.5kg/cm2)	Terrace tanks installed along with high pressure of 3.5 kg/cm2 at farthest point
2	Only the hydrant fire lines installed	Hydrant lines along with sprinkler lines (branch lines included) and valves are installed to distribute the water uniformly to the farthest point
3	The hydrant pumps were operated on DOL	The hydrant and jockey pumps are automated and are operated by VFD

S. No	Earlier provisions	Retrofitting provisions
4	No fire doors	Atleast 2 hours fire rated fire doors installed as per the guidelines to create a separate evacuation pathway in the stairway.
5	General provisions without extensive detailing.	Must feature 75mm signage, ventilation, first aid, public address speakers, fireman talk-back, drinking water, and full sprinkler coverage,fire command centres and automatic detection system..
6	Staircase pressurization was not done	Pressurization of the staircase was done to prevent the entry of the fire into the stairway
7	Suppression system was not installed	Suppression system was installed in the panels to restrict fire due to electrical hazards.
9	UGR and terrace tank capacity- comparatively lower	More than 2,00,000 litres for UGR fire tank and more 20,000 litres (properly waterproofed and retrofitted)
10	Basement- no sprinkler and detection system	Properly installed sprinklers (pendent type wherever required), automated detection and alarm system installed, pressurization and mechanical ventilation was ensured
11	Signage- no strict norms (basic exit signage and arrows)	Done to current standard- equipped against power failures, smoke conditions, long distance visibility which included glow signages.
12	Pump House- no strict norms (basic jockey and hydrant pumps)	Retrofitted to current standard- standby pumps, alternate power supply, diesel pumps. Fire resistant cables, electrical panel protected and ventilation ensured. Also to prevent flooding of the pump house, proper waterproofing of the walls was done (prevent ingress of water through seepage) along with that drainage was provided to divert the flood water.

Scope of Retrofit: The project (tender issued Oct 2021 by IDCO) added a full suite of systems[20]. Key measures included: installing new fire pumps (electric and diesel), pump-house controls, sprinkler and hydrant piping, fire detection and alarm panels, and a combined fire water storage system. Specifically, four electric 900 LPM pumps (for hydrant/sprinkler) and one 900 LPM diesel pump were added (see tender BOQ[21]). Four jockey pumps (180 LPM) were also installed. A new Pump Control Room (with an 800A MCC) and Automation panels were provided. The existing underground water tank (fire +drinking water) was done waterproofing and crack free and terrace tank was supplied (with capacity ~100,000 L)[22] on top of stair rooms at 3 different zones. The retrofit included laying ~100 m of external hydrant piping around the tower, and ~120 m of internal hydrant branch lines (DVC/IS pipes with FM-approved valves). Sprinkler heads were added on all floors; flow switches and pressure sensors integrated into the fire alarm system. Civil works included cutting slab openings, constructing RCC pump room enclosures (2h fire-rated walls), and installing a fire command panel room, along with major portion for cutting of false ceilings to install the branch lines and header lines and making the false ceilings back to original. Additionally Smoke and heat detectors were integrated with sounders and a Public Address (PA) system to manage large-scale evacuations effectively. An alternative suppression systems utilizing gaseous or chemical agents were installed for environments where water is unsuitable. To secure escape routes, the retrofitting included staircase and lift pressurization systems to prevent smoke infiltration, alongside an atrium smoke extraction system designed to clear smoke and allow firefighter access. A centralized Fire Control Room was established to automate these mechanisms. Detailed Survey and Assessment of existing firefighting system including fire escape route was undertaken and deficiencies were recorded by in-house multidisciplinary team of Arch, Civil, Elect, and PH. Addition and alterations in all components over the years were recorded. An external fire safety expert was hired to give inputs in Planning and implementation. CFO and Odisha Fire Department's vetting was ensured before execution.

Timeline: Work started in late 2021 and completed by end-2023. Major civil and mechanical installations were done nights/weekends to avoid occupant disruption. All new components were tested in late 2022, and final commissioning occurred by end of 2023.

Cost: The retrofit contract totaled to approx Rs 4 crores. (For example, the items above – pumps, panels, tanks – sum to several crores.)

Challenges: Installing these systems in an occupied, historic building posed hurdles. Work could only occur nights/holidays in many areas. Cutting through basement floors and roads for underground pipework required coordination and traffic diversion. Existing false ceilings had to be removed and rebuilt. Also, the retrofit displaced some tenant spaces temporarily (requiring relocation to other floors). Laying sprinkler pipes and detector cables required dismantling diverse, thematic false ceilings and meticulously repairing them to match their original state. Ongoing tenant renovations frequently disturbed the continuity of fire detectors, necessitating constant rework and reprogramming. Installing AHU fire dampers meant shutting down the active HVAC system, dismantling ducts, and refixing them post-installation.

Results: The upgraded system now provides NBC-2016-compliant protection. At remotest hydrants the design pressure is ≥3.5 bar[12], with adequate flow. Fully automatic detection (smoke/heat detectors) and a host of manual call points were added. This overhaul addresses earlier shortcomings: e.g. previously the building lacked continuous sprinkler coverage and had an undersized pump. Post-retrofit drills show all occupants can evacuate within the NBC travel-distance limits, and firefighters have easily accessible stair/tower connections.

CASE STUDY 2: IDCO TOWER, BHUBANESWAR

Building: The IDCO Tower on Janpath is an older government high-rise (10+ floors) and 3 different buildings. Its existing fire system was outdated, lacking modern pumps, sprinklers, and controls.

Scope of Retrofit: A comprehensive installation was carried out. New hardware included the following:

- **Fire Pumps & Controls:** Two 2850 LPM terrace pumps (electric motor-driven) and one 2850 LPM diesel pump were installed[21]. Additionally, two 180 LPM jockey pumps and two 900 LPM booster pumps were added. All pumps were fitted with soft starters (VFDs) per NBC 2016 requirements, and backed by a new automation/control panel. A dedicated fire pump house (2-hour fire rating) was constructed on the ground level.
- **Water Storage:** A 1,00,000 L underground fire water tank and an 80,000 L rooftop tank (combined for domestic/fire service) were properly retrofitted to be fit for use. Proper cross-tapping ensures domestic supply

S. No	Description	Response
1	Location	IDCO Towers, Janpath, Unit-9, Bhoinagar, Bhubaneswar-751022
2	Year Built	i) Main Building- 1981-1985 ii) Annexe Building- 2000 iii) Multi-level car parking-2015
3	Area (approx)	i) Main building- 13862.40 sqm (B1+GF+10) ii) Annexe Building- 3727.30 sqm (S1+5) iii) Multi-Level car parking- 1459.08 sqm (S1+3)
4	Height (approx)	i) Main Building- 38.85 mtr ii) Annexe Building- 21mtr iii) Multi-Level car parking-9.65 mtr
5	Occupancy (approx)	1200 persons/day (commercial + PSUs +IT offices)
6	Urgency for retrofitting	To adhere to the NBC-2016 guidelines as a matter of life safety, as per the demand received from tenants for fire and life safety and compliance to the Odisha fire department.

Information Box-2

S. No	Earlier provisions (Main Building)	Retrofitting provisions (Main Building)
1	No terrace tank (only hydrant pipe till top with 2.5kg/cm2)	High pressure of 3.5 kg/cm2 at farthest point
2	No provision for diesel pump	The entire pump house was retrofitted to accommodate the 2 Nos hydrant, 2 Nos Jockey and 1 No. Jockey pump.
3	Only the hydrant fire lines installed	Hydrant lines along with sprinkler lines (branch lines included) and valves are installed to distribute the water uniformly to the farthest point
4	The hydrant pumps were operated on DOL	The hydrant and jockey pumps are automated and are operated by VFD
5	No fire doors	Atleast 2 hours fire rated fire doors installed as per the guidelines to create a separate evacuation pathway in the stairway.
6	General provisions without extensive detailing.	Must feature 75mm signage, ventilation, first aid, public address speakers, fireman talk-back, drinking water, and full sprinkler coverage.
7	Lift pressurization was not done	Pressurization of the lifts was done to prevent the entry of the fire into the lift.
8	Suppression system was not installed	Suppression system was installed in the panels to restrict fire due to electrical hazards.
9	UGR and terrace tank capacity- comparatively lower	More than 2,00,000 litres for UGR fire tank and more 20,000 litres (properly waterproofed and retrofitted)
10	Basement- no sprinkler and detection system	Properly installed sprinklers (pendent type wherever required), automated detection and alarm system installed, pressurization and mechanical ventilation was ensured
11	Signage- no strict norms (basic exit signage and arrows)	Done to current standard- equipped against power failures, smoke conditions, long distance visibility which included glow signages.
12	Pump House- no strict norms (basic jockey and hydrant pumps)	Retrofitted to current standard- standby pumps, alternate power supply, diesel pumps. Fire resistant cables, electrical panel protected and ventilation ensured. Also to prevent flooding of the pump house, proper waterproofing of the walls was done (prevent ingress of water through seepage) along with that drainage was provided to divert the flood water.

draws after the fire line tap, per updated NBC guidance.

- **Hydrant/Sprinkler Network:** ~80 m of new internal wet-riser piping was laid (250/150 mm MS GI pipes) to serve all floors. ~30 external yard hydrants (63 mm outlets) were installed around the tower. ~50 new sprinkler heads were fitted in ceilings as per hazard zoning. Copper detection cabling was routed to connect new smoke/heat detectors on each floor to a Fire Detection & Alarm (FDA) panel.

- **Power/Electrical:** Emergency power cabling was run from the electrical panel to feed the new fire pumps, fire alarm panel, exit lighting and lift machine room – satisfying NBC's emergency supply criteria[8]. All electrical conduits in fire shafts were re-insulated and shafts upgraded to 2h fire rating[14].

- **Pump House Constraints:** The existing pump house was entirely inadequate for the new hydrant, jockey, and diesel pumps. Expanding it was an engineering challenge because the pump house was flanked by a drinking water sump on one side and an underground fire sump on the other. The solution required dismantling the existing slab to raise the ceiling height and heavily reinforcing the walls and columns through structural jacketing.

- Detailed Survey and Assessment of existing firefighting system including fire escape route was undertaken and deficiencies were recorded by in-house multidisciplinary team of Arch, Civil, Elect, and PH. Addition and alterations in all components over the years were recorded. An external fire safety expert was hired to give inputs in Planning and implementation. CFO and Odisha Fire Department's vetting was ensured before execution.

Challenges: Installing these systems in an occupied, historic building posed hurdles. Work could only occur nights/holidays in many areas. Cutting through basement floors and roads for underground pipework required coordination and traffic diversion. The original pump room footprint was too small, so a new shaft was excavated beside the existing sump for the additional pumps. Existing false ceilings had to be removed and rebuilt. Also, the retrofit displaced some tenant spaces temporarily (requiring relocation to other floors). Laying sprinkler pipes and detector cables required dismantling diverse, thematic false ceilings and meticulously repairing them to match their original state. Ongoing tenant renovations frequently disturbed the continuity of fire detectors, necessitating constant rework and reprogramming. Installing AHU fire dampers meant shutting down the active HVAC system, dismantling ducts, and refixing them post-installation.

Timeline: The retrofit spanned 2022–2025. Design and approvals took much of late 2022, with construction and installation in beginning of 2023 through spring 2023. System testing and certification were completed by mid-2025.The construction of pump house took much of the time as the previously installed pump house had water tank on one side, fire tank on the other and the road was passing on the front side. So, after careful consideration, all design changes were made implemented.

Cost: The project was similarly high-value. Individual components (panels, pumps, piping, valves) each cost lakhs of rupees[21][23]. Overall contract value was approx 3.2 crores.

Results: Post-retrofit, IDCO Tower now has a modern fire-protection infrastructure. The fire pumps deliver ≥3.5 bar at the furthest hydrants, and flows meet NBC 2016 demands. The building has full sprinkler coverage and electronic detection, with a staffed fire control centre on the main floor (with dedicated phone lines). Fire and evacuation drills show significantly improved response capabilities. Importantly, electrical systems are now segregated and fire-rated where needed, reducing short-circuit risk.

Information Box-3 (photos related to firefighting system of IDCO Towers and Fortune Towers)

LESSONS LEARNED

From these cases and research, several lessons emerge:

- **Upgrading Pumps & Pressure:** Both buildings needed greater pump capacity and pressure. This aligns with NBC 2016's 3.5 bar requirement[12]. Retrofitting often means adding pumps or replacing undersized units.

- **Dedicated Water Supply:** Original single-tank arrangements were insufficient. The retrofits installed large dedicated fire water tanks (with separation from domestic supply)[11], in some cases combining systems with isolation valves (allowed in NBC 2016). Ensuring dedicated, maintained water is crucial.

- **Electrical Fireproofing:** Upgrades to wiring and electrical rooms are as important as mechanical systems. NBC now requires fire-rated shafts and backup power for all fire equipment[14][8]. In practice, this meant adding fire barriers around new conduits and using emergency circuits for alarms/pumps. The suppression system of the panels also plays a major role to check the spread of fire due to electrical faults.

- **Occupant Safety Features:** Exit routes and refuge areas must meet current criteria. For example, fully-sprinklered conditions allow longer travel distances[18]. Retrofits provided additional exits or enlarged stairwells as needed, and added exit lighting/fire lifts.

Fig. 1: Installation of Fire hydrant lines, branch/sprinkler lines and hose reel pipe

Fig. 2: Successful checking done after installation and connection of automated system controller to control the operation of the fire pumps

Fig. 3: The fire control module being installed Successfully after programming to properly Number and loop the detection system

Fig. 4: The retrofitting work of the pump house being done to current standard and to improve performance, safety and lifespan

Fig. 5: Fire Mock drill

Fig. 6: Fortune Towers

Fig. 7: IDCO Towers

- **Tenant Coordination:** Retrofitting an occupied building requires phased work and communication. Both projects worked nights and holidays, and took care to restore tenant spaces. They illustrate the necessity of detailed scheduling.
- **Regulatory Compliance:** Aligning with the latest NBC is non-negotiable. Inspectors now routinely demand compliance with 2016 provisions. These retrofits serve as demonstrations to regulators and occupiers that even old structures can meet modern safety norms.
- **Cost Justification:** Though expensive, the retrofit costs are justified by the vastly improved safety. The tragic hospital ICU fire in Odisha (2026) shows the stakes – lives can be lost when equipment is outdated[4]. Investment in retrofits can prevent such outcomes.

CONCLUSION

High-rise fire safety cannot be static. As codes evolve, existing buildings must be brought up to date. The Fortune Tower and IDCO Tower projects demonstrate how comprehensive retrofits (pumps, tanks, alarms, pipes, rated enclosures) can transform a vulnerable structure into one meeting current NBC standards. These upgrades mitigate the heightened fire risk from electrical and occupancy changes. The history of fire disasters (from the Siddharth Hotel fire[5] to modern Odisha tragedies[4]) underscores that vigilance and modernization save lives. Owners of older high-rises should view retrofitting not as optional but as essential maintenance feature to protect property and people.

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FIRE & LIFE SAFETY DESIGN AND IMPLEMENTATION FOR SCB MCH REDEVELOPMENT, CUTTACK

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Abstract

The redevelopment of Shri Ram Chandra Bhanja Medical College and Hospital (SCBMCH), Cuttack, represents one of India's largest healthcare infrastructure initiatives, aimed at transforming the institution into a world class tertiary care and medical education hub. A critical component of this transformation is the design and implementation of an integrated fire protection and detection system tailored to the unique risks of healthcare facilities, where vulnerable occupants and critical medical services demand uncompromising safety. The system has been developed in compliance with NBC 2016, NFPA, IS codes, and NABH guidelines, combining active fire protection measures—automatic sprinklers, hydrants, suppression systems—with passive strategies such as compartmentation and fire rated construction.

INTRODUCTION

Healthcare infrastructure presents unique challenges in terms of safety, resilience, and operational continuity. Hospitals are highoccupancy buildings with a diverse profile of occupants, including patients, staff, visitors, and nonambulant individuals requiring assisted evacuation. Fire safety in such environments is therefore not only a regulatory requirement but a critical lifesafety imperative. In India, several largescale healthcare projects are underway to meet growing demand, and among them, the redevelopment of Shri Ram Chandra Bhanja Medical College and Hospital (SCBMCH), Cuttack, stands out for its scale and ambition.

Established in 1883, SCBMCH is one of the oldest and most prestigious medical institutions in the country. Today, it caters to approximately 10,000 outpatients daily and operates nearly 2,400 beds, including intensive care and highdependency units. With the rising healthcare needs of Odisha and neighbouring states, the Government of Odisha has initiated a comprehensive redevelopment program to transform SCBMCH into a 5,000bed tertiary care facility, equipped with advanced medical technology and sustainable infrastructure. The project is envisioned as an AIIMS++ category hospital, integrating clinical services, medical education, and research at par with global standards.

Within this transformation, fire protection and detection systems occupy a central role. Hospitals are particularly vulnerable to fire incidents due to the presence of electrical equipment, medical gases, and flammable materials, combined with the difficulty of evacuating patients under treatment. The redevelopment therefore emphasizes a fully integrated fire safety strategy, combining active and passive protection measures, advanced detection technologies, and structured evacuation planning. The design adheres to national and international codes, including NBC 2016, NFPA standards, IS specifications, and NABH guidelines, ensuring compliance and reliability.

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NEED FOR EXPANSION

Since its inception, SCB Medical College and Hospital (SCBMCH) has grown incrementally to meet healthcare demand. However, with the rapid expansion of Cuttack city and Odisha state, the hospital's existing capacity of 2,396 beds is no longer adequate. Daily outpatient attendance exceeds 10,000, and the demand for superspecialty services continues to rise.

To address this, the Government of Odisha has initiated a **mega redevelopment project** across ~136 acres on the banks of the Mahanadi River. The new SCBMCH campus is designed as a **5,000bed tertiary care facility**, with clinical blocks rising to ~45 meters (G+11 floors), a builtup area exceeding **4.5 million sq.ft**, and multiple wings dedicated to medicine, surgery, diagnostics, trauma, and specialty care.

The scale and verticality of the new structures introduce heightened **fire vulnerability**:

- **Highrise occupancy** with complex evacuation requirements.

- **Critical care zones** (ICUs, operating theatres) where patients cannot selfevacuate.
- **Dense medical equipment and electrical load**, increasing ignition risk.
- **Large public areas and courtyards**, requiring external hydrant coverage.

Thus, the redevelopment objectives extend beyond capacity expansion to include **worldclass fire protection and detection systems**. These installations are essential to safeguard vulnerable occupants, ensure continuity of medical services, and align with global standards of healthcare infrastructure safety.

DESIGN CRITERIA & METHODOLOGY

The fire protection and detection system for SCB Medical College and Hospital (SCBMCH) has been developed through a structured methodology that integrates hazard identification, risk assessment, and compliance with national and international codes. Hospitals, classified under Group C1 (Institutional Buildings) in NBC 2016, present unique risks due to the presence of vulnerable occupants, critical medical equipment, and flammable materials. The design therefore emphasizes early detection, rapid suppression, and safe evacuation.

Codes and Standards

The system adheres to **NBC 2016 Part 4**, **NFPA standards**, **IS specifications** (IS 2189, IS 15105, IS 3844, IS 13039), and **NABH guidelines**. These frameworks define requirements for detection spacing, sprinkler density, hydrant placement, and evacuation protocols. Compliance ensures statutory approval and operational reliability.

Hazard Identification

Key hazards include : *Electrical faults and mechanical failures* | *Medical gas leakage and flammable storage* | *Humanrelated risks such as negligence or procedural lapses*. Risk assessment was conducted to evaluate fire load, occupant vulnerability, and evacuation complexity. This informed equipment sizing, compartmentation strategy, and redundancy provisions.

Methodology

The design process followed a **layered approach**:

- **Active Fire Protection (AFP):** automatic sprinklers, hydrants, suppression systems, smoke extraction, and addressable detection.
- **Passive Fire Protection (PFP):** firerated walls, compartmentation, fire doors, and structural coatings.
- **Evacuation Planning:** zoned evacuation strategy, integrated public address system, and assisted evacuation provisions for nonambulant patients.
- **Integration with BIM:** clash detection, realtime monitoring, and linkage with Primavera scheduling for construction safety.

This methodology ensures that fire safety is embedded into the hospital's operational framework, balancing technical compliance with patientcentric evacuation strategies.

SYSTEM OVERVIEW

The fire protection and detection framework at SCB Medical College and Hospital (SCBMCH) has been conceived as a multilayered system, integrating active and passive measures to ensure comprehensive safety in a highrisk healthcare environment. The clinical blocks, each rising to approximately 45 meters, accommodate diverse functions ranging from general medicine to specialized surgery, necessitating a robust and adaptable fire safety strategy.

Active Fire Protection

Active systems include automatic sprinklers, internal and external hydrants, gas suppression in critical areas, and kitchen hood suppression systems. A fully addressable fire detection and alarm network, comprising over 10,000 smoke detectors and 393 manual call points, provides early warning and precise fire localization. Integration with public address systems, smoke extraction fans, pressurization units, and building management systems ensures coordinated emergency response.

Passive Fire Protection

\Passive measures are embedded into the building fabric, with firerated walls, doors, and compartmentation designed to contain fire spread. Structural elements are protected with vermiculite coatings, enhancing resilience under hightemperature exposure. These provisions support phased evacuation by maintaining safe zones and escape routes.

Evacuation and Emergency Response

The evacuation strategy is tailored to hospital operations, emphasizing assisted evacuation for nonambulant patients. Zoned evacuation, supported by clear signage and voice guidance, minimizes panic and ensures orderly movement. Smoke control systems maintain visibility and breathable air along escape paths, while firefighter telephone jacks and hydrant cabinets enable coordinated intervention.

Integration and Monitoring

All systems are designed in compliance with NBC 2016, NFPA, IS codes, and NABH guidelines. Building Information Modelling (BIM) has been employed for clash detection, coordination, and realtime monitoring, linking fire safety systems with project scheduling and facility management. This integrated approach ensures reliability, redundancy, and operational continuity in a complex healthcare setting.

TECHNICAL SPECIFICATIONS

The fire protection and detection system at SCB Medical College and Hospital (SCBMCH) has been designed to comply with NBC 2016, NFPA, IS codes, and NABH guidelines. However, given the unique operational profile of a large tertiary hospital, several **departures and enhancements** were necessary to ensure patient safety and continuity of care. This section highlights those key specifications and deviations.

Detection and Alarm Systems

Approximately 10,022 multicriteria smoke detectors and 65 heat detectors have been installed, exceeding minimum code requirements. The departure lies in the **density of coverage**: detectors are spaced closer than the maximum permissible limits to account for complex ceiling geometries, air movement from HVAC systems, and the need for rapid detection in critical care areas. Manual call points are positioned at ≤30 m travel distance, with redundancy to ensure accessibility even during partial evacuation.

Sprinkler & Hydrant Systems

Sprinkler spacing was reduced to ensure no coverage gaps in areas with obstructed ceilings, medical equipment, or suspended services. The total installation of ~55,000 sprinklers (pendent, upright, sidewall) represents a scale significantly beyond typical healthcare facilities, reflecting the hospital's size and patient load.Internal hydrants (~407 units) are strategically located near staircases and fire lobbies, with hose lengths calculated to cover entire floor plates. External hydrants were added beyond code minimums to support firefighting access in congested hospital courtyards. This departure ensures redundancy in case internal systems are compromised.

Pumping Systems

The pumping arrangement includes electrical and dieseldriven hydrant and sprinkler pumps, jockey pumps, and water curtain pumps. Departures include **dual standby diesel pumps** (instead of one) due to the large number of hydrants (>100) and the criticality of uninterrupted supply. Terrace booster pumps were added in UB1, Town Centre, and Fire Station blocks to maintain pressure in localized zones, exceeding standard requirements.

The pumping arrangement for CN1–CN4 and UB1–UB2 blocks is common, serving both basement and superstructure. To ensure redundancy and reliability, the following pump sets were considered.\

Water Storage

Codes mandate dedicated fire water storage, but SCBMCH adopted **segregated compartments** (2 × 250 cu.m) to ensure redundancy. Terrace tanks

Table 1: Pumping system configuration for CN and UB blocks.

Description	Drive	Capacity	Pressure	Quantity	Remarks
Hydrant Pump	Electrical Driven	2850 lpm	10.5 bar	1	1. No. of Hydrants greater than 100 Nos. 2. Utility Block-2 (Basement)
Sprinkler Pump	Electrical Driven	2850 lpm	10.5 bar	1	
Stand-by Pump	Diesel Engine Driven	2850 lpm	10.5 bar	2	
Jockey Pump	Electrical Driven	180 lpm	10.5 bar	2	
Water Curtain Pump	Electrical Driven	1620 lpm	5.0 bar	1	
Water Curtain Pump	Diesel Engine Driven	1620 lpm	5.0 bar	1	

(10–20 cu.m per block) provide localized reserves, a departure aimed at supporting immediate response in case of pump failure or delay.

The inclusion of dual standby diesel pumps and terrace booster pumps represents a deliberate departure from standard practice, ensuring uninterrupted supply across highrise blocks.

Passive Fire Protection

Beyond standard compartmentation, SCBMCH introduced **firerated zones tailored to hospital functions**: operating theatres, ICUs, and diagnostic labs are isolated with higher fireresistance ratings. Vermiculite coatings were applied to structural steel in critical blocks, exceeding minimum requirements to ensure structural integrity during prolonged fire exposure.

Evacuation Strategy

Codes prescribe phased evacuation, but SCBMCH adopted a **zoned evacuation model** integrated with voice guidance and smoke control. This departure reflects the difficulty of evacuating nonambulant patients and ensures that evacuation can be localized without disrupting critical care operations elsewhere.

Integration and Monitoring

A major innovation is the **BIMenabled monitoring system**, linking fire safety installations with Primavera scheduling and facility dashboards. This goes beyond code compliance, enabling realtime tracking of fire system performance, maintenance, and emergency readiness.

CHALLENGES AND INNOVATIONS

The redevelopment of SCB Medical College and Hospital (SCBMCH) presented several challenges that directly influenced the fire protection and detection design. The foremost difficulty was the requirement to maintain uninterrupted hospital operations during construction. With over 10,000 outpatients daily and nearly 2,400 inpatients, any disruption to clinical services was unacceptable. This necessitated phased construction and careful sequencing of fire safety installations, ensuring that existing facilities remained functional while new systems were integrated.

Another challenge was the **availability of skilled manpower** for specialized tasks such as highrise welding, installation of addressable detection systems, and commissioning of largecapacity pumps. The scale of the project demanded workforce training and strict adherence to safety protocols, which slowed progress but ensured quality and compliance. In response, several innovations were introduced. **Building Information Modelling (BIM)** was employed not only for clash detection but also for realtime monitoring of fire safety installations, linking them with Primavera scheduling to track progress and compliance. The hospital adopted **IGBC Green Hospital standards**, integrating energyefficient materials, solar power, and rainwater harvesting with fire safety infrastructure. Advanced **ELV systems**—including nurse call, pneumatic tube transport, and asset management—were integrated

Table 2: Fire water storage and distribution capacities

S. No.	Compartments/ Building	Fire water Tank Capacity / Over Head Tank Capacity	Remarks
1	Compartment – 1	250 cu.m	Location: UB-2
2	Compartment – 2	250 cu.m	Systems: Hydrant, Sprinkler & Water Curtain System
1	CN-1	20 cu.m	1 **No**
2	CN-2	20 cu.m	1 **No**
3	CN-3	20 cu.m	1 **No**
4	CN-4	20 cu.m	1 **No**
5	UB-1	10 cu.m	1 **No**
6	UB-2	20 cu.m	1 **No**
7	Fire Station	10 cu.m	1 **No**
8	Town Center	20 cu.m	1 **No**

with fire detection and evacuation systems, creating a smart hospital environment.

Most significantly, the project introduced **zoned evacuation with voice guidance**, tailored to the needs of nonambulant patients, and **redundant pumping and water storage systems** to ensure reliability under all conditions. These departures from conventional practice highlight how SCBMCH sets a benchmark for fire safety in largescale healthcare infrastructure.

DISCUSSION

The redevelopment of SCB Medical College and Hospital (SCBMCH) demonstrates how fire protection in healthcare infrastructure must go beyond minimum code compliance to address operational realities. Conventional design standards such as NBC 2016 and IS codes provide baseline requirements, but they do not fully capture the complexity of evacuating nonambulant patients, maintaining continuity of critical care, or integrating fire safety with advanced hospital systems. SCBMCH's approach—closer detector spacing, higher sprinkler density, redundant pumping, and zoned evacuation—illustrates how departures from standard practice can significantly enhance resilience.

The lessons from SCBMCH are broadly applicable: healthcare facilities must adopt a patientcentric fire safety philosophy, prioritize redundancy in active systems, and integrate passive measures with operational planning. By doing so, hospitals can ensure not only compliance but also resilience, safeguarding both lives and infrastructure in highrisk environments. Unlike many tertiary hospitals in India where fire safety remains codeminimum, SCBMCH demonstrates how redundancy and integration can redefine resilience in healthcare infrastructure.

CONCLUSION

The redevelopment of SCB Medical College and Hospital (SCBMCH), Cuttack, demonstrates how fire protection in healthcare infrastructure must be conceived as a comprehensive, patientcentric framework rather than a compliance exercise. By integrating active and passive fire safety measures, adopting zoned evacuation tailored to nonambulant patients, and embedding redundancy in pumping and water storage systems, the project goes beyond conventional standards to address the unique risks of a large tertiary hospital.

Departures from codeminimum requirements—such as closer detector spacing, higher sprinkler density, dual standby pumps, and enhanced compartmentation—reflect a deliberate strategy to safeguard vulnerable occupants and critical medical services. The use of BIM for coordination and monitoring, coupled with IGBC Green Hospital standards, further illustrates how safety, sustainability, and digital innovation can be harmonized in modern healthcare design.

SCBMCH thus sets a benchmark for fire safety in Indian healthcare infrastructure, offering lessons in resilience, redundancy, and integration that can guide future hospital projects across the country.

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FIRE SERVICES IN HIGH-RISE HOSPITAL BUILDINGS

D.S. Panwar* and Kuldeep Sharma**

Abstract

Health facilities are critical in responding to emergencies and disasters. Health care facilities are the frontline agencies that required to remain prepared for any hazardous event and first one to come in response action with other frontline agencies immediately as soon as the hazardous event strikes. And for this reason, it is very essential to ensure that the health facilities remain structurally safe and functional all the time. The recent incidents of fire in hospitals stressed on the need for necessary preventive, mitigation and preparedness measures to be taken by health facilities to avert or minimize the impact of any such fire hazard incidents.

Firefighting system in high-rise hospital buildings are critical complex networks combining active suppression (sprinklers, hydrants), early detection (smoke sensors), and passive containment(compartmentation) to protect patients who cannot evacuate immediately. Key components include pressurized stairwells, dedicated fire lifts, automatic sprinkler systems and reliable emergency power. In high rise hospitals, the strategy focuses on defend in place (managing the fire in the zone of origin) and horizontal evacuation before vertical evacuation.

This paper presents fire service approaches including smart detection systems, advanced sprinklers and water mist systems, intelligent smoke control, and integrated building management systems along with best practices for planning, design, and operation of high hospital buildings.

INTRODUCTION

Healthcare facilities represent one of the most critical categories of buildings from a fire safety perspective. Unlike office buildings, shopping malls, or residential complexes, hospitals accommodate occupants who may be unconscious, immobile, elderly, or dependent on life-support equipment. Consequently, evacuation during a fire emergency becomes considerably more complex.

The increasing demand for tertiary healthcare services in metropolitan cities has encouraged vertical development of hospitals. Multi-specialty healthcare facilities with heights exceeding 30 m are now common in Delhi, Mumbai, Bengaluru, Hyderabad, and other urban centers.

A study published by Juyal, S., Tabassum-Abbasi, et.al on "An Analysis of Failures Leading to Fire Accidents in Hospitals; revealed that 49% of the fires were seen in Private hospitals and 51 % in Government hospitals. 50 % of the hospitals were found to be non-compliant with the Safety Norms.

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In high-rise hospitals, fire safety engineering must address not only life safety but also continuity of healthcare operations. Even a localized fire incident can disrupt critical services, resulting in significant operational and social consequences.

UNIQUE FIRE RISKS IN HIGH-RISE HOSPITALS

Electrical Installations

Modern hospitals contain extensive electrical infrastructure supporting diagnostic equipment, HVAC systems, lighting, elevators, information technology networks, and life-support equipments.

Common causes of fire includes:

- Overloaded electrical circuits
- Loose electrical connections
- Improper cable termination
- Failure of UPS and battery systems
- Inadequate preventive maintenance

Medical Gas Pipeline Systems

Medical oxygen significantly increases combustion intensity. Leakage from oxygen pipelines, manifolds, or cylinders can create oxygen-enriched atmospheres where ordinary combustible materials ignite rapidly.

HVAC Systems

Air-conditioning systems can contribute to smoke migration if smoke dampers fail or maintenance is inadequate. In many fire incidents, smoke rather than flame has been responsible for casualties.

Combustible Materials

Hospitals contain large quantities of combustible materials including:

- Linen
- Mattresses
- Medical records
- Disposable medical products
- Packaging materials

NBCS REQUIREMENTS FOR HIGH-RISE HOSPITAL BUILDINGS

The National Building Construction Standards (NBCS) 2026 classifies hospitals under Institutional Occupancy.

Major fire safety provisions include:

NBCS Requirements for High-Rise Hospitals:

Component	Requirement
Automatic Sprinklers	Mandatory
Wet Riser System	Mandatory
Fire Detection System	Addressable System Preferred
Fire Detection System	Mandatory
Fire Lift	Mandatory
Refuge Area	As per NBCS Provisions
Fire Command Centre	Mandatory
Staircase Pressurization	Mandatory
Emergency Power Supply	Mandatory

The NBCS emphasizes compartmentation, protected escape routes, smoke management, and redundancy in critical fire protection systems.

- As per National Building Code Standard (NBCS) of India 2026 (Part F), it is important to limit the spread of fire in special/high rise buildings, usually through the use of fire barriers.
- The compartmentation can be achieved with following type of construction/type of fire barrier with protected openings:

  a) Type A — Masonry construction with fire rated door assembly;

  b) Type B — Fire rated fabric dropdown curtain assembly;

  c) Type C — Fire rated glazed partition and door assembly;

  d) Type D — Fire rated gypsum board/ cementitious board assembly;

  e) Type E — Masonry construction with fire rated metal sliding door

How Compartmentation Works?

Containment: Elements like fire doors, walls, and glazing are engineered to withstand fire for a specified duration (e.g., 60 to 240 minutes), ensuring thereby that fire does not easily jump to adjoining rooms/ floors.

Protected Routes: It isolates high-risk areas from essential escape corridors & stairwells, creating clear paths for evacuation.

Concealed Space Blocking: Cavity barriers and intumescent seals are used in hidden ceiling voids or gaps around pipes to prevent smoke and flames from bypassing fire-rated walls.

Key Benefits

- **Life Safety:** Gives occupants ample time to escape multi-story buildings or large complexes.
- **Property Protection:** Limits the total area destroyed by a blaze, minimizing structural damage and financial loss.
- **Firefighter Access:** Slows the progression of the fire, allowing emergency services to enter the building safely and tackle the source

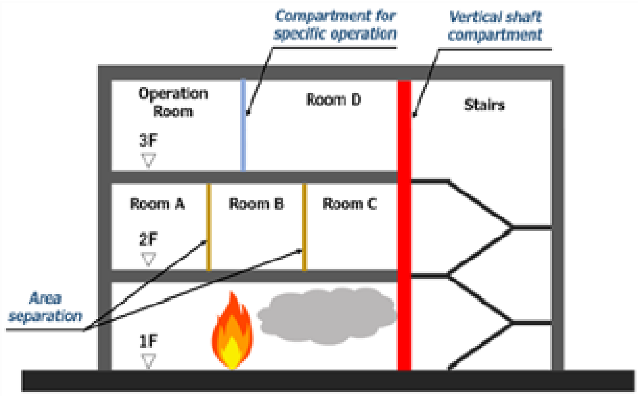


Plate:1

FIRE PROTECTION STRATEGIES

Passive Fire Protection

Passive protection forms the foundation of hospital fire safety.

- The passive measure includes:
- Fire-resistant walls
- Fire-rated doors
- Fire-stopping of service penetrations
- Compartmentation
- Protected staircases

Compartmentation is particularly important because it facilitates horizontal evacuation.

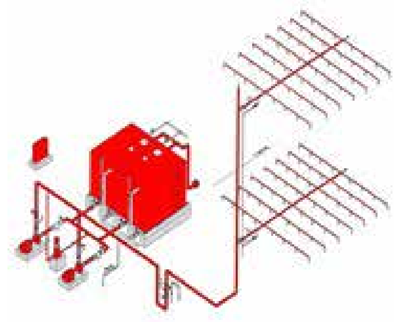
Active Fire Protection

Active systems provide early detection and suppression.

The active measure includes:

(a) Automatic sprinkler systems.

- Designed to automatically detect and suppress fires at their earliest stages, it controls flames and prevents them from spreading without the need for human intervention.
- Thus, Sprinkler has two functions to perform i.e. to detect fire and then to provide adequate distribution of water to control or extinguish it.



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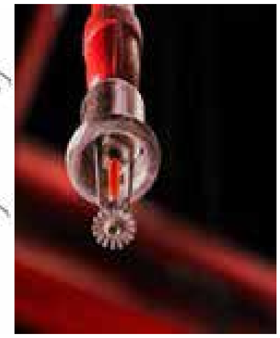

Plate:3

(b) Wet riser systems.

- Fixed, internal firefighting System permanently charged with pressurized water.
- Designed for high-rise buildings, provides firefighters instant access to water on every floor without delay of manually filling the pipes or relying on external fire truck pumps.

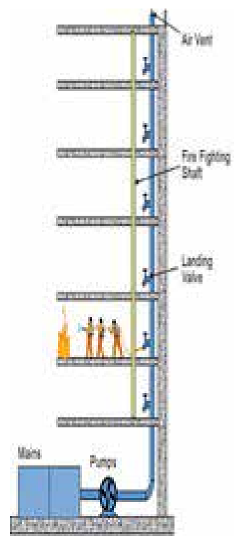

Plate:4

(c) Hose reels.

- The starting of terrace pump shall be automatic i.e. with the opening of any hydrant valve or hose reel on any floor, the pump will start automatically with fall in line pressure. In addition, start/stop push buttons shall be provided at ground floor near internal hydrant for starting the pump manually. Where fire control room has been provided, remote operation of terrace pump may be done from fire control room in place of near internal hydrant. The control panel for terrace pumps shall be provided near the pumps in a suitable enclosure to avoid unauthorized operation.

(d) Portable extinguishers.

- Portable fire extinguishers serve as the first line of defense for controlling small, incipient fires in hospital buildings. Because hospitals contain highly vulnerable patients and sensitive equipment, staff training, quick accessibility, and the use of specialized extinguisher types are critical for effective fire management.

Plate:5

(e) Fire alarm systems.

- Designed to detect early signs of fire & alert occupants, Includes smoke detectors, heat sensors, and Manual Call Boxes (MCB).
- All terminated into a Fire Control Panel

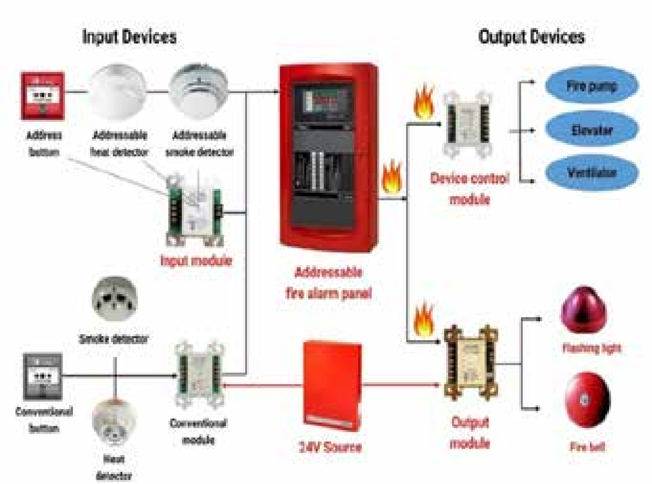

Plate:6

(f) Public address systems.

- An electronic sound amplification and distribution system with a microphone, amplifier, and loudspeakers, to allow a person to address a large public.

Plate:7

Smoke Management

Effective smoke management is essential because smoke inhalation is a major cause of fatalities.

Key provisions include:

- Staircase pressurization
- Lift lobby pressurization
- Smoke extraction systems
- Smoke dampers

ENGINEERING CHALLENGES OBSERVED IN PRACTICE

Based on observations from public healthcare projects, several recurring challenges are encountered.

Space Constraints

Hospital architects often face pressure to maximize usable clinical space. As a result, fire engineering requirements such as fire tanks, pump rooms, refuge areas, and fire shafts may receive inadequate consideration during early planning stages.

Coordination Between Services

Fire services interact with architecture, electrical systems, HVAC systems, plumbing, and structural engineering.

Typical coordination issues include:

- Pipe routing conflicts
- Inadequate shaft dimensions
- Obstruction of sprinkler coverage
- Improper placement of detectors

Post-Handover Maintenance

One of the most significant challenges is maintaining fire protection systems after commissioning.

Common observations include:

- Isolated sprinkler valves left closed
- Non-functional detectors
- Corroded hydrants
- Defective fire pumps

CASE STUDY 1 : LESSONS FROM THE AMRI HOSPITAL FIRE, KOLKATA

The fire at AMRI Hospital in Kolkata (09.12.2011) highlighted the catastrophic consequences of inadequate fire safety management.

Plate:8

The fire began in the basement where a pharmacy and the godown were located. The area was stacked with highly combustible material such as PVC pipes, mattresses, oxygen and LPG cylinders, and even mobil(engine oil). When the fire was sparked off, dense smoke started billowing out of the basement and entered the upper floors catching many persons unaware in their sleep.

Observed Issues:

- Smoke spread through building areas
- Difficult evacuation conditions
- Inadequate emergency response coordination
- Delayed occupant notification

Engineering Lessons

1. Smoke control is as important as fire suppression.
2. Escape routes must remain free of obstructions.
3. Emergency preparedness training is essential.
4. Fire detection systems must be fully functional at all times
5. No combustible materials to be stored in basements

CASE STUDY 2 : AHMEDABAD HOSPITAL FIRE DURING COVID-19 PERIOD

A devastating fire broke out in the ICU ward on the top floor of Shrey Hospital on 06.08.2020, which was treating COVID-19 patients.

Plate:9

Key Findings

- Electrical systems were implicated
- ICU patients faced evacuation challenges
- Healthcare staff became first responders

Lessons Learned

- Critical care units require enhanced fire monitoring.
- Electrical safety audits should be periodic.
- Staff training must include patient relocation procedures.

OBSERVATIONS FROM GOVERNMENT HEALTHCARE PROJECTS

Experience from government healthcare infrastructure projects indicates that fire safety challenges extend beyond code compliance.

Common Design Observations

- Provisions of NBCS should be strictly incorporated in design
- Fire safety considerations are sometimes introduced late in project development.

- Future expansion requirements are not always accounted for.
- Fire consultant involvement is occasionally limited to approval stages.

Construction Stage Observations

- Fire stopping around cable penetrations is often overlooked.
- Sealing of electrical services shafts are not done
- Fire doors may be replaced with non-compliant alternatives.

Operational Stage Observations

- Fire drills are not always conducted regularly.
- Fire safety awareness among staff varies considerably.
- Maintenance records may not be systematically maintained.

EMERGENCY EVACUATION OF HIGH-RISE HOSPITALS

Unlike conventional buildings, hospitals typically follow a phased evacuation strategy.

Phase 1 – Horizontal Evacuation

Patients are moved to an adjacent fire-safe compartment.

Phase 2 – Vertical Evacuation

If conditions worsen, occupants are relocated to lower floors.

Hospital Evacuation Hierarchy

Fire Origin

↓

Horizontal Evacuation

↓

Safe Compartment

↓

Vertical Evacuation

↓

Assembly Area

Challenges

- Bedridden patients.
- Ventilator-dependent patients.
- Limited staff availability.
- Time-sensitive medical procedures.

EMERGING FIRE SAFETY CONCERNS

Modern hospitals are increasingly adopting new technologies that introduce additional risks.

Battery Energy Storage Systems

Lithium-ion batteries used in UPS systems require specialized fire protection measures.

Solar Photovoltaic Systems

Rooftop solar installations create electrical hazards during firefighting operations.

Smart Hospitals

- Integration of digital systems offers opportunities for:
- Remote monitoring.
- Predictive maintenance.
- Intelligent fire detection.

TECHNOLOGIES FOR FUTURE FIRE-FIGHTING SYSTEM.

- Electric vehicles: These vehicles reduce fuel costs, emissions, noise, providing equipment with more space, power & flexibility.
- Mobile computing: Mobile devices like smartphones, tablets, and wearables can offer firefighters access to all essential information, i/c building plans, medical records, incident reports, and weather conditions besides more innovative team communications, video streaming, remote control, and situational awareness.
- Drones and robots: Drones and robots can assist firefighters and teams in performing tasks that are too dangerous or complicated for humans, such as reconnaissance, surveillance, mapping, search and rescue, water delivery, ventilation, and chemical detection. They can also give thermal imaging, live video feeds, and data analysis.

- Wearable Technology: Firefighters can benefit from wearable technology such as smart helmets/ suits that can monitor vital signs and provide real-time data on the wearer's health. This can help prevent injury & improve safety.

FUTURE PERSPECTIVE

The future of firefighting is always evolving, and new firefighting technology has helped keep firefighters safe and increased their ability to more effectively put out blazes in many different settings. Arguably, the most impactful and significant of these recent technological advances are firefighting robots.

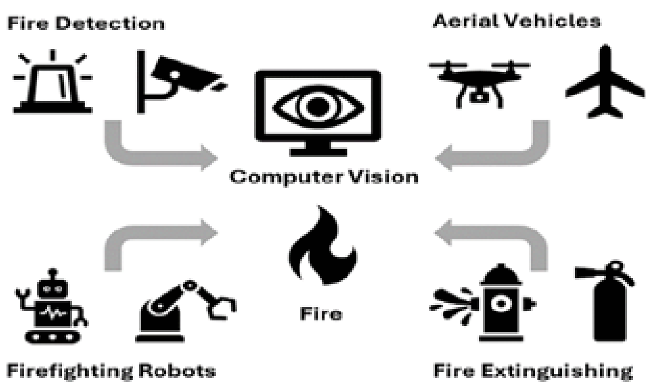

Plate:10

RECOMMENDATIONS

Based on the study, the following recommendations are proposed:

1. All statutory and regularity compliance to be strictly implemented by the management not only to get adequate NOCs but in view to safeguard life of people

2. Disaster management plan to be prepared and implemented at site providing clear-cut guidelines to staff and concerned about actions in various emergency scenarios. The plan to be followed up with training of staff and continual improvements through on site mock drills.

3. Firefighting / life safety systems to be commissioned and to be maintained in a Ready to Operate condition all the time Fire safety planning should begin at concept stage.

4. All emergency staircases and lifts should open in enclosed lobby (that can be pressurized by blowers upon activation of fire alarm) to avoid vertical smoke and flame travel. At least one emergency staircase shall open directly outside building at Ground floor for safe evacuation and rescue.

5. Fire vehicle approach: Approach and peripheral roads to be designed to cater 20 meter turning radius for Fire Tender / Hydraulic Ladders and should be capable of taking 40 tons load of Fire Vehicle.

6. Hospitals should adopt risk-based fire safety management.

7. Fire consultants should be involved throughout project development.

8. Third-party fire safety audits should be mandatory.

9. Staff training should be conducted at regular intervals.

10. Digital monitoring of fire protection systems should be encouraged.

11. Fire compartmentation integrity should be verified periodically.

12. Electrical safety audits should be undertaken annually.

13. Hospital administrators should prioritize maintenance budgets for fire protection systems.

14. Mock drills should include realistic patient evacuation scenarios.

CONCLUSION

Fire safety in high-rise hospital buildings is a multidisciplinary challenge requiring coordinated efforts from architects, engineers, hospital administrators, and fire authorities. While NBCS 2026 provides a robust regulatory framework, actual safety depends on effective implementation, maintenance, and emergency preparedness.

Experience from Indian hospital fire incidents demonstrates that code compliance alone is insufficient. Fire safety systems must remain operational throughout the building life cycle, and staff must be adequately trained to respond to emergencies. Future healthcare facilities should integrate intelligent monitoring systems, robust compartmentation strategies, and comprehensive maintenance programs to enhance resilience.

The ultimate objective of fire safety engineering in hospitals is not merely regulatory compliance but the protection of vulnerable occupants and the uninterrupted delivery of healthcare services.

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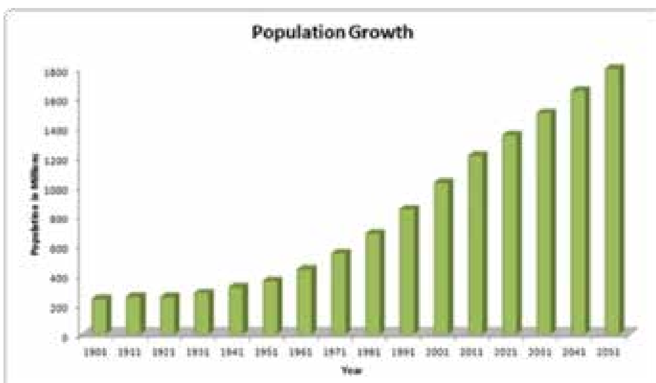
SERVICES IN HIGH-RISE BUILDINGS

K.T. Gurumukhi* and Kishore Gurumukhi**

Abstract

As India faces an unprecedented urban transition with a projected population of 1.8 billion by 2050, high-rise development has shifted from an architectural choice to a strategic necessity for national resilience. This paper explores the critical role of vertical development in addressing developable land scarcity and the economic inefficiencies of urban sprawl, noting that compact cities can reduce infrastructure costs by two to three times per capita compared to horizontal expansion. The paper provides a technical review of essential building services—including fire safety, vertical transportation, plumbing, and electrical systems, emphasizing that service reliability is fundamental basis for habitability in tall structures. It highlights the transformative impact of modern technology, such as AI-powered fire detection, smart water management, and integrated Building Management Systems (BMS), in enhancing efficiency and safety. Ultimately, the paper argues that for India to achieve; "Viksit Bharat" and futuristic vision, it must adopt a National High-Rise Building Services Policy to standardize technology and service benchmarks. It concludes by advocating for transit-oriented development and simplified building regulations and standards to create livable, sustainable, and climate-resilient urban centers.



URBANIZATION SCENARIO IN INDIA AND NEED FOR HIGH-RISE BUILDINGS

India's urban population is rapidly rising: from 1.4 billion and 65 metro cities (2021) to an estimated 1.8 billion in cities by 2050, with 14–15 megacities. By 2100, India could approach 2.8 billion people, 65–70% urban, and 20–25 megacities. Current megacities (2021) include Delhi NCR 35.5Mn, Mumbai MMR 27.7Mn, Kolkata KMR 14.1Mn, Bangalore BMR 14.8Mn, Chennai 13.0Mn, Hyderabad 11.6Mn, Pune 7.6Mn. Such growth will strain land, services, and spatial expansion choices (horizontal vs vertical).

Urbanization in India is driven by rural-to-urban migration and growth in IT, services, logistics, and manufacturing, concentrating demand near employment hubs and sharply increasing housing, rental, and social infrastructure needs. Poorly planned growth can overwhelm civic capacity and deepen inequality between formal and informal settlements.

Urban sprawl or horizontal growth is costly: sprawling cities often incur two to three time higher per capita costs for roads, water, sewerage, power distribution, and public transport than compact, vertical cities. Such development also worsens traffic congestion, travel times, water scarcity, and sewerage Challenges, highlighting the importance of national programs like Smart Cities Mission and AMRUT and the case for compact, high-rise development.

WHY THE HIGH RISE BUILDING? AND IT'S BENEFITS

Given economic challenges of horizontal sprawl across megacities, vertical development is the preferred compact growth strategy, familiar in landmarks like Empire State Building, World Trade Centre, and skyscrapers in London, Tokyo, Paris, and Dubai. Rising land and service costs, multimodal transport, water, sewerage, drainage, communications, firefighting systems, AC plants, and maintenance make highrises attractive because they reduce strain on urban infrastructure and improve connectivity.

High-rises offer major land efficiency: a single tower can house thousands on a small footprint,

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preserving agricultural edges, wetlands, and open space. Environmentally, well-designed towers with green roofs, terraces, vertical gardens, and energy-efficient envelopes can reduce urban heat islands. Higher FSI unlocks land value, and mixed-use vertical projects; sustain property values in well-served urban corridors. Vertical development allows to accommodate, contribute directly to city GDP by creating employment, attracting investment, and sustaining property value in well-served urban centers.

CHALLENGES IN SERVICES OF HIGH-RISE BUILDINGS

The challenge is the complexity of integrated systems. Plumbing, electrical networks, fire safety systems, access control are interdependent systems; that must work in harmony every minute. A fault affect others so, service reliability is not a luxury, but it is the basis of habitability. Maintenance becomes harder with height and age: façade cleaning, sealant replacement, lift servicing, pump houses, and mechanical upkeep are difficult as buildings age and are often deferred, turning small defects into major performance failures.

The cost of neglect in high-rise is always higher than the cost of routine care. Water pressure and supply assumes acute in tall buildings. Fire safety is critical and complex. Evacuating thousands from towers beyond firefighting reach requires smoke management, refuge areas, pressurized stairwells, protected lobbies and dependable communications, which become essential.

WHAT IS A HIGH-RISE BUILDING?

A “tall building” is a multi-story structure in which most occupants depend on elevators or lifts to reach their destinations. However, a high-rise building can be defined as follows:

- “Any structure where the height can have a serious impact on evacuation” (The International Conference on Fire Safety in High-Rise Buildings), if adequate safety measures are taken.
- “For most cases, high-rise buildings are around 10 to 12 stories. Sometimes, even higher stories are defined as high-rise; the definition applies to more stories.
- “Generally, a high-rise structure is considered to reach beyond the range of fire-fighting equipment.

“The word skyscraper is just as it sounds, cosmetic, rather exaggeratedly said to communicate people’s excitement about tall buildings. In reality, its meaning has changed in recent years. Today, the word high-rise is used to describe building of more than twenty to fifty stories. “Most European cities, like London, Paris, East Asian cities like Tokyo, Hong Kong, Singapore and Kuala Lumpur, have accepted tall buildings. Today, most countries are giving up horizontality in favor of vertical scale due to pressure on land and very high per-unit land prices. Therefore, a high-rise building can be defined as “any structure where height extends higher than maximum reach of available fire-fighting equipment.”

DEFINING HIGH RISE DEVELOPMENT OF THE BUILDINGS

It is clear that planning norms and standards prepared by state agencies such as the Town and Country Planning Department or the State Urban Development Authority cannot be applied uniformly to all cities, including metro and mega cities. Each city needs its own planning norms and building bye-laws or standards. At the same time, fire safety regulations, as well as norms for services need to be in accordance with the National Building Construction Standards, 2026.

Transit-Oriented Development (TOD) is especially important if high-rise clusters located in the area within half a kilometer or a kilometer radius of metro stations, bus terminals, and other transport hubs. This approach reduces private vehicle dependence, lowers traffic load on major roads, improve livability within a compact urban structure.

TYPES OF HIGH-RISE BUILDINGS: Can be categorized as -

- High-rise buildings from 10 to30 stories
- Super high-rise buildings: 31 to 50 stories

- Skyscrapers: 51 stories and above

The building has a major influence on security, fire, life safety. There are different types of high-rise buildings classified according to primary use.

1. OFFICE BUILDINGS: An office building is a "structure designed for the conduct of business, generally divided into individual offices, offering space for rent or lease."
2. HOTEL BUILDINGS: "The term 'hotel' is an all-inclusive designation for facilities that provide comfortable lodging, food, beverage, entertainment, a business environment, and services away from home."
3. RESIDENTIAL AND APARTMENT BUILDINGS: A residential building contains separate residences where a person may live. Each residence contains cooking and toilet known as apartment.
4. MIXED-USE BUILDING: A mixed-use building may contain offices, apartments, and hotel rooms in separate sections of the same building. Hotel residences have kitchens, amenities and services.
5. INSTITUTIONAL BUILDINGS: Include hospitals, educational institutions, corporate/ government offices that are increasingly designed to serve urbanites.

CONSTRUCTION OF HIGH-RISE BUILDINGS

Historically, high-rise buildings and tall structures were built, like the Pyramids and towers like Tower of Pisa, Eiffel Tower, and Statue of Liberty, all have become landmarks and tourist attraction. Advancements in technology have significantly influenced design of high-rise buildings and expanded their use, making them more convenient and comfortable. Empire State Building, 319 meters, World Trade Center, 415 meters, became landmarks - 8th wonder of the world.

In India, height of high-rise buildings was limited to 26 to 30 meters as per building bye-laws. Practicality and convenience such multi-story structures relied on elevators or lifts as vertical transportation systems. The construction of high-rise buildings for hotels, offices, mercantile buildings, residential apartments, and mixed-use buildings has extended to 50 to 120 floors. In Mumbai, super-tall residential skyscrapers at Worli, with 117 floors and height of 442 meters, have been built due to very high land prices and limited scope for expansion. Similarly, in other cities—Delhi, Kolkata, Chennai, Bangalore, Hyderabad, and Pune—super tall towers have come up.

TECHNALOGY IN SERVICES OF HIGH-RISE BUILDINGS

Fire detection and AI-powered smoke detection systems can distinguish between actual fire and false alarms such as cooking smoke or steam, while improving safety. Addressable fire alarm systems pinpoint the exact location of fire, helping responders to act quickly and accurately. Several high-rise buildings in Singapore used AI-integrated fire detection systems reducing false alarm by over 60%.

Water and energy management systems are transformed by technology. Smart water meters, leak detection sensors, automated pressure management helps building operators, reduce loss and maintain more stable supply across different floors. On the energy side, solar panels, wind turbines, and battery energy storage systems (BESS) are integrated into towers to improve resilience and reduce dependence on the grid. The Pixel Building in Melbourne is often cited as a net-zero energy high-rise that generates all its energy through rooftop solar, wind, biogas system. In Indian context, adoption is growing. Indian high-rise developers and government agencies started technology mandated for government projects above a certain cost threshold.

FIRE PREVENTION

Covering aspects of fire prevention pertaining to the design and construction of buildings:

a) Passive fire protection measures, describing the various types of building materials and their fire ratings;

b) Life safety — covering life safety provisions in the event of fire and similar emergencies, addressing construction, occupancy features necessary to minimize danger to life from fire, smoke, fumes;

c) Fire protection — covering the significant appurtenances and their related components, along with guidelines for selecting the correct type of equipment and installation for fire protection depending upon classification, type of building.

- Passive fire protection includes fire-rated walls, fire doors, floor compartmentalization, and sealed openings that slow the spread of flames and smoke from one zone to another.
- Life safety systems include refuge floors, pressurized stairwells, emergency signage, and safe evacuation pathways that help occupants exit efficiently during an incident.
- Fire protection equipment include sprinkler systems, portable fire extinguishers, fire hose reels, dedicated fire control rooms to coordinate emergency response within the building.

GENERAL BUILDING REQUIREMENTS

FIRE SAFETY PLAN AND EXIT DIRECTIONS – It is important to display fire safety measures clearly to ensure that exit direction is easy to see from inside the building. This becomes important to occupants who may not be familiar with every floor. A clear fire safety plan helps guide emergency evacuation, reducing confusion during a fire or other crisis.

INSTALLATION OF AUTOMATIC FIRE DETECTION AND ALARM SYSTEM – A system that provides automatic fire detection and alarm in the lobby on every floor to receive immediate alerts to exit.

ATRIUM – Adequate floor space for easy movement by occupants. It improves daylight, orientation, internal circulation in large buildings, but it must be designed carefully to manage smoke movement and fire separation.

DRY RISER EMERGENCY LIGHTING — Lighting provided for use when the normal lighting supply fails. Dry risers are useful for supporting firefighting operations where direct hose access from the ground would be difficult.

EVACUATION LIFT — Lift that is used during an emergency for self-evacuation, other than the lifts provided in core area. Evacuation lifts are particularly valuable for occupants who may have difficulty using stairs, including people with disabilities.

FIRE FIGHTING SHAFT — An enclosed shaft with a protected area of fire resistance comprising a protected lobby, staircase, fireman's lift connected directly to exit or through exit passage at every floor.

FIRE SUPPRESSION SYSTEMS - a) Gas-based systems — Systems that use gaseous agents as fire suppression media, b) Water-based systems — Systems that use mainly water as the firefighting medium, such as hydrant systems, sprinkler systems, water spray systems, foam systems, and water mist systems.

LIFT LOBBY — Space from which people directly enter lift car or wait for lift to arrive. Lift lobbies must be arranged so that circulation remains clear and passengers can wait without blocking escape routes.

WATER-BASED SYSTEMS

HYDRANT SYSTEM — Distribution system consisting of network of piping installed underground, above ground, with landing valves at regular intervals. The distribution system is connected to water supply system for firefighting.

AUTOMATIC SPRINKLER SYSTEM — System of water pipes fitted with sprinkler heads at suitable intervals and heights, designed to operate automatically and control or extinguish fire through discharge of water.

AUTOMATIC WATER SPRAY SYSTEM — Special fixed pipe system connected to a reliable source of fire protection water supply and equipped with water spray nozzles for specific water discharge and distribution over the surface or area.

WATER MIST SYSTEMS — A distribution connected to pumping and water supply system, equipped with nozzles capable of delivering water mist to the part or entire enclosure or area intended to control, suppress, or extinguish fire, capable of meeting the specified performance requirements.

FOAM PROTECTION SYSTEM — Fire-fighting systems in which foam is produced by mechanically mixing air with a solution of fresh water and a foaming agent (liquid concentrate). Foam systems are effective for flammable liquid hazards as they cut off oxygen and suppress vapors.

WET RISER — An arrangement for firefighting within the building by means of vertical rising mains not less than 100 mm in nominal diameter, with landing valves on each floor for firefighting purposes, and permanently charged with water from a pressurized supply.

ELECTRICAL INSTALLATION - electrical installations from the point of view of fire safety, reference made to good practices in Building Services, Electrical and Allied Installations of the Code. Electrical design must account for cable segregation, fire-resistant wiring in critical systems, safe routing through shafts and service ducts. Substation/Transformers Areas in substations must not be used as storage or dump or for any utility purpose other than those required for the functioning of substation.

STATIC WATER STORAGE TANKS AND PUMP HOUSE - Arrangements needed in the context of resilience. Rainwater harvesting systems, grey water recycling, sewage treatment plants (STPs) are mandated in high-rise buildings to reduce dependence on municipal water supply.

SEWERAGE AND DRAINAGE PIPES – Based on the volume, the diameter of sewerage and drainage pipes should be designed accordingly. Another aspect of plumbing is drainage. Drainage refers to that part of a plumbing installation which conveys wastewater, sanitary water, rain-water from a building to connect sewer, a drain, or any other means of sewage disposal.

WASTE REFUSE CHUTE – Design of waste refuse chute based on the number of occupants in building should be designed for hygiene, fire safety, ease of collection, proper ventilation and cleaning access.

COMMUNICATION CABLES – Design of ducts for installing various types of cabling for the purpose should provide enough space for current and future systems while maintaining segregation from power cables and wet services.

HELIPAD ON THE TERRACE – If permitted, a helipad can be provided on building terrace. Helipad must follow strict regulatory and structural requirements, including load capacity, access control, fire safety provisions, and clear operational markings.

VERTICAL TRANSPORTATION

The vertical transportation system is important and can be divided into three categories: elevators, escalators, and material movers. Elevators and escalators are commonly referred to as "people movers". Elevator capacity planning is a critical part of high-rise design because the number, speed, and grouping of elevators must match building population, peak demand, floor distribution. Poor planning can lead to long waits, congestion in lobbies, and inefficient floor access. Machine-room-less (MRL) elevators are used because they save space and simplify building layouts, while hydraulic lifts remain practical for floors where speed and height requirements are more modest.

PLUMBING SYSTEMS

The plumbing system consists of three major categories: gravity-drained waste systems, pressure-driven systems, and pumped waste systems. Gravity drainage systems include sloped lines, which must keep natural gradient. One of the biggest challenges in high-rise plumbing is managing water pressure across many floors. Pressure-reducing valves, booster pumps, zoned water supply systems are often required to ensure that lower floors are not over-pressurized but receive consistent service.

ELECTRICAL SYSTEMS

For electrical systems, design parameters are set in accordance with National Electric Code (NEC). These are the minimum requirements. The major categories of the electrical system are supply, distribution, motor loads, and lighting. Backup power is important in high-rise buildings because outages can affect lifts, fire systems, lighting, water supply, and security. Diesel generators and UPS systems are used for emergency support.

SPECIALTIES / COMMUNICATIONS + SECURITY

Communication Systems: include intercoms, paging devices, sound systems, TV, CCTV, LAN, and telephone, which is the most prevalent.

TYPES OF COMMUNICATION SYSTEMS

Phone Fed through the main cable connecting to rooms, where they are split into riser cables;

- Risers are typically located near the core and connect at each floor;
- Multiple lines are supported by a phone switch;
- Each phone is connected to the switch via a copper cable;
- Security Systems - Centralized control unit and sensors & magnetic contact points;
- Access Control - Includes a centralized control unit and access points;
- Access points are connected to the control with cables and open when user verifies identity by the desired method; - Includes card readers, keypads, and biometric sensors;
- CCTV - Video network for security; - Video cameras are placed throughout a building and campus and wired to TV monitors in a central security location.

Building Management Systems (BMS) and other smart building technologies are important to operation of high-rise buildings. Integrated platforms allow facility teams to monitor and control, lighting, security, fire alarms, energy use, and maintenance alerts from a single dashboard. This centralized management improves efficiency, reduces manual errors, helps building operators respond more quickly. AI-powered video analytics are also used in CCTV for facial recognition, crowd density monitoring, anomaly of detection, and these tools are integrated with access control systems.

CONCLUSION

Policy decisions on a national urbanization strategy identifying places with the strongest potential for economic growth, fast and efficient mobility, connectivity, that can support exploration and development of integrated high-rise complexes, smart cities, with future expansion to absorb more people through compact planning in metro and mega cities. This will help make India a vibrant, prosperous, developed nation and support the vision of "**VIKSIT BHARAT**". This will require action plan as suggested below:

1. Land being a state subject, each state should prioritize a state urban strategy for metro and mega cities to grow faster, within the broader framework of population distribution, economic activity.
2. Develop city forest with dense foliage trees, green areas to balance urban temperature, create lung spaces, plant trees along water bodies, drains and roadside for activities of all age groups.
3. Simplify city wise development control rules for high-rise and density balancing built up area with open spaces, natural conservation areas, flora and fauna, scenic areas discouraging horizontal development, and optimizing developable land resources. Complete ban on plotted development in class I towns and cities.
4. Plan India's vision for next 100 years with futuristic view of socio-economic development and distribute projected population by redirecting it into large cities, developing high density smart cities and adopting National Building Construction Standards as statutory requirement.
5. Build social and economic infrastructure including non-conventional energy like solar power, wind energy, electrical and electronic devices, and related needs.
6. Identify project priorities of implementation over next 20/25 years

7. Prepare a fiscal plan based on project prioritization, using public-private partnerships and attracting Foreign Direct Investment (FDI).

Future urbanization in India, making it an economic power and world leader is not impossible. People, the Government must show full determination to achieve the goals. Many challenges require detailed strategy for development and implementation. The broader vision is about creating livable, sustainable, and resilient cities for future generations. High-rise development can support that vision when citizens, urban planners, architects, engineers, and policymakers work together. There is a need for National High-Rise Building Services Policy. Such policy should standardize technology adoption, service delivery benchmarks across Indian cities. It is time we approach high-rise services with seriousness and care for the millions who will call these towers their home.

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ENGINEERING INFORMATION CONTINUITY (EIC): AN OPENBIM-ENABLED SOVEREIGN DIGITAL TWIN (SDT) FRAMEWORK FOR LIFECYCLE MANAGEMENT OF MEPF SERVICES IN INDIAN HIGH-RISE BUILDINGS

Dr. Amarnath C.B.* and Lt. Col. Onkar Bhandurge**

Abstract

India's rapid urbanisation and increasing vertical development have significantly increased the complexity of Mechanical, Electrical, Plumbing, and Fire (MEPF) services in high-rise buildings. While digital technologies have improved design coordination and project delivery, maintaining reliable engineering information throughout the operational life of buildings remains a significant challenge. Engineering information associated with MEPF assets is often fragmented across multiple stakeholders, resulting in information loss during project handover, inefficient maintenance, reduced operational resilience, and difficulties in statutory compliance.

This paper proposes Engineering Information Continuity (EIC) as a lifecycle engineering approach and introduces an OpenBIM-enabled Sovereign Digital Twin (SDT) as its implementation framework for managing MEPF services in Indian high-rise buildings. The proposed framework establishes a structured and owner-controlled engineering information environment that enables the continuous creation, verification, exchange, maintenance, and utilisation of engineering information from planning and design through construction, commissioning, operation, maintenance, refurbishment, and eventual asset replacement.

The framework is developed with reference to the Indian Buildings Congress publication "BIM and Digitalisation Initiatives in Indian AECO", the National Building Code of India 2026 (NBC 2026), CPWD BIM Guidelines, the Energy Conservation Building Code (ECBC), relevant Bureau of Indian Standards (BIS) provisions, and internationally accepted OpenBIM information exchange standards including IFC and BCF. The paper demonstrates how Engineering Information Continuity can improve multidisciplinary coordination, digital handover, lifecycle asset management, preventive maintenance, regulatory compliance, and operational decision-making.

INTRODUCTION

High-rise buildings represent highly complex engineering assets whose long-term safety, sustainability, and efficiency depend on interconnected MEPF systems. In India, rapid urban development and transit-oriented planning have accelerated high-rise construction, evolving MEPF networks to include intelligent Building Management Systems (BMS), smart sensors, and renewable energy integration. Consequently, engineering decisions made across the asset's lifespan directly dictate operational resilience and compliance.

Despite advancements in digital engineering, the architecture, engineering, and construction (AEC) industry struggles to preserve data post-construction. Information is often fragmented across consultants, contractors, and software platforms. At handover, this knowledge degrades into disconnected documents and spreadsheets, causing duplication of effort, reactive maintenance, and inflated lifecycle costs.

While initiatives like NBC 2026, ECBC, and CPWD BIM Guidelines encourage structured data management, achieving lifecycle efficiency requires continuous information governance, not just static 3D models. To address this, the proposed Engineering Information Continuity (EIC) concept ensures engineering records remain interoperable, accurate, and continuously updated. By integrating EIC with an OpenBIM-enabled Sovereign Digital Twin (SDT), building owners maintain software-independent control over their most valuable long-term asset: engineering information.

OBJECTIVES OF THE PAPER

- Introduce EIC for the lifecycle management of MEPF services.

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- Present an OpenBIM-enabled SDT framework for owner-controlled information management.
- Demonstrate the framework's application across HVAC, electrical, plumbing, fire protection, and vertical transportation disciplines.
- Align the methodology with Indian regulatory standards and OpenBIM principles.
- Provide a roadmap to strengthen lifecycle asset management in India.

HIGH-RISE BUILDINGS AND MEPF SERVICES IN THE INDIAN CONTEXT

Metropolitan areas in India are witnessing a surge in residential, commercial, and mixed-use high-rise developments. These structures rely entirely on interconnected MEPF services to sustain indoor environmental quality, provide reliable power distribution, ensure public health through plumbing, safeguard life via fire protection, and facilitate vertical transportation.

The delivery and operation of these systems demand rigorous collaboration among architects, MEP consultants, contractors, commissioning agencies, and facility managers. Unfortunately, standard industry practice frequently results in fragmented information environments. Although immense effort is invested in coordination and statutory approvals, engineering data is usually transferred at project completion as static, disorganized files. Facility managers must subsequently recreate asset registers and maintenance schedules from scratch.

The Indian construction sector promotes collaborative information management through the Indian Buildings Congress and BIS codes. However, Building Information Models (BIM) are still primarily utilized as design and construction deliverables rather than dynamic operational tools. As buildings increasingly rely on the Internet of Things (IoT) and predictive technologies, continuous engineering information governance is necessary to guarantee system interoperability and regulatory compliance regardless of changes in facility management personnel or software.

Key Challenges in Current Practice

- Fragmented engineering information across project stages.
- Loss of valuable engineering knowledge during project handover.
- Poor integration between design models and operational facility management.
- Heavy dependence on disconnected documents for maintenance and compliance.
- Inconsistent asset information hindering lifecycle decision-making.
- An urgent need for interoperable, standards-based, and owner-controlled data environments.

LITERATURE REVIEW AND RESEARCH GAP

The digital transformation of the AECO sector has expanded BIM into a collaborative methodology supported by OpenBIM standards like Industry Foundation Classes (IFC) and BIM Collaboration Format (BCF). While international research successfully demonstrates the use of BIM and Digital Twins for predictive maintenance and energy optimization, the bulk of this work focuses heavily on technology implementation and software capabilities rather than the long-term preservation of engineering information.

Within MEPF engineering, current studies typically isolate specific domains, such as HVAC optimization or IoT fire safety, failing to treat building services as an integrated, coordinated ecosystem. Furthermore, Indian projects involve unique implementation hurdles due to the high volume of disparate stakeholders and regulatory bodies involved. Even with frameworks provided by NBC 2026 and ECBC, a distinct gap remains between digital project delivery and operational asset continuity.

Research Gap Identified

- Existing studies prioritize software/technology over comprehensive lifecycle information management.
- Integrated lifecycle management of unified MEPF services remains underexplored.
- Current practices fail to mitigate data discontinuity after project handover.
- There is a lack of practical methodologies integrating Indian engineering regulations with OpenBIM interoperability.

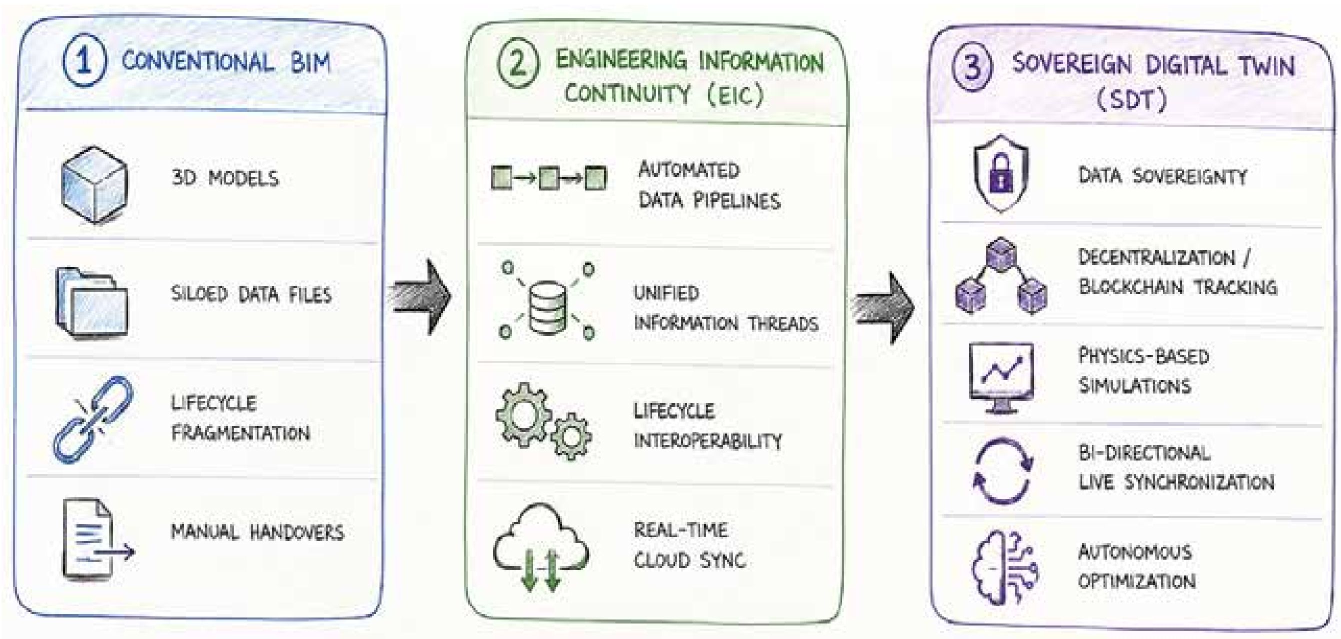

Fig. 1: Evolution of Engineering Information from Conventional BIM to Engineering Information Continuity (EIC) and Sovereign Digital Twin (SDT).

ENGINEERING INFORMATION CONTINUITY (EIC) AND SOVEREIGN DIGITAL TWIN (SDT): THE PROPOSED FRAMEWORK

To solve the fragmentation of asset data, this paper proposes the EIC–SDT Framework for lifecycle management of MEPF services. EIC mandates the continuous creation, validation, accessibility, and enrichment of engineering data across a building's lifespan. The SDT serves as the operational environment for EIC, securing the owner's data sovereignty so that information remains completely accessible and software-agnostic.

The Six Integrated Information Layers

- **Engineering Information Governance:** Establishes organizational workflows, asset information requirements, regulatory obligations, and quality control procedures.
- **Engineering Information Environment:** A structured digital space to manage, review, and exchange design documents, BIM models, calculations, and revision histories.
- **Physical MEPF Assets:** Assigns a unique engineering identity to every maintainable physical system (e.g., HVAC units, transformers, elevators).
- **Operational Information Integration:** Links engineering data with active operational networks, such as BMS, Computerized Maintenance Management Systems (CMMS), and energy metering.
- **Engineering Intelligence:** Translates collected data (maintenance logs, performance trends, and failure histories) into actionable insights for preventive maintenance and reliability assessment.
- **Lifecycle Decision Support:** Empowers facility managers and owners to utilize verified data for statutory compliance, emergency preparedness, and lifecycle investment planning.

ENGINEERING APPLICATIONS OF THE EIC–SDT FRAMEWORK FOR MEPF SERVICES

The true value of the EIC-SDT Framework is realized through its direct application to MEPF lifecycle operations, preventing the stagnation of data post-handover.

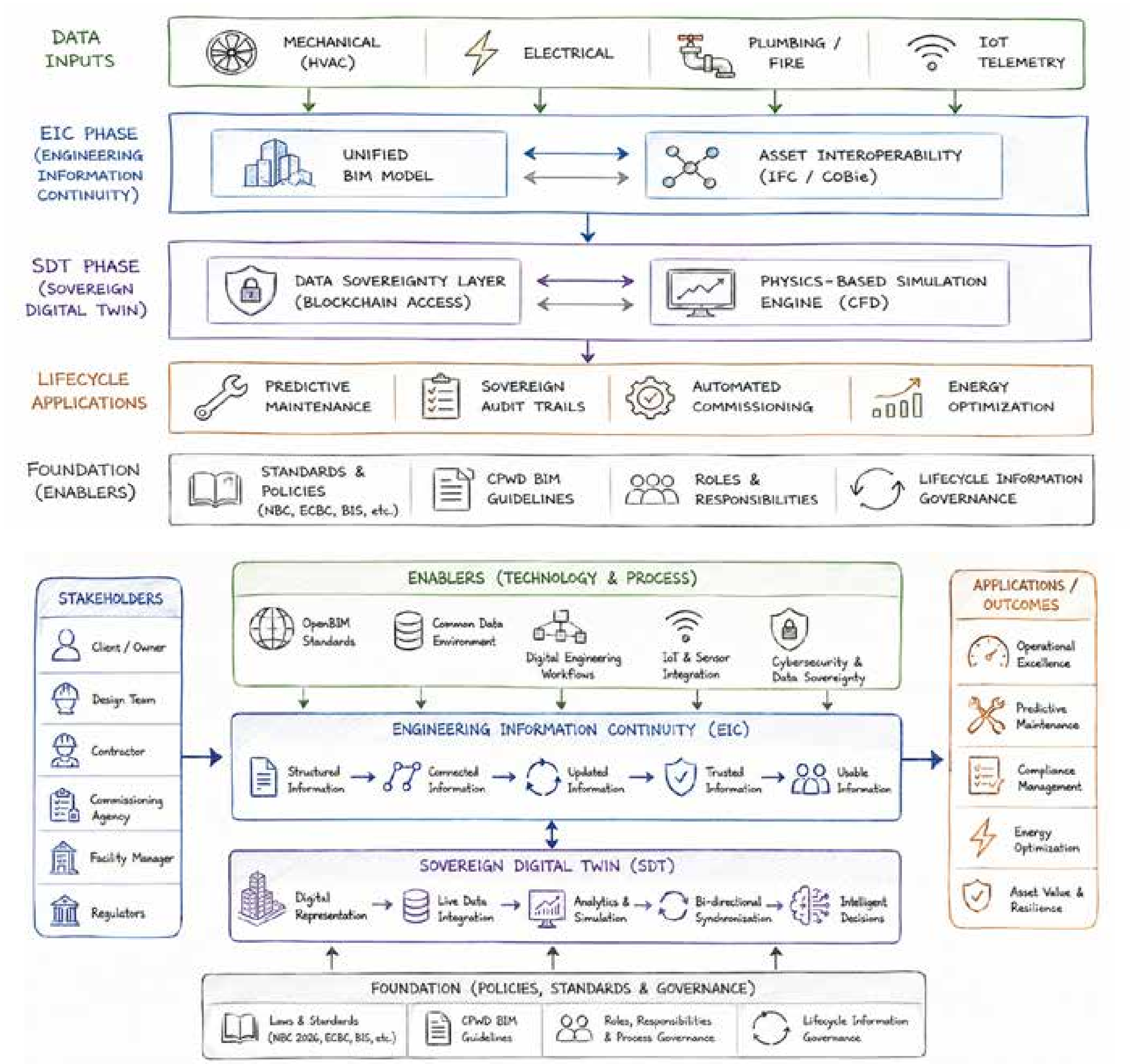

Fig. 2: Proposed Engineering Information Continuity–Sovereign Digital Twin (EIC–SDT) Framework for Lifecycle Management of MEPF Services.

- **HVAC Systems:** Links energy-intensive assets like chillers, cooling towers, and Air Handling Units (AHUs) directly to their Testing, Adjusting and Balancing (TAB) records and active BMS performance trends, facilitating superior fault diagnosis and energy evaluation.
- **Electrical Systems:** Structures engineering data for high-voltage and low-voltage networks, transformers, and emergency power systems, associating single-line diagrams and thermographic inspections with the specific physical asset to assist in capacity planning and reliability assessment.
- **Plumbing and Public Health Engineering:** Organizes hydraulic calculations, water quality records, and inspection reports for pressure boosting systems, sewage treatment plants (STPs), and drainage networks to maintain sanitary continuity and environmental statutory compliance.

Table 1: Engineering Info Requirements Across the Lifecycle of Typical MEPF Assets

Asset	Design	Construction	Commissioning	Operation	Maintenance	Compliance
Chiller	Capacity, COP	Installation	Performance Test	BMS Data	Service History	ECBC
AHU	Airflow, ESP	Duct Installation	TAB Report	Filter Status	Maintenance Log	IAQ
Fire Pump	Hydraulic Calculation	Installation	Acceptance Test	Weekly Test	Pump Servicing	NBC 2026
Transformer	Rating	Installation	FAT/SAT	Load Data	Oil Testing	Electrical Inspector
Lift	Traffic Analysis	Installation	Functional Test	AMC Records	Breakdown History	IS 16441
STP	Process Design	Installation	Trial Run	Water Quality	O&M Records	SPCB

- **Fire Protection and Life Safety Systems:** Categorizes critical life-safety data, matching fire pumps, smoke management systems, and emergency lighting directly to their NBC 2026 compliance certificates, hydraulic calculations, and weekly test logs for simplified regulatory audits.

- **Vertical Transportation Systems:** Integrates traffic design criteria, functional test records, and modernization documentation for elevators and escalators, enabling predictive component replacement and mobility optimization.

Engineering Information Continuity During Digital Handover

Traditional handovers rely on disconnected manual transfers. By contrast, EIC integrates data dynamically. For example, the lifecycle of a fire pump begins with design specifications and pump curves, which are subsequently merged with construction installation records. Commissioning adds acceptance testing and statutory certifications. During regular operation, breakdown histories and annual compliance certificates are continually appended to the asset's digital identity. Consequently, full engineering context is instantly available when replacements or upgrades are required. This approach eliminates information discontinuity and preserves engineering knowledge throughout the asset's life.

Table 2 : Lifecycle Engineering Information Matrix for HVAC, Electrical, Plumbing, Fire Protection and Vertical Transportation Systems.

S No	Stakeholder	Primary Responsibility
1	Client	Asset Information Requirements
2	Architect	Spatial Coordination
3	Structural Engineer	Structural Information
4	MEP Consultant	Engineering Information
5	Contractor	Installation Records
6	Commissioning Agency	Test & Validation Records
7	Facility Manager	Operational Information
8	Owner	Lifecycle Governance

BENEFITS, IMPLEMENTATION STRATEGY AND INDUSTRY ROADMAP

The EIC-SDT Framework replaces project-centric documentation with dynamic organizational asset knowledge.

Stakeholder Benefits

- **Building Owners:** Secures independent control of asset data, preventing vendor lock-in and optimizing lifecycle investments.
- **Consultants & Engineers:** Improves

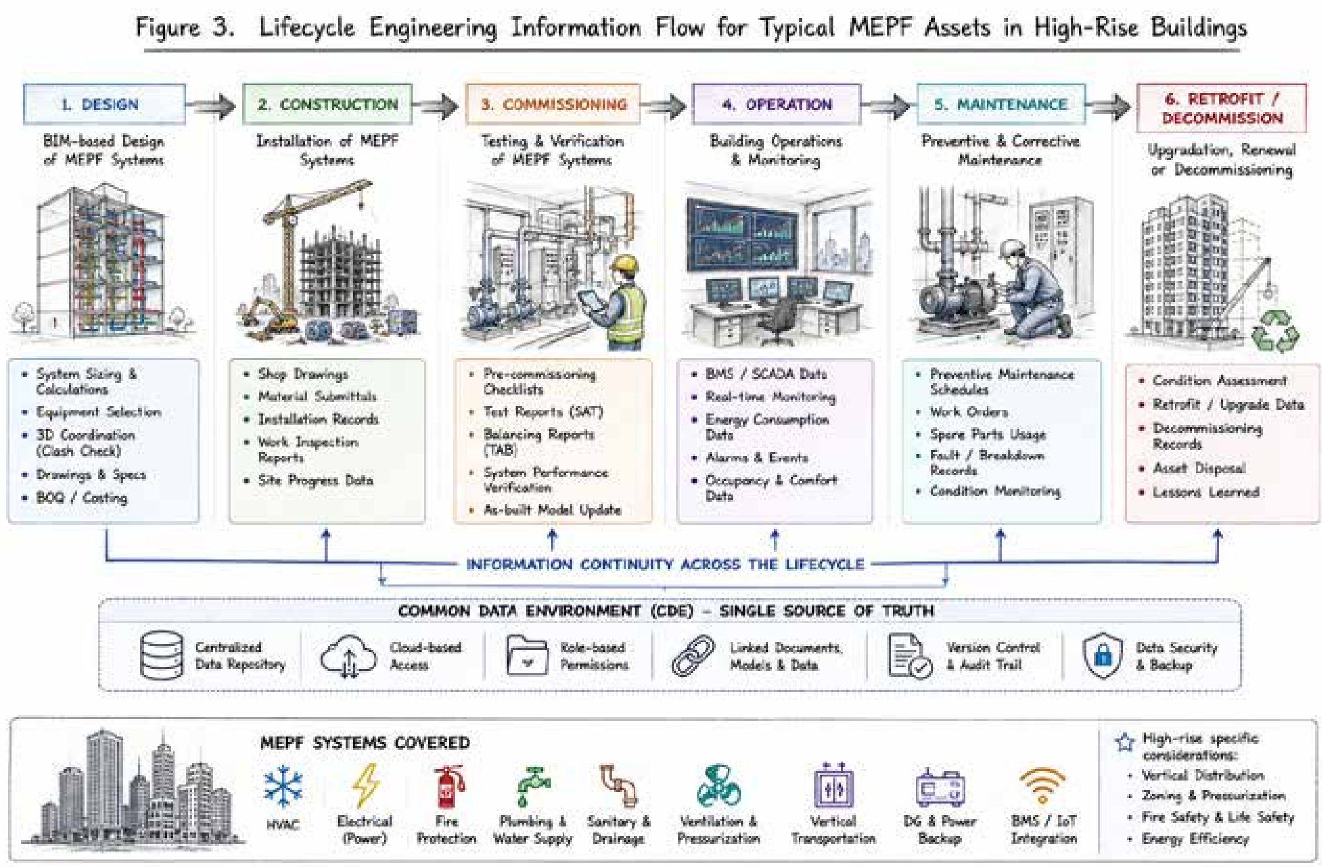

Fig.3. Engineering Information Continuity Across the Lifecycle of Typical MEPF Assets

multidisciplinary coordination and preserves design rationales through structural traceability, reducing redundant effort on future projects.

- **Contractors & Commissioning Teams:** Facilitates structured quality assurance and smooth integration of testing records into the final operational model.
- **Facility Management:** Provides immediate, verifiable access to warranties, maintenance schedules, and previous modification histories, vastly improving preventive asset management.
- **Regulatory Authorities:** Increases transparency for compliance audits regarding fire protection, electrical safety, and environmental standards.

Implementation Strategy

Adoption should be phased to avoid operational disruption. Organizations must first define Employer's Information Requirements (EIR) and Asset Information Requirements (AIR). Construction and commissioning data must then be systematically mapped to individual physical assets using OpenBIM standard formats. Finally, during regular building operation, all maintenance tasks, retrofits, and compliance checks must continuously feed back into the central asset model.

Industry Roadmap

- **Digital Engineering:** Implementing standard BIM-enabled design and spatial coordination.
- **Collaborative Information Management:** Enforcing standardized document governance and multidisciplinary collaboration protocols.
- **Digital Project Delivery:** Merging procurement, construction, and commissioning data into cohesive project information environments.
- **Engineering Information Continuity:** Structuring the continuous validation and updates of data during regular facility operations.

- **Sovereign Digital Twin:** Deploying fully owner-controlled, OpenBIM-integrated platforms that synthesize regulatory compliance, engineering records, and real-time operational metrics.

EMPIRICAL BENCHMARKS FOR EIC IMPLEMENTATION

While the widespread adoption of Sovereign Digital Twins in Indian high-rise infrastructure is still in its nascent stages, the empirical value of Engineering Information Continuity can be quantified using established industry benchmarks for digital asset management.

Quantifiable Lifecycle Outcomes

The transition from conventional document handovers to the proposed EIC-SDT framework addresses specific, measurable inefficiencies in facility management:

- **Reduction in Information Search Time:** Industry studies consistently indicate that facility management personnel spend approximately 15% to 30% of their operational time searching for, verifying, or recreating lost engineering data. By establishing a unified, OpenBIM-enabled environment, the EIC framework eliminates information silos, directly converting this lost time into productive preventive maintenance hours.
- **Mitigation of Interoperability Costs:** The financial impact of fragmented engineering information is substantial. By enforcing data sovereignty and utilizing vendor-neutral standards like IFC, building owners are protected against software vendor lock-in and the recurrent costs of data recreation during facility management transitions.
- **Improved Fault Diagnostics and MTTR:** Linking dynamic operational data (from BMS) with static engineering data (from BIM) within an SDT has been shown to significantly reduce the Mean Time to Repair (MTTR) for critical MEPF assets. When maintenance teams have instantaneous access to structural traceability, hydraulic calculations, and maintenance logs within a single digital identity, diagnostic accuracy improves substantially.

By implementing the EIC-SDT framework, the Indian AECO sector can move beyond theoretical digital delivery to realize these proven, quantifiable operational efficiencies throughout the asset lifecycle.

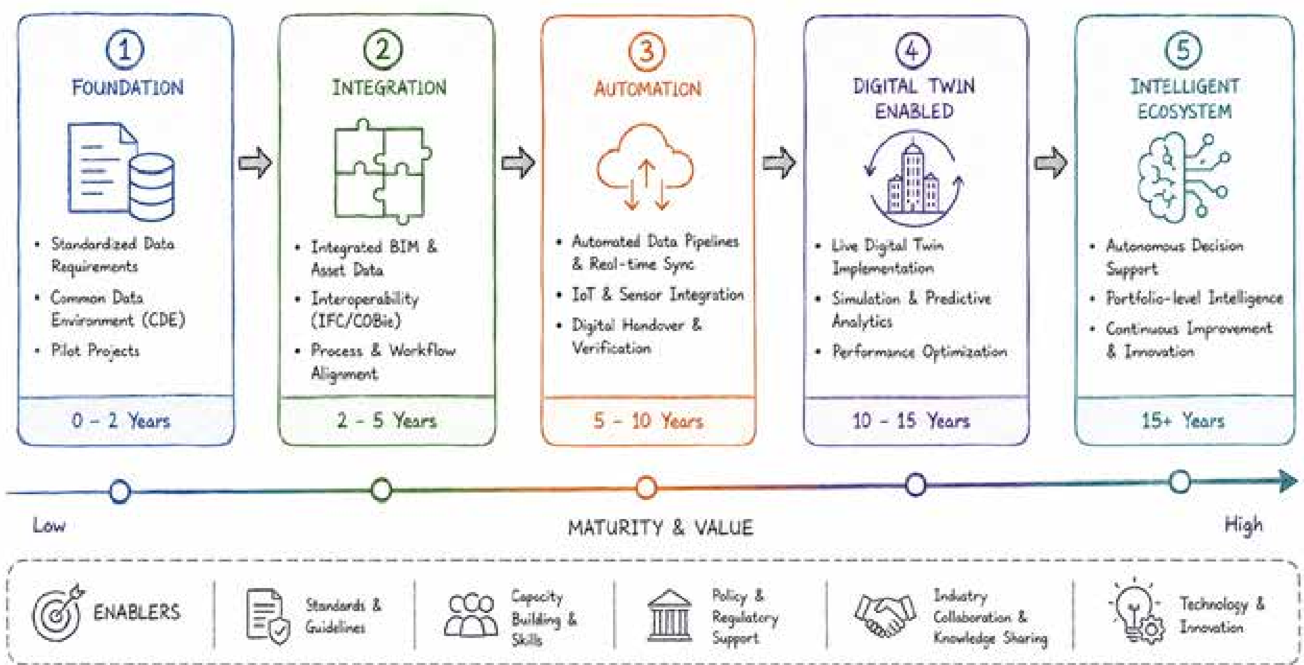

Fig. 4: Industry Roadmap for Progressive Adoption of Engineering Information Continuity in Indian High-Rise Buildings.

Table 3. Comparison of Conventional Digital Handover and Engineering Information Continuity

S No	Conventional Handover	Engineering Information Continuity
1	Drawings	Engineering Information
2	Manuals	Asset Knowledge
3	PDF Documents	Structured Asset Records
4	Static Files	Continuously Updated Information
5	Project Close-out	Lifecycle Management

CONCLUSION

As high-rise MEPF networks grow increasingly interdependent, isolated 3D models and static handover documents are no longer adequate. This paper establishes Engineering Information Continuity (EIC) as a necessary lifecycle discipline to preserve, govern, and enrich engineering data across the full span of building operations.

Executed through an OpenBIM-enabled Sovereign Digital Twin, this methodology ensures owners maintain permanent, software-agnostic control over their facility's core intelligence. By fully aligning with the Indian Buildings Congress, NBC 2026, and ECBC regulations, the EIC-SDT framework transitions the industry away from disconnected project delivery toward highly resilient, operationally optimized lifecycle asset management. Ultimately, Engineering Information Continuity bridges the critical gap between initial digital construction and the safe, intelligent, and sustainable operation of India's high-rise infrastructure.

Engineering Information Continuity is not merely a digital methodology; it is an engineering discipline that enables high-rise buildings to preserve, utilise, and continuously enhance engineering knowledge throughout their lifecycle. By combining Indian engineering practice with interoperable digital information management, the proposed EIC–SDT Framework offers a practical pathway towards safer, more resilient, sustainable, and efficiently managed high-rise buildings.

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THE LIVING MONOLITH:
REDEFINING BUILDINGS AS BIO-MECHANICAL MACHINES

Manoranjan Misra*

PART A: THE CORE PHILOSOPHY & CAPEX REALITIES

INTRODUCTION: BREAKING THE CIVIL BIAS

For generations, the construction fraternity has viewed buildings through a purely civil-centric lens—as static assemblies of bricks, mortar, concrete, and steel. The traditional approach dictates calculating structural loads, designing foundations, casting columns, beams, and shear walls, and considering the primary engineering mandate complete. Mechanical, electrical, plumbing, and fire services are historically treated as secondary add-ons, tucked away inside shafts simply to provide occupant comfort.

To understand the fallacy of this static mindset, we can trace the historical evolution of modern landmarks:

- **The Classic Passive Envelope:** Think of the iconic **Empire State Building** built in the 1930s. It represents a triumph of pure, monumental civil engineering—heavy steel rivets, massive stone cladding, and immense foundations built to stand passively against gravity and wind. It was a sort of tall stone monument, with braced steel structure encased in concrete with belt trusses and a shear core, riveted steel columns and beams. If the main power line failed, the building became uncomfortable, but the structure itself remained stable.

- **The Tubular Spatial Revolution:** A massive shift toward utility integration occurred in the late 1960s with the construction of the **John Hancock Center** in Chicago. Designed by the legendary structural engineer Fazlur Rahman Khan, this masterpiece introduced the world's first *trussed-tube structural system* using visible *external diagonal bracing*. By pushing the structural load-bearing elements to the exterior perimeter, Khan freed up the building's interior floor plates. This spatial revolution allowed engineers to stack entirely different service ecosystems, commercial offices, high-density residential apartments, and dedicated mechanical plant floors, within a single structure. It was the world's first true prototype of a self-contained vertical town.

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Today, the modern building has evolved far beyond these early landmarks. Once a structure crosses a critical volume, height, or density, it undergoes a complete operational mutation. It stops acting like a passive block of masonry and transforms into a highly active, power-hungry, and responsive Bio-Mechanical Machine. If you cut the main power grid and shut down the automated control loops today, a modern complex becomes entirely unliveable within minutes.

THE FINANCIAL REALITY CHECK: THE 25% STRUCTURAL SHELL

To shift the perspective of traditional project review boards, one only needs to examine the capital expenditure (CapEx) allocation of modern mega-projects. Global construction cost indices and benchmarks from bodies like the Council on Tall Buildings and Urban Habitat (CTBUH) reveal a striking financial reality as shown below:

- **25% – 30% of the cost is consumed by** Foundations, Columns, Beams, Shear Walls, Slabs

- **30% – 45% is for** Lifts, HVAC Chillers, Electrical Risers, Pumping Loops, Fire Deluge

- **25% – 35% is for** High-Perf Glass Curtain Walls, Thermal Seals, Architectural Finishes

As we see, 70% to 75% of the capital investment goes directly into making the building functional. Mechanical, Electrical, Plumbing, and Fire Fighting (MEPFP) networks devour a massive 30% to 45% of the project budget, while high-performance glass facades and thermal envelopes take up another 25% to 35%. Once the civil engineering team finishes casting the bare concrete skeleton, it is nothing more than a dark, unventilated shell. The overwhelming majority of project capital is dedicated to bringing that skeleton to life with active, automated services.

THE INTERDEPENDENCE OF ENGINEERING DISCIPLINES

Even within the 25% to 30% civil share, structural execution cannot advance a single meter without heavy mechanical fluid dynamics and electrical infrastructure operating in perfect harmony from day one:

- **Concrete Pumping Logistics:** Look at the construction of the **Burj Khalifa** in Dubai. Pumping high-grade concrete nearly 600 meters straight up against gravity in a single stage was a world-record mechanical fluid-dynamics challenge. It required specialized heavy-duty hydraulic pumps operating at pressures exceeding 350 bar, coupled with highly precise chemical concrete mixes to prevent the material from setting prematurely inside the delivery pipes. A failure in a single mechanical piston or valve instantly brought the entire structural progress on the top floors to a halt.
- **Foundation Instrumentation:** Casting a massive basement raft or deep pile cap requires continuous electrical dewatering pump networks working 24/7 to counter groundwater pressures. Furthermore, modern foundations are embedded with electronic sensors, strain gauges, and load cells to stream real-time settlement and stress data to engineering teams.
- **Post-Tensioning (PT) Hydraulics:** Pulling high-tensile steel tendons in modern PT slabs requires specialized mechanical hydraulic jacks and calibrated electronic pressure gauges to ensure precise tension alignment and prevent structural failure.

PART B: THE BIOLOGICAL METABOLISM (BUILDING PHYSIOLOGY)

MAPPING THE BIO-MECHANICAL ANATOMY

By viewing the building through a bio-mechanical lens, the traditional boundaries separating civil, mechanical, and electrical engineering dissolve. The building mimics a living biological organism, transforming static elements into functional anatomy:

The Structural Exoskeleton

The civil engineering works—the foundations, shear walls, and columns—are re-conceptualized as the building's **structural exoskeleton**, mimicking the hard outer shell of an crustacean. This exoskeleton's primary job is passive: it provides physical containment, absorbs dead loads, and shields the delicate internal infrastructure from severe external wind forces and seismic loads.

The Circulatory System (Plumbing & Hydraulics)

The high-pressure booster pumps, intermediate transfer tanks, and distribution pipe networks act exactly like a biological heart and blood vessels. They maintain a continuous, pressurized volumetric flow of fluids across the structure, balancing pressure tiers to prevent systemic failure.

To see this high-stakes engineering reality deployed locally, look at one of India's tallest completed residential skyscrapers: Lokhandwala Minerva in Mumbai. Towering at a massive 301 meters across 78 floors, this supertall structure handles an enormous, highly decentralized residential water demand.

You cannot simply pump water from the ground floor to the 78th floor in a single run; the gravity-induced static head pressure () would obliterate plumbing fixtures and valves on the lower levels. The engineering team must implement strict hydrostatic pressure zoning, breaking the tower into independent vertical sectors separated by dedicated mechanical plant floors. High-pressure multi-stage booster pumps push water up to local transfer tanks, where parallel lines fitted with heavy-duty Pressure-Reducing Valves (PRVs) throttle the dynamic pressure. This ensures that a resident on the 10th floor and an occupant in a penthouse on the 75th floor experience the exact same uniform, safe water pressure without risking pipe ruptures or valve cavitation during peak morning hours.

Furthermore, managing the gravity-defying velocity of solid waste dropping down Minerva's 300-meter drainage stack requires specialized aeration pipe fittings and velocity-breakers. Without this active mechanical design, falling waste would build up catastrophic pneumatic air pressure, blowing out the trap seals of apartments on lower floors and destroying the building's sanitation integrity.

The Respiratory System (HVAC)

The pressurized air distribution plenums, variable-frequency drive (VFD) air handlers, and extractors act as the building's lungs. They regulate gas concentrations, filter out ambient contaminants, introduce fresh oxygen, and modulate thermodynamic enthalpy so that the occupants can breathe safely.

In massive volumes like multi-story lobbies, central atriums, and large public spaces, traditional "overhead mixing" designs—which force cold air down from ceiling diffusers at high speeds—are highly inefficient. It takes an immense amount of fan energy to push cold air down while fighting the natural tendency of hot air to rise, leading to massive energy waste. To fix this, modern building services deploy Underfloor Air Distribution (UFAD) systems.

UFAD introduces conditioned air at low velocities through a pressurized plenum beneath a raised floor, right within the occupied zone (the bottom 2 meters of the room). By working *with* natural thermal buoyancy instead of fighting it, cool air picks up heat from occupants and equipment and naturally rises to the ceiling, leaving the massive dead-air space at the top unconditioned. This keeps occupants comfortable while saving a tremendous amount of chiller energy. A brilliant real-world example of this fluid stratification and underfloor plenum engineering is the heritage conversion of the Kushabhau Thakre Hall (Old Minto Hall) in Bhopal, where such modern, uniform air conditioning to a massive, high-ceilinged historic hall without spoiling its heritage aesthetics with exposed ductwork.

The Nervous System - ELV & Cybernetics

The low-voltage cabling, register-level sensor buses, and object-oriented mainframes function as the sensory and motor nerves of the machine. The Ground-Level Sensors (Modbus): At the equipment level, rugged, register-based Modbus RTU/TCP protocols are deployed. These are the local nerve endings connected directly to physical field sensors, such as current transformers on electrical risers, pressure transmitters in plumbing lines, or vibration sensors on pumps. Modbus excels at streaming raw data instantly to the local controller without processing lag. The High-Level Integration (BACnet): To make these different systems talk to each other, an object-oriented BACnet/IP layer is laid on top. BACnet acts as the master translator, allowing equipment from completely different vendors (like a fire alarm system, an HVAC chiller, and an elevator controller) to communicate smoothly without compatibility bottlenecks.

SUPER-CRITICAL MONOLITHS: AIRPORTS & HOSPITALS

To appreciate the full reach of this philosophy, we must look beyond skyscrapers to other massive, high-density structures that act as continuous bio-mechanical machines:

The Sprawling Horizontal Machine: Modern Airports

A modern international airport terminal is a massive horizontal bio-mechanical machine. Its payload is a continuous, high-velocity flux of thousands of human beings arriving, departing, and transitioning every hour of the day. You can never press the "pause" button on a major airport hub.

The terminal building handles massive volumetric HVAC requirements, dynamically adjusting cooling loads as a single wide-body aircraft drops 500 hot, breathing passengers into a localized gate area all at once. Simultaneously, its internal digestive tract—the automated Baggage Handling System (BHS)—uses kilometers of high-speed inline conveyor belts, automated scanners, and tilt-tray sorters to move thousands of bags per hour with zero human intervention. A single sensor failure or belt jam stalls the entire terminal's circulation. Beneath the concrete aprons run high-pressure underground aviation fuel hydrant networks and massive utility loops handling sanitation loads for a daily population larger than many tier-2 cities.

The Critical Life-Support Monolith: Modern Hospitals

While high-rises and airports support comfort and commerce, a modern hospital is a bio-mechanical machine where the mechanical and electrical services are literally the difference between life and death on a minute-by-minute basis. The payload inside is highly vulnerable, meaning the MEPFP systems operate like an advanced, specialized life-support system:

- **Medical Gas Pipeline Systems (MGPS):** This is a critical respiratory network, running miles of degreased copper piping to carry pressurized Medical Oxygen, Nitrous Oxide, and Medical Vacuum directly to Operation Theatres (OTs) and ICUs. A drop in pressure for even five seconds can cause ventilator failure.

- **Positive Pressure & Laminar Airflow:** In an OT, the HVAC system acts as an active germ barrier. It forces ultra-clean air through HEPA filters downward in a smooth, one-way laminar stream at positive pressure. This ensures that contaminated air from the rest of the hospital can never leak into the theater during a surgical procedure.

- **Uncompromising Power Redundancy (or):** Hospitals cannot tolerate a microsecond of power interruption. An uninterrupted power supply (UPS) backs up every heart monitor and anesthesia machine, while automated diesel generators are synchronized to take over the entire critical load within 8 to 10 seconds of a main grid failure.

PART C: LIFECYCLES, GOVERNANCE & CONTROL

THE BIOLOGICAL LIFE CYCLE: FROM BIRTH TO DEATH

It is an engineering error to view a building as a static product finished on the day of handover. Like any living organism, a bio-mechanical machine undergoes a complete life cycle: Birth, Growth, Decay, and Death.

Birth and Circadian Rhythms (The Night Cycle)

A building's operational life begins at commissioning, but it quickly develops a daily rhythm. It is a misconception that an infrastructure machine must stay at 100% capacity around the clock. Like a living creature, a major airport, a premium hotel, or a residential tower follows a circadian rhythm.

When passenger traffic drops after midnight, or when a residential tower enters the pre-dawn hours, the building shifts into a low-metabolic standby mode. The central HVAC chillers shed non-essential load, switching to an energy-conservation baseline. Water pumping pressures are modulated downward to reduce stress on the piping network—effectively lowering the building's "heart rate."

However, while the metabolism slows, the building's autonomic nervous system—the fire-detection, security, and gas-leak sensors—remains fully alert. The machine is not turned off; it is simply sleeping, conserving energy while keeping its life-support networks active.

Growth and Adaptation (Future-Proofing the Machine)

Over a 30- or 50-year lifecycle, a building's usage will grow and mutate along with the human society inside it. A commercial tower may suddenly need to host high-flux data server rooms requiring triple the original electrical and cooling load; a mega-building—like China's Regent International, which stands at 206 meters and houses up to 30,000 residents as a vertical city—sees its internal population grow and shift over decades.

If a building cannot accommodate this growth, it suffers a functional death. It becomes an obsolete, inefficient monument, even though its concrete skeleton remains perfectly sound. Because growth is an undeniable biological reality, the original design team must leave deliberate provisions for expansion:

1. **Volumetric Space Reserves:** Designing oversized vertical service shafts (MEP risers) and generous floor-to-ceiling clearances so that future generations can run advanced utilities without coring structural concrete slabs.

2. **Modular Plug-and-Play Footprints:** Leaving designated vacant space on mechanical plant floors to install an extra chiller, add a secondary booster pump, or upgrade a transformer array without interrupting existing services.

3. **Structural Load Allowances:** Building a calculated structural buffer into the core exoskeleton to support future retrofits, such as high-performance triple-glazed solar facades or heavy roof-mounted energy storage banks.

The Final Phase: Demolition as Natural Death

When a building reaches the absolute end of its lifecycle—when structural components suffer from irreversible material fatigue or its internal services become completely un-upgradable—it enters its final phase: Death.

In modern engineering, this death manifests as controlled demolition. But just as a biological entity decomposes and returns its elements back to nature, the death of a modern building must be managed as a structured, circular process. We systematically harvest the building's internal organs first—stripping out kilometers of valuable copper busducts, recycling aluminum facade frames, and isolating electronic waste.

Finally, the concrete exoskeleton is brought down through controlled implosions or high-reach processors, crushing the structural core back into aggregate. This crushed concrete is reborn as sub-base material for new roads or recycled aggregate for new concrete mixes. Dust returns to dust, and the dead machine provides the raw resources to birth the next generation of monoliths.

EMERGENCY TRANSIENT REFLEXES & OVERRIDES

In a traditional building, systems operate in isolated, siloed loops, where separate fire alarms, manual fan switches, and manual elevator keys introduce dangerous human delays during a crisis. In a bio-mechanical machine, an emergency demands an immediate, automated, cross-service reflex loop. The moment a smoke or heat sensor trips, the centralized control system triggers a simultaneous cascading logic loop across multiple platforms:

1. **Fire Protection:** The system instantly fires up high-pressure main and jockey fire pumps to maintain full hydraulic head pressure up the wet riser and sprinkler lines.

2. **HVAC Mechanics:** Variable Air Volume (VAV) dampers instantly close to isolate the fire zone and starve it of oxygen. Dedicated smoke exhaust fans ramp up to full speed to draw out toxic gases, while positive-pressure stairwell pressurization fans fire up to keep evacuation routes completely clear of smoke.

3. **Vertical Transportation Kinetics:** The system overrides normal variable-voltage variable-frequency (VVVF) elevator drive cycles, bypassing manual call buttons to bring all lift cabs straight down to the ground floor via a Phase 1 Emergency Recall, opening the doors immediately so occupants can exit safely.

OPERATIONAL REALITIES & THE SYSTEMS GOVERNOR

The Fallacy of Digital Over-Confidence

As building automation systems become more advanced, there is a strong industry push to move 100% to condition-based maintenance (CBM) driven entirely by predictive AI software and smart sensors. While real-time data streaming is invaluable, we must avoid the dangerous trap of **digital over-confidence**.

Field sensors are susceptible to physical vulnerabilities: they suffer from calibration drift, get fouled by dust and sludge, experience communication bus packet drops, and can be damaged by electrical surges. More critically, an electronic sensor measuring motor current or water temperature cannot detect internal structural changes, such as subsurface material fatigue in a suspension cable or micro-fissures inside a high-pressure hydraulic line. Relying blindly on automated alerts creates an operational blind spot. If a sensor fails silently, a catastrophic breakdown can occur without any warning.

The 80/20 Hybrid Governance Matrix

To bridge this gap and ensure absolute life-safety protection, we propose to enforce a balanced **80/20 Hybrid Governance Matrix**. This framework splits maintenance operations into two distinct approaches based on asset criticality.

- **The 80% Automated Telemetry Layer:** High-frequency automated monitoring handles eighty percent () of the building's asset management. Continuous vibration analysis, thermal telemetry, and real-time sensor polling track continuous-duty rotating machinery—such as HVAC chiller compressors, multi-stage water booster pumps, and ventilation fans. Because these systems operate constantly, data-driven CBM can accurately detect efficiency loss and catch anomalies long before a mechanical breakdown occurs.

- **The 20% Statutory Auditing Layer:** The remaining twenty percent () enforces a strict, non-negotiable protocol of manual, physical engineering inspections that cannot be bypassed by digital systems. This layer focuses on critical-path life-safety mechanisms—such as the physical brake pads on VVVF elevator traction drives, emergency fire-door seals, structural anchoring tendons, and high-pressure fire deluge valves. These systems often sit idle until an emergency arises, meaning their automated sensors face a single point of failure. This 20% baseline uses manual pressure testing, physical thickness gauges, and non-destructive testing (NDT) conducted by senior engineers to guarantee absolute performance when lives are on the line.

Alignment with National Standards and the NBCS, 2026

This hybrid governance model is designed to align with the safety, structural, and operational mandates of the National Building Code (NBC) of India and the latest directives of the NBCS, 2026.

The NBCS, 2026 explicitly emphasizes that while smart building controls and digital automation dashboards are valuable tools for operational efficiency and energy optimization, they must never replace statutory physical testing and legally mandated safety checks. The 80/20 matrix fulfills both requirements. By combining real-time data streaming with structured physical verification, it provides a practical framework that satisfies both the performance goals of modern automation and the strict safety requirements of national building codes.

Looking toward the ultimate horizon of this evolution, we see projects like **The Line** in Saudi Arabia—a continuous, 170-kilometer-long linear city, spanning a width of **200 meters** and soaring to a height of **500 meters**, enclosed by mirror-faced structures. On this mega-scale, traditional civil engineering is completely reduced to an outer casing for a 100% automated, continuous bio-cybernetic machine run by real-time telemetry to manage human survival.

PART D: CONCLUSION

The Mandate for the Systems Governor

The modern building has permanently outgrown the traditional boundaries of isolated engineering trades. We can no longer afford to manage building services in disconnected silos—where the lift technician, the electrical engineer, and the plumbing team operate independently without overarching coordination.

The era of the living monolith demands a complete professional evolution, transforming the role of our traditional engineer in charge of a building into a **Systems Governor for** such living Bio-mechanical facilities. The Systems Governor is a multidisciplinary coordinator equipped with a deep understanding of interface engineering. Treating the building as a single, integrated, bio-mechanical organism, the Systems Governor uses continuous digital telemetry to keep the building's internal metabolism steady, while enforcing the strict physical checks of the 80/20 framework to eliminate cybernetic blind spots.

By anchoring operations in unified mechanical logic, structural flexibility for future growth, and unwavering compliance with national safety standards, the Systems Governor ensures that the modern building achieves maximum operational efficiency, enduring structural resilience, and absolute protection for human life.

AUTOMATION AND SAFETY SERVICES IN MODERN HIGH RISE BUILDINGS

Dr. Laxmikanta Tripathy*

Abstract

Automation and Safety in the building is very important factor for the serviceability and smoot functionality, As we know the construction stage is also important like the post construction period. So, the safety measures are also to be taken care of , as we consider the post construction stage. As the subject itself is vary vast, automation of the most essential objectives like water, AC, Gas etc of automation and safety services have been considered in the here in this article. Along with some important case study examples . These brief expansion breaks down the core phases and systems mentioned, detailing the mechanisms, technologies, and operational benefits required for modern high-rise engineering for sustainability.

INTRODUCTION

High Rise Building- A building Having height more then 15m As per National Building Code 2005 of India is called High Rise Building. There are many responsibilities on this high-rise building. The mobility, structural stability and smooth functionality are the most important for any modern high-rise building. Further the role of automation and safety services play a major role in the building. For this, some of the major essential tasks have been narrated in this article.

CONSTRUCTION PHASE SAFETY & INFRASTRUCTURE

Building vertically introduces exponential risk factors during the execution phase. Ensuring structural integrity and worker safety requires a proactive, tech-driven approach.

Fall Protection & Perimeter Integrity: Implementation of self-climbing perimeter safety screens and heavy-duty guardrails that adapt to the building's rising height.

Debris Management: Enclosed debris chutes and perimeter netting systems to mitigate the hazard of falling objects in dense urban zones.

Real-Time Structural Health Monitoring (SHM): Embedding wireless sensor networks (such as strain gauges, inclinometers, and accelerometers) into the concrete core during casting to monitor curing stress, tilt, and lateral displacement in real time.

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Vertical Logistics Safety: Utilizing smart, load-monitored tower cranes and high-speed personnel hoists equipped with automatic overspeed brakes, limit switches, and anti-collision algorithms.

POST-COMPLETION FIRE & LIFE SAFETY SYSTEMS

Once occupied, high-rise buildings present unique challenges for evacuation and firefighting. The reliance shifts heavily onto integrated, automated internal systems.

Suppression & Smoke Management: Automated Sprinklers: Zoned, pressure-regulated sprinkler networks to handle high hydrostatic pressure.

Smoke Control: Automated HVAC override systems that pressurize escape stairwells and lift shafts while exhausting smoke from the fire zone to create a clear, breathable path for occupants.

Egress Infrastructure:

Refuge Areas: Specially reinforced, fire-rated floors equipped with independent ventilation, communication links, and emergency water supplies.

Fire Lifts: Dedicated elevators with water-resistant electrical components, dual-source power backups, and prioritized control overrides for emergency responders.

Lightning & Structural Protection: Advanced Early Streamer Emission (ESE) lightning conductors coupled with comprehensive grounding grids to shield sensitive digital automation infrastructure from massive electrical surges.

BUILDING MANAGEMENT SYSTEMS (BMS) & SMART AUTOMATION

A centralized Building Management System (BMS) acts as the central nervous system of a modern skyscraper, synthesizing data from disparate subsystems to optimize efficiency and security. The attributes narrated in the table 1.

Table 1: System Integration Matrix

Subsystem	Core Technologies	Primary Operational Benefit
Security & Surveillance	AI-enabled CCTV, Biometric Access Control, ANPR (Automatic Number Plate Recognition)	Restricts unauthorized entry; automates threat detection and crowd analytics.
Energy & Lighting	Smart occupancy sensors, daylight harvesting, automated LED dimming loops	Dramatically minimizes baseline operational energy consumption
HVAC & Air Quality	IAQ (Indoor Air Quality) sensors, automated CO_2 scrubbing, variable air volume (VAV)	Dynamically balances occupant health and thermal comfort with energy efficiency
Waste Management	Automated pneumatic waste chutes, volume-sensing smart bins	Streamlines waste segregation, reduces manual handling, and prevents odors.

SUSTAINABILITY & ENVIRONMENTAL ENGINEERING

To ensure long-term viability, high-rises must minimize their massive ecological footprints by acting as self-sustaining ecosystems.

Solar Energy Harnessing: Integrating Building-Integrated Photovoltaics (BIPV) into the facade panels and deploying high-efficiency solar arrays on the rooftop to offset peak grid dependency.

Rainwater Harvesting & Greywater Recycling: Utilizing the building's massive roof catchments and facade run-off for rainwater collection. This water is directed to on-site treatment plants and recycled for cooling towers, flush systems, and landscaping.

ADVANCED SPECIALIZED FACILITIES & STRUCTURAL RESILIENCE

The extreme height of modern skyscrapers introduces severe aerodynamic and operational maintenance challenges that require specialized engineering interventions.

Wind Resistance & Aerodynamics: Installation of structural dampers—such as **Tuned Mass Dampers (TMDs)** or viscous dampers at upper levels—to counter wind-induced oscillations, preventing structural fatigue and ensuring occupant comfort during high-velocity wind events.

Intelligent Parking & Facade Maintenance:

Smart Parking: Automated, multi-level robotic parking garages that optimize space utilization and reduce vehicle emissions within enclosed basements.

Facade Maintenance Units (BMUs): Automated, track-mounted roof rigs equipped with intelligent cradles to safely facilitate glass cleaning, structural inspections, and panel replacements at extreme heights.

Aviation Safety: High-intensity, synchronized LED aviation warning lights integrated with ambient light sensors to guarantee visibility for low-flying aircraft under all weather conditions.

LONG-TERM OPERATION, SAFETY AND SUSTAINABILITY

When we talk about high-rise construction and long-term operation, safety and sustainability can no longer live in separate silos. Integrating them means designing systems where a safety feature during construction either transitions into a permanent operational asset or directly minimizes environmental impact.

Here is an elaboration of these concepts, backed by real-world case studies that demonstrate how mega-projects handle integrated safety and sustainable infrastructure.

Automated Debris Management & Vertical Logistics

In high-rise construction, moving materials and managing waste across 50+ floors is a massive logistical and safety nightmare. Traditional gravity chutes can create dust hazards, falling debris risks, and high labor costs.

Case Study: The Shanghai Tower (Shanghai, China)

During the construction of the 632-meter Shanghai Tower, engineers utilized an integrated vertical logistics system.

The System: Instead of standard external hoists, they used heavy-duty, synchronized tower cranes anchored to the building's core structural health monitoring (SHM) system, alongside fully enclosed high-speed construction hoists.

Safety & Sustainability: Debris was strictly segregated at the source on individual floors and transported down using enclosed, dust-controlled systems to prevent high-altitude wind displacement. By monitoring the crane loads and building sway in real-time via sensors, they eliminated the risk of crane collision or structural overloading. The structural health sensors used during this chaotic construction phase remained in the building, transitioning into the permanent operational SHM system that monitors the tower's reaction to typhoons today.

Dynamic Fall Protection & Perimeter Guardrails

As a building grows taller, wind speeds increase exponentially. Traditional netting and static scaffolding become liabilities. Modern high-rises use self-climbing perimeter protection shields.

Case Study: One World Trade Center (New York City, USA)

Building a 1,776-foot skyscraper in a dense urban environment required unprecedented safety measures.

The System: The project utilized a hydraulic *Self-Climbing Cocoon system*. This acted as a fully enclosed, multi-level perimeter guardrail and fall protection system that wrapped around the top floors under construction.

How it worked: As the concrete floors were poured and cured, the entire protective enclosure hydraulically lifted itself up the building. It featured heavy-duty solid mesh that kept 100% of debris, tools, and workers contained, completely neutralizing the high-velocity wind hazards of Lower Manhattan.

Operational Transition: The precision alignment required for this construction phase meant that the structural anchor points were perfectly placed for the building's permanent, sustainable BMUs (Building Maintenance Units), which now handle window washing and exterior facade maintenance safely.

Structural Health Monitoring (SHM) & Smart Escalators

SHM involves placing IoT sensors (fiber optics, accelerometers) into the concrete and steel core during construction to monitor stress, tilt, and curing rates. During operation, this shifts to monitoring seismic activity and live loads.

Case Study: Burj Khalifa (Dubai, UAE)

The tallest building in the world relies heavily on a seamless transition from construction safety to operational sustainability. The attributes have been briefly narrated in Table 2.

Table 2: Attributes for System type used in the high rise building.

System Type	Construction Phase Role	Operational Phase Role
Structural Health Monitoring (SHM)	Monitored real-time concrete shortening, foundation settlement, and crane load stress on the core.	Monitors seismic activity, wind tower displacement, and structural integrity over time
Vertical Transportation (Elevators/ Escalators)	High-capacity, temporary hoist systems with automated overspeed governors and emergency braking.	Ultra-high-speed double-deck elevators with **regenerative drives** that feed power back into the building's grid, paired with smart escalators that slow down when empty to save energy.

The Burj Khalifa's integrated fire prevention system also highlights this crossover: the structural concrete core was built with specialized fire-resistant compositions, and the high-speed lifts can be switched into a controlled life-safety evacuation mode during emergencies.

Advanced Fire Prevention & Mitigation

Fire during the construction phase of a high-rise is incredibly dangerous because permanent standpipes, sprinklers, and compartmentalization walls are not yet fully functional.

Case Study: The Hudson Yards Development (New York City, USA)

Building a massive "city within a city" over active rail yards required innovative, sustainable fire and safety integration.

The System: Developers implemented **temporary-to-permanent hybrid standpipe systems**. As the buildings grew, the permanent fire suppression infrastructure was pressurized and extended concurrently with the top floors, rather than waiting for structural completion.

Sustainable Infrastructure Integration: The fire safety plan was tied directly to the project's smart grid infrastructure. The buildings utilize massive rainwater harvesting tanks located on mechanical floors. During construction, these tanks served as emergency water reservoirs for fire suppression. Today, during operation, they serve a dual purpose: providing water for the building's cooling towers (reducing municipal water use) and acting as a primary water source for the automated internal sprinkler systems.

Summary of the Integrated Lifecycle

Construction Phase: Focused on protecting workers from immediate hazards (falls, falling debris, crane failures) using heavy mechanics and IoT tracking.

Transition: The data baselines, anchor points, and internal plumbing established during construction become the backbone of the operational phase.

Operational Phase: Focused on energy efficiency (regenerative escalators), occupant safety (dynamic fire zones), and longevity (SHM analysis)—proving that a building's lifecycle safety is a single, continuous continuum.

DAMPER IN HIGHRISE BUILDING

High-rise buildings act like vertical cantilever beams. When powerful wind forces strike a skyscraper, they exert massive lateral loads, causing the building to sway. While structural steel and concrete provide the strength to prevent collapse, they are inherently elastic. Without intervention, wind-induced oscillations can cause structural fatigue over time and severe motion sickness for occupants on upper floors.

To mitigate this, structural engineers deploy '**dampers**'—essentially massive shock absorbers—to absorb and dissipate the kinetic energy introduced by the wind.

Here is a detailed breakdown of the primary types of dampers used in modern high-rise engineering, how they work, and their technical mechanisms.

Tuned Mass Dampers (TMDs)

A Tuned Mass Damper is a massive block of concrete or steel suspended near the top of a skyscraper. It acts as a pendulum that is precisely tuned to the natural vibration frequency of the building.

Mechanism of Action

When strong winds push the building to the left, inertia keeps the heavy mass momentarily in place, causing it to lag behind. As the building moves, the pendulum sways in the **opposite** direction (out of phase) of the building's movement. This counter-inertial force cancels out a significant portion of the kinetic energy, rapidly stabilizing the structure.

Key Components: A massive inertial weight (often thousands of tons), steel cables or hydraulic suspension arms, and viscous dampers attached to the mass to dissipate the energy as heat.

Iconic Example: Taipei 101features a 660-metric-ton steel pendulum suspended from the 92nd to the 87th floor, capable of reducing wind sway by up to 40%.

Tuned Liquid Dampers (TLDs) & Tuned Liquid Column Dampers (TLCDs)

Instead of a solid steel mass, Tuned Liquid Dampers use the sloshing motion of water to absorb structural energy.

Mechanism of Action

Tuned Liquid Dampers (TLD): Large, shallow sloshing water tanks are placed on the roof. When the building sways, the water moves back and forth. Energy is dissipated through the internal fluid friction (viscosity) of the water and wave-breaking action against internal baffles.

Tuned Liquid Column Dampers (TLCD): These utilize a giant **U-shaped concrete or steel tube** filled with water. As the building oscillates laterally, the liquid column is forced to flow through a restricted orifice at the bottom of the "U". The resulting pressure drop and fluid shear stresses convert kinetic energy into heat.

Operational Advantage: TLDs double as the building's emergency fire-suppression water reserves, optimizing space and weight utilization.

Viscous and Friction Dampers (Direct Supplemental Dampers)

Unlike TMDs, which sit at the top of a building, supplemental dampers are integrated directly into the structural framework (often within diagonal bracing or outriggers) across multiple floors (Fig.1).

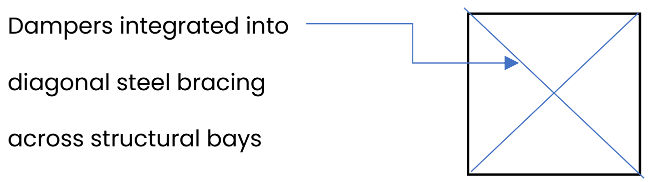

Fig.1 Mechanism of Action

Viscous Dampers: These function similarly to automotive shock absorbers. They consist of a piston head inside a cylinder filled with high-viscosity silicone fluid. When wind forces cause structural frames to deform or shear, the piston is forced through the fluid. The fluid resistance converts mechanical energy into thermal energy.

Friction Dampers: These consist of heavy steel plates bolted together with high-strength friction pads. Under extreme wind loads, the plates slide past one another. The mechanical friction between the sliding surfaces absorbs the kinetic energy, preventing it from transferring into the primary columns.

Aerodynamic Mitigation vs. Mechanical Damping

While dampers are highly effective at managing energy, modern engineers pairing them with aerodynamic optimization to prevent wind forces from organizing in the first place. By introducing architectural modifications, engineers can disrupt vortex shedding—the phenomenon where wind creates alternating low-pressure whirlpools behind a building, causing it to shake violently perpendicular to the wind direction.

Tapering and Stepping: Reducing the building's cross-section with height to alter its natural frequency along the vertical axis (e.g., Burj Khalifa).

Softened Corners & Open Apertures: Rounding off sharp edges or introducing massive wind tunnels (through-building apertures) near the top floors to allow wind to pass directly through the structure, drastically reducing wind drag.

he integration of smart, automated utilities within modern high-rise engineering is essential for managing dense occupant numbers, driving resource conservation, and maintaining rigid safety profiles. Operating under a unified Building Automation System (BAS) or Building Management System (BMS), these services transform high-rises into highly responsive, efficient vertical environments.

ADVANCED AC & HVAC AUTOMATION

In high-rises, heating, ventilation, and air conditioning (HVAC) consume the highest percentage of operational energy. Automating this system balances internal air metrics with grid efficiency.

Variable Air Volume (VAV) & Chiller Plant Optimization: Centralized chillers use smart loops to modulate refrigerant and airflow based on dynamic demands rather than running at static peak capacities.

Occupancy-Driven Zone Control: Integrated with PIR (Passive Infrared) motion sensors and localized smart thermostats, the AC dynamically dials

Table 3: Technical Comparison of Damper Systems

Damper Type	Primary Physics Principle	Spatial Requirements	Maintenance Complexity	Best Suited For
Tuned Mass Damper (TMD)	Inertia & Out-of-phase oscillation	High (Requires dedicated multi-story core space)	Medium to High (Cables and hydraulics require regular tuning)	Ultra-tall, slender skyscrapers (>300\ text{m})
Tuned Liquid Damper (TLD)	Fluid sloshing & Hydrodynamic drag	Medium (Can utilize rooftop footprint)	Low (Mainly water quality and corrosion control)	Medium to tall towers; structures looking to combine fire water storage
Viscous Damper	Fluid resistance & Viscous shear	Low (Distributed within standard structural walls/bracing)	Low (Sealed units, requires periodic seal inspection)	Flexible frames, outrigger systems, and seismic-wind dual zones

back airflow or adjusts temperature setpoints in unoccupied boardrooms, apartments, or common areas.

Indoor Air Quality (IAQ) Integration: Automation systems continuously evaluate internal CO_2, humidity, and particulate levels. If CO_2 spikes in high-density floors, the BAS triggers an automated fresh-air override to purge the zone without overworking the entire tower's ventilation network.

SMART WATER MANAGEMENT SYSTEM

Managing water across an vertical axis involves combating high hydrostatic pressure zones, minimizing massive pump electricity usage, and mitigating catastrophic leak risks.

Intelligent Pump Controls & VFDs: High-rises utilize Variable Frequency Drive (VFD) booster pumps. Rather than running at full speed and stressing the lower-level piping, the system uses digital pressure transducers to adjust pump velocity in real-time based on actual consumption spikes.

Automated Multi-Tank Levelling: Using analog ultrasonic level sensors or digital float switches connected to Direct Digital Controllers (DDC), the system automatically sequences motorized butterfly or solenoid valves. This fills distributed overhead and break tanks automatically, preventing pump dry-runs or overflow waste.

Acoustic Leak Detection & Automated Shut-off: Inline smart flow meters continuously baseline flow patterns. If abnormal flow occurs during low-occupancy night windows (indicating a burst pipe or leak), the system instantly isolates that specific riser using automated shut-off valves and pushes localized alerts to facility teams.

Automated Treatment and Recycling: Integration with greywater filtration and rainwater harvesting plants triggers backwash cycles and chemical adjustments dynamically based on real-time turbidity and sensor data.

SMART GAS MANAGEMENT SYSTEM

Because gas leaks present an immediate fire or explosive hazard in enclosed, vertical infrastructures, gas automation focuses entirely on continuous monitoring, localized isolation, and life safety.

Continuous Multi-Gas Sensing Networks: Highly sensitive, point-configuration gas sensors (such as MQ-series or electrochemical sensors) are permanently mounted in high-risk zones, including basement utility rooms, riser shafts, and individual kitchens. They provide 24/7 continuous analysis of LPG, PNG, or toxic gas thresholds.

Automated Interlocking Isolation:

[Gas Leak Detected] → [BMS Alarms Activated]

↓

[Solenoid Valve Tripped] → [Gas Supply Isolated Instantly]

If a minor leak is logged, the smart system immediately energizes an main Automatic Gas Shut-off Solenoid Valv at the source riser to kill the gas feed long before a combustible concentration is reached.

HVAC Exhaust Interlocking: Upon gas detection, the system triggers safety scenarios that auto-start specialized explosion-proof exhaust fans in the affected zone while closing surrounding AC dampers to prevent the toxic or flammable gas from circulating to upper floors.

Digital Consumption Tracking: Automated smart gas meters utilize Modbus or IoT wireless networks to transmit exact, automated billing data to the building administration dashboard, tracking localized trends and flagging creeping consumption anomalies that indicate slow micro-leaks.

CONCLUSION

A truly self-sustainable and resilient high-rise is realized only when construction safety parameters, robust life-safety systems, and smart automation are engineered as a cohesive, interconnected ecosystem. This integrated approach ensures that modern iconic structures remain safe for workers during construction, secure for occupants during operation, and gentle on the environment across their entire lifecycle. Also, some resilient system can help for the sustainability of the building. The capacity building of technicians and smart maintenance team is also essential along with the automated systems of the High rise building projects.

NEXT-GENERATION BUILDING MAINTENANCE THROUGH AUTOMATION & INNOVATION: AN OVERVIEW

Prof. B. P. Suneja*

Abstract

High-rise buildings have become an integral part of urban development, offering solution to the space constraints and population density. They accommodate residential, commercial, and mixed-use needs, supporting the growing demand for urban living and working environment. However, the maintenance of these buildings presents unique challenges due to their complexity, height, and diverse system. Since many maintenance activities are repetitive, time-sensitive and resource-intensive, integrating modern automation techniques into conventional practices can significantly reduce manual effort, enhance accuracy, and ensure timely interventions. By enabling early problem detection, improving safety and boosting productivity with limited resource, automation transforms maintenance from reactive process to proactive process. As buildings become increasingly intelligent, it is essential for maintenance practices to evolve accordingly- embracing technologies that make operations faster, safer and more reliable.

This paper presents an overview of key maintenance challenges in high rise buildings and explores strategies for effective maintenance management by using the innovative automation techniques particularly focusing on critical areas such as HVAC (Heating, Ventilation & Air Conditioning) systems.

INTRODUCTION

In the context of accelerating global urbanization, the rapid expansion of both newly constructed and existing buildings, has created significant challenges for building maintenance and management. Ensuring structural safety, extending service life, and promoting sustainable development now demand more effective strategies than ever before. Effective routine maintenance can reduce equipment downtime, prolong the lifespan of components, and enhance operational safety, thereby playing a critical role in preserving the functionality and value of buildings [1]. It's truly said "A stich in time save nine".

As maintenance tasks grow increasingly complex, teams are often confronted with challenging environments and inadequate equipment, particularly in highrisk scenarios such as façade inspections and work at height. These conditions exacerbate safety hazards and highlight the limitations of traditional maintenance approaches, which struggle to deliver efficiency, precision and reliable safety assurance. Consequently, such methods are proving insufficient to meet the escalating demands of modern cities for building safety and sustainability [2, 3].

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In response to these challenges, the application of emerging technologies in the field of building maintenance has become an important focus in engineering practice [4]. The rapid advancement of digital technologies, most notably artificial intelligence (AI), has opened new avenues for innovation in maintenance strategies [5]. AI enables automated monitoring of building conditions, intelligent diagnostics, and predictive maintenance, thereby enhancing efficiency and accuracy, reducing operational costs, and proactively preventing major safety incidents [6]. Collectively, these capabilities mark a paradigm shift from reactive, labour-intensive operations toward proactive, data-driven, and intelligent systems, thereby fostering greater efficiency, resilience, and sustainability in urban development.

MAINTENANCE STRATEGY

The specific technical processes involved in the building maintenance are typically explained in the following Figure 1.

AI enabled automated monitoring of building conditions & intelligent diagnostics play an important role in the 'predictive maintenance processes'.

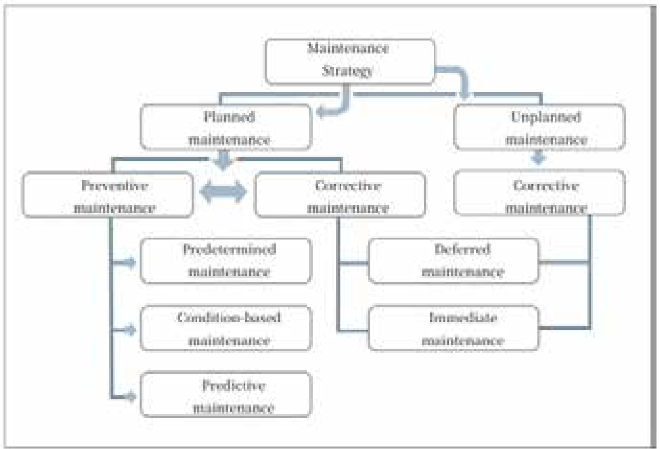

Fig.1 : Technical Processes of Building Maintenance

REACTIVE (TRADITIONAL) MAINTENANCE V/S PREDICTIVE (AI-BASED) MAINTENANCE

Prevailing maintenance practices remain largely dependent on traditional methods such as manual inspections and reactive repairs [2, 7]. These approaches are not only labour-intensive and time-consuming but also rely heavily on the subjective judgment and experience of personnel. As a result, they often fail to deliver comprehensive, consistent and objective inspection outcomes, limiting their effectiveness in addressing the complex demands of modern urban infrastructure. Moreover, many building maintenance tasks are inherently repetitive, timesensitive, and resourceintensive. Automating these processes can substantially reduce manual workload, improve accuracy, and ensure timely interventions, thereby advancing both operational reliability and sustainability in modern building management.

Compared with traditional manual inspections and reactive repair methods, artificial intelligence (AI) offers transformative advantages for building maintenance [8]. By integrating sensors with intelligent algorithms, AI enables continuous, roundtheclock monitoring, thereby enhancing the timeliness and accuracy of hazard detection [9]. Through the analysis of large volumes of historical and realtime data, AI strengthens maintenance decisionmaking while reducing the costs associated with manual inspections and operations [10].

Applications such as deep learningbased image analysis have significantly advanced the efficiency and precision of defect identification [11]. Furthermore, the convergence of AI with complementary technologies, including the Internet of Things (IoT) and Building Information Modeling (BIM), has accelerated the digital and intelligent evolution of building management systems. This integration supports performance optimization, energy conservation, and predictive fault detection [12]. As a result, AI has emerged as a central driving force for innovation and modernization in the field of building maintenance [13].

HAVC SYSTEMS MONITORING IN BUILDING MAINTENANCE

Heating Ventilation and Air conditioning systems (HVAC) are integral part of modern buildings. HVAC systems, being one of the most energy-intensive components in buildings, contribute to almost half the total energy consumption within structures [14]. HVAC system operation efficiency directly relates to reduced energy consumption and carbon emissions.

Effective maintenance of the HVAC systems is essential as it

- controls the ambient temperature,
- keeps humidity levels in check,
- ensures optimal air quality inside the building,
- ensures system longevity & energy efficiency and
- results in cost savings in both commercial & residential buildings.

Proper upkeep not only sustains operational efficiency and consistent comfort but also prevents expensive emergency repairs and premature equipment replacement. Neglected systems can consume up to 20% more energy, experience more frequent failures, and have significantly shorter lifespans. In contrast, wellmaintained systems can extend equipment life from 12 to over 20 years.

KEY COMPONENTS OF HVAC SYSTEM

A comprehensive HVAC maintenance program should include all major system components to ensure optimal performance, safety, and efficiency:

- **Heating Systems**: Furnaces, boilers, heat exchangers, and heat pumps require regular inspection, cleaning, and calibration to maintain safe and efficient operation.

- **Cooling Systems**: Central air conditioners, evaporator and condenser coils and refrigerant lines need routine cleaning, refrigerant level checks, and efficiency testing to prevent performance degradation.
- **Ventilation**: Ductwork, fans, blowers, and filters must be cleaned and inspected to sustain airflow, regulate humidity, and remove airborne contaminants, thereby preserving indoor air quality.
- **Controls**: Thermostats, sensors, and electrical connections should be tested and calibrated to optimize system performance and energy use.
- **Specialized equipment**: Components such as chillers, cooling towers, pumps, motors, and variable air volume (VAV) boxes require detailed inspections, lubrication, and performance testing to ensure reliability and longevity.

MAINTENANCE STRATEGIES OF HVAC SYSTEM

A robust HVAC maintenance strategy should integrate multiple layers of practice to ensure reliability, efficiency, and sustainability:

1. **Preventive Maintenance**: Routine inspections, cleaning, lubrication, and component testing minimize breakdowns, improve indoor air quality, and sustain energy efficiency.
2. **Scheduled Maintenance**: Tasks should be performed monthly, quarterly, or annually depending on equipment type and operating conditions. Highdemand systems, such as data centre cooling or kitchen exhaust etc., may require more frequent servicing.
3. **DataDriven Predictive Maintenance**: Leveraging business intelligence and analytics, modern systems monitor performance in real time, predict potential failures, and schedule timely interventions, thereby reducing unplanned downtime and enhancing efficiency.
4. **Documentation and Tracking**: Maintaining detailed records of inspections, repairs, and calibrations ensures accountability, supports warranty compliance, and provides data to optimize future maintenance schedules.

BENEFITS OF A COMPREHENSIVE MAINTENANCE PROGRAM

Some of the potential benefits of Comprehensive Maintenance Program are as below:

1. **Energy Savings**: Clean, calibrated systems operate at peak efficiency, lowering utility costs and reducing environmental impact.
2. **Extended Equipment Life**: Regular maintenance minimizes wear and tear, preventing premature failures and costly replacements.
3. **Improved Indoor Air Quality**: Routine filter changes and duct cleaning remove dust, allergens etc., and creating healthier indoor environments.
4. **Operational Reliability**: Preventive and predictive maintenance reduce unexpected breakdowns and service disruptions, ensuring consistent performance.

CHALLENGES AND MAJOR ISSUES IN AI BASED BUILDING MAINTENANCE

Despite its promise, the engineering application of artificial intelligence (AI) in building maintenance management continues to face significant challenges as describe below:

1. **Data Collection:** Data sources related to building maintenance are highly diverse yet lack unified standards [15]. Data quality is inconsistent, formats vary, and effective sharing remains limited. For example, large volumes of building operation and maintenance data are neither systematically collected nor stored, and openaccess databases are scarce—available primarily for energy consumption rather than maintenance [16]. This severely constrains the integration of heterogeneous multisource data and hinders the widespread adoption of AI models.
2. **AI Models:** Current AI models often struggle to adapt across building types, climatic conditions, and operational scenarios, reflecting insufficient generalization capability [17]. The scarcity and fragmentation of training datasets limit model transferability across climate zones and structural variations [18]. Differences in operating conditions between regions and buildings frequently result in poor performance of “welltrained” models

when applied in new environments [19]. Moreover, the "blackbox" nature of AI systems renders their decisionmaking opaque, making it difficult for building operators to interpret recommendations [20]. This lack of transparency undermines user trust and poses a major barrier to realworld adoption.

3. **Data Exchange:** Many existing building maintenance platforms, sensor networks, and Building Information Modeling (BIM) systems operate in isolation, restricting AI from accessing comprehensive and standardized data. Legacy equipment and software often lack interoperable interfaces; for instance, older building systems are incompatible with modern IoT edge nodes, preventing seamless data exchange [21]. These information silos increase deployment complexity and necessitate extensive customization to bridge disparate systems.

4. **Policy Related:** Finally, disparities in resource investment, policy support, and technology transfer capacity across countries and regions exacerbate uneven global development of intelligent building maintenance.

Looking ahead, future efforts should prioritize advancing data standardization, improving the generalizability of AI models, and enhancing their interpretability. Equally important is the optimization of system integration pathways to overcome information silos. At the policy level, reinforcing resource allocation and tailoring support to regional contexts will be critical to ensuring the highquality implementation and sustainable development of AI technologies in building maintenance management.

CONCLUSION

The maintenance of high-rise buildings is a complex and multidisciplinary task that requires systematic planning, effective execution, and continuous monitoring. By ensuring structural integrity, maintaining mechanical and electrical systems, preserving façade performance, and adhering to rigorous safety protocols, building owners and facility managers can enhance the safety, reliability, and service life of these structures. As urban landscape continues to expand, it is essential to adopt sustainable and resilient maintenance practices to meet the challenges of the future.

This review demonstrates the evolving role of AI in building maintenance, highlighting a transition from reactive, labour-intensive maintenance to proactive, data-driven, and intelligent asset management. AI is also advancing from isolated task-specific applications to integrated, system-level solutions through the convergence of Building Information Modeling (BIM), digital twins, IoT, and Computerized Maintenance Management Systems (CMMS). This paradigm shift enables continuous asset monitoring, predictive decision-making, optimized resource allocation, enhanced energy efficiency, and improved risk management. As these technologies continue to mature, their successful implementation will depend on robust governance, standardized data integration, model transparency, and collaboration among researchers, industry practitioners, and policymakers.

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