Identifying and Reviewing Green Building Alternatives for Navi Mumbai

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ABSTRACT

The massive construction boom observed in Indian cities in the last two decades has resulted in a number of environmental issues such as pollution, urban heat islands, deterioration of green areas and natural vegetation; making the cities unliveable. Navi Mumbai, the city situated on the Indian west coast is surrounded by various ecologically sensitive elements both on land and in waters. As the city keeps on growing, these areas also become vulnerable so as the population residing in the city. The present article is an attempt to identify and review green building alternatives for the city by studying the various parameters and strategies given by different rating organisations in the context of Navi Mumbai and Indian scenario for sustainable development of the city in the future.

Keywords: *Green buildings, sustainable development, urban heat islands, natural vegetation, ecologically sensitive areas.*

INTRODUCTION

Buildings account for approximately 19 per cent of all Global Greenhouse Gas (GHG) emissions in the world, and about 31 per cent of global final energy demand (Šujanová, Rychtáriková, Mayor, & Hyder, 2019). As the urban population of the world grows, the green building concept has become a cornerstone of sustainable development for maintaining environmental, economic and social sustainability in the long term (Yoon & Lee, 2003). A green building refers to the exercise in which environmentally appropriate and resource-efficient strategies are practiced throughout the lifecycle of building (Chan, Darko, & Ameyaw,

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2017). A sustainable project is planned, constructed, operated and reused in an environmental and resource efficient manner (Akadiri, Chinyio, & Olomolaiye, 2012). Green buildings can also be defined as the structures that seek to minimise the overall impact of the built environment on human health and the natural environment by utilising electricity, water and other resources effectively and reducing waste, pollution and deterioration of the ecosystem. (USGBC, 2009).Green buildings offer opportunities to establish sustainable buildings, utilising integrated architecture strategy to reduce the ill-effects due to construction, on the atmosphere and the occupants (Ali & Al Nsairat, 2009). Cities create large amount of pollution and waste, placing both human and ecological safety under strain, but buildings themselves may provide a solution to the problem (Nowakowski, 2017).[1] Green building design not only has a positive impact on environment and public health but also helps to reduce operating costs, improves building performance and productivity of occupants and thereby creates a sustainable community (Fowler & Rauch, 2006).

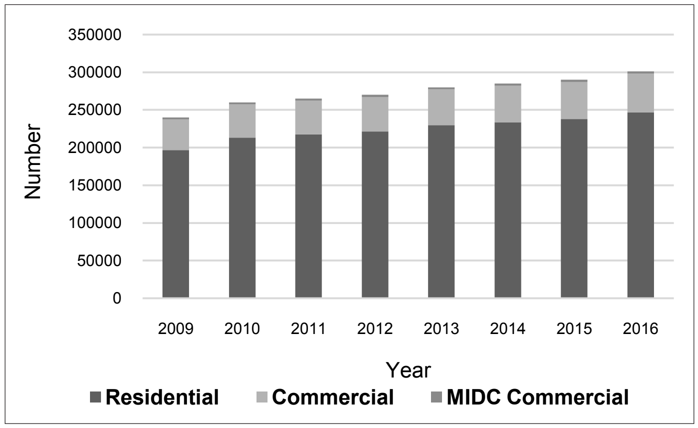
NAVI MUMBAI: A BRIEF DESCRIPTION

Established in 1972, Navi Mumbai is a planned city of India which is located on the west coast of the state of Maharashtra in Konkan division; this planned decentralisation resulted from efforts done by the government to make the city of Bombay (now Mumbai) more ‘sustainable’ (Bombay Metropolitan Regional Planning Board, 1973). For the individual development of the city, the city is divided into two parts known as North Navi Mumbai and South Navi Mumbai, which include the area from Kharghar to Uran, these are actually a group of islands located near the coast of north Konkan (19.0330° N, 73.0297° E). As per the reports of Census of India, the population of Navi Mumbai in 2011 was 1,120,547.[2]

Research Concern

Navi Mumbai is growing with decadal positive growth rate of 88.91 per cent recorded in 2001(NMMC, 2017).The policy adopted by The Maharashtra Government resulted in industrial area development in Navi Mumbai which led to migration/re-location of people from Mumbai to Navi Mumbai for better lifestyle and job opportunities (NMMC, 2017). Developing industrial belt led to rapid industrialisation which has been among the prime economic drivers for the city. The population of nodal areas of city is expected to grow at faster rate resulting in increase in use of land resource for population accommodation. The number of properties in Navi Mumbai Municipal Corporation (NMMC) have increased by almost 25 per cent since 2009-10 as shown in Fig. 1.

Fig. 1: Trend of property development over the last eight years in Navi Mumbai



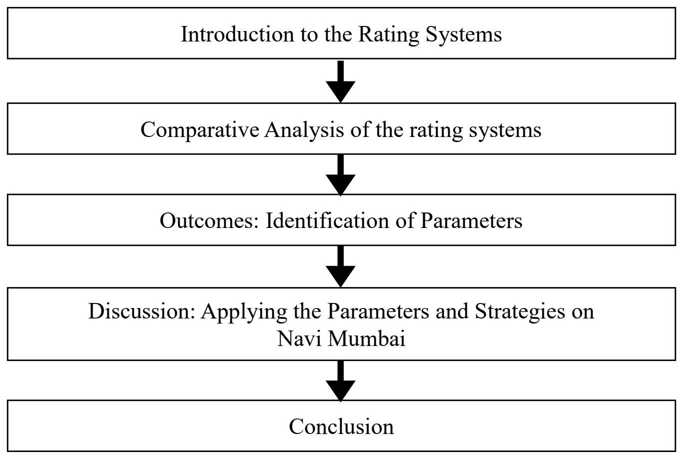
Source: Town Planning Department, NMMC.

For the year 2016-17, residential properties recorded highest at 82 per cent of total properties, followed by commercial with 17 per cent and MIDC commercial with one per cent share. Also, a huge crisis emerged in the city as buildings were found unsafe to stay in over 53 societies (NMMC, 2017). The construction and use of buildings, driven by rapid urban expansion, is imposing tremendous pressures on the natural environment and public health. Urbanisation is often cited as a major reason for loss of native biodiversity and its replacement with non-native vegetation across the world (Mckinney, 2002). City is surrounded by ecologically sensitive areas important to the natural ecosystem of the city, such as mangroves, lakes and wetlands (NMMC, 2017). The impact of rapid urbanisation in Navi Mumbai is severe and environmental degradation is occurring rapidly. A green building approach is an alternative of sustainable growth ensuring, minimal impact on the environment throughout building's life. Using a green rating (assessment) system in the design/build process can produce significant benefits such as preventing local ecological degradation (habitat, air, soil, and water), improving public health and building performance through efficient site and building design, sustainable construction practices, and low impact building materials.

Research Methodology

For this study, different green building rating systems are studied and a list of green building alternatives is identified by analysing various parameters and strategies given by leading green building rating systems in India by a comparative analysis. These alternatives are then reviewed in context of Navi Mumbai and Indian scenario to study their applicability. See Fig. 2 for further clarification.

Fig. 2: Research Methodology (Process Flow)



SUSTAINABILITY RATING SYSTEMS—INTRODUCTION

Green Rating for Integrated Habitat Assessment (GRIHA) rating system applies to new building stock – commercial, institutional and residential – of varied functions (GRIHA, 2020). Endorsed by the Ministry of New and Renewable Energy (MNRE), Government of India as of November 1, 2007, GRIHA is a five Star rating system, developed by the Energy and Resources Institute (TERI) and MNRE as an indigenous building rating system, especially for addressing and evaluating buildings which are not air conditioned or partly air conditioned (TERI, 2016). The Indian Green Building Council (IGBC) classification framework for new buildings is a voluntary, consensus-driven rating system focused on the quality of current materials and technologies. It is a part of the Confederation of Indian Industry (CII), formed in the year 2001 (IGBC, 2020). IGBC rating system focuses on designing environmentally sustainable buildings through architectural programmes, water efficiency, efficient waste management, energy efficiency, sustainable buildings, and occupant comfort and well-being (TERI, 2016). Leadership in Energy and Environmental Design (LEED) rating system is developed by USGBC (United States Green Building Council), United States, initially piloted in the US and later expanded to many countries across the world (USGBC, 2017). Green features such as sustainable design and architecture, site selection and planning, water conservation, energy efficiency, construction materials and resources, indoor environmental quality, innovation and development are addressed in the rating system.

Comparative Analysis

Table 1 establishes a comparative relation between the different parameters and their respective strategies for green buildings and green developments that are given by IGBC, GRIHA and LEED. The parameters found common in all the three organisations are listed alongside to analyse the commonalities and differences in the strategies under those particular parameters. The strategies which come out to be common are highlighted providing analogous shade. The parameters strategies having no repetitions are also identified. The parameters and strategies which observe the maximum repetition tend to be the most important and rudimentary pertaining to green development. The parameters and strategies which are not or less repetitive, but are still important for green development are also identified. Hence, all the parameters and strategies which are repetitive/ basic and non- repetitive but still equally important, are identified which are cardinal for green development in Navi Mumbai.

Common Parameters and Strategies

These are the parameters and strategies which are common in the organisations under study, hence are rudimentary and cardinal for green building development and are to be included for green building solutions for Navi Mumbai.

(i) ***Sustainable site planning:*** The strategy observing maximum repetition is designing to reduce the heat island effect. Other common strategies are to reduce soil erosion, preserving the topography, using natural and regional vegetation for landscaping purposes.

(ii) ***Water efficiency:*** Reducing the use of water by using efficient low flow fixtures for different uses and rainwater harvesting are the most common strategies. Management and reduction of water usage for irrigation purposes for landscaping, reuse and treatment of water are also common.

(iii) ***Energy efficiency:*** Using renewable and clean sources of energy, generated on-site or off-site is the most common strategy. Other repetitive strategies are energy monitoring and using efficient appliances, systems and lighting to reduce the usage of energy.

TABLE 1: TABLE SHOWING THE COMMON AND UNIQUE ELEMENTS IN IGBC, GRIHA AND LEED

IGBC	*GRIHA*	*LEED*
Site Selection and Planning	*Site Planning*	*Sustainable Sites*
• Following local building regulations. • Preventing soil erosion. • Preserving natural topography and vegetation. • Preventing heat island effect caused by site activities. • Providing parking facilities for visitors and electric charging facility for vehicles. • Providing universal access. • Providing basic facilities for construction workforce.	• Site Selection by considering the surrounding natural environment. • Following low environmental impact principle. • Prevent urban heat island effect. • Considering imperviousness factor of site while designing.	• Discouraging green field developments. • Minimising building impact on ecosystems and waterways. • Encouraging regionally sound landscaping. • Managing storm-water runoff. • Promoting smart transportation choices and green energy solutions. • Reducing erosion and light pollution. • Reducing heat island effect. • Preventing construction pollution.
Water Efficiency	*Water*	*Water Efficiency*
• Promoting rainwater harvesting. • Using Water efficient fixtures. • Managing water used for landscaping. • Waste water treatment, reuse and water metering.	• Using low-flow fixtures and water efficient systems. • Reducing water used for landscaping. • Ensuring good water quality. • On-site water treatment and reuse to reduce water consumption. • Promoting rainwater recharge and recycle.	• To encourage smarter use of water indoor and outdoor. • Water reduction, through efficient and low flow appliances, fixtures and fittings inside. • Using water wisely for landscaping • Rainwater harvesting.
Energy Efficiency	*Energy*	*Energy and Atmosphere*
• Using CFC-free equipment. • Following Minimum energy performance principle. • Using renewable energy. • Using energy saving appliances and equipment. • Using distributed power generation. • Energy metering.	• Ensuring energy efficiency in the building. • Using renewable energy. • Using low ODP materials.	• Energy use commissioning. • Energy use monitoring. • Energy efficient design and construction. • Efficient appliances, systems, and lighting. • Using renewable and clean energy sources.

(contd. Table 1)

Materials & Resources	*Sustainable Building Materials & Solid Waste Management*	*Materials and Resources*
• Segregating household waste. • Managing organic waste. • Managing construction waste. • Using materials with recycled content and reusing the salvaged materials. • Using local materials for construction and finishing purposes of the buildings. • Using rapidly renewable building materials & certified wood.	• Using BIS recommended waste materials in building construction. • Reducing structural embodied energy of building. • Using low-environmental impact materials in building interiors. • Avoiding post-construction landfill. • Treat organic waste on site of generation.	• Encouraging use of sustainably grown, harvested, produced, and transported products/ materials. • Promoting waste reduction, reuse and recycling.
Indoor Environmental Quality	*Occupant Comfort and Well-Being*	*Indoor Environment Quality (IEQ)*
• Utilising day-lighting for visual comfort. • Providing fresh air ventilation and tobacco smoke control measures. • Using low VOC materials. • Providing cross ventilation and exhaust systems for thermal comfort.	• Achieving indoor visual comfort requirements. • Achieving indoor thermal comfort. • Achieving indoor acoustic comfort. • Providing healthy indoor air quality for the occupants of the building. • Using low-VOC materials and compounds in building interiors to decrease the indoor air pollution.	• Promoting strategies that can improve indoor air quality. • Providing access to daylight and views for visual comfort. • Improving acoustics.
Innovation & Design Process	*Socio-Economic Strategies*	*Awareness and Education*
• Innovation in design process. • IGBC Accredited Professional for innovative practices.	• Ensuring labour safety and sanitation. • Designing for Universal Accessibility. • Providing dedicated facilities for service staff. • Increasing environmental awareness.	• Encouraging home owners and real estate professionals for providing home owners, tenants, and building managers the education tools for making the buildings and surroundings green.

(contd. Table 1)

	Performance Monitoring & Validation	*Regional Priority*
	Using smart performance metering and monitoring systems Following operation & maintenance protocols. Practicing building performance assessment. Promoting innovation to enhance building performance.	Identifying and considering environmental concerns that are locally cardinal for different regions in the country (additional six LEED credits are given to project that addresses those local priorities selected for each region). A project earning a regional priority credit earns one additional bonus point in addition to any other initial points that have been awarded for that credit.
	Construction Management	*Locations and Linkages*
	• Controlling air/ water pollution and preserving/ protecting landscape during construction. • Efficiently managing construction practices	• Encouraging buildings constructed away from environmentally sensitive areas and promoting green field development. • Promoting buildings constructed/ located near existing infrastructure. • Encourage access to open space for walking and physical activity.
		Innovation in Design
		• Promoting projects that use innovative technologies/strategies (other than LEED credits requirement or green building practices which are not specified by LEED) to improve performance of building by providing bonus points. • Promoting projects ensuring a holistic, integrated approach to the design and construction phase.

Sources: (GRIHA, 2020)**;** (Fithian & Sheets, 2009)**;** (IGBC, 2020)**;** (USGBC, 2017)

(iv) ***Building materials and resources:*** Promoting reduction, reuse and recycling of different waste materials is a common strategy under this parameter. Other common strategies are to use local and environment-friendly materials and on-site treatment/ management of organic waste.

(v) ***Indoor environment quality:*** Indoor air quality depends upon adequate air, light and acoustics. Hence the strategies are focused upon indoor air quality through adequate ventilation, cross ventilation, exhaust systems to ensure fresh air; providing daylight access and improving acoustics.

Unique Strategies

Besides the common parameters and strategies, a number of unique parameters and strategies are observed in the organisations under study. These unique elements are also to be considered as they fill the gaps left by each organisation under study. In other words, the lack of one organisation is to be filled by the abundance of the other.

IGBC

For site selection and planning, IGBC includes unique strategies focusing on consideration of local planning regulations. Providing parking facilities for visitors, charging stations for electric vehicles as a part of site planning and accounting requirements of Persons with Disabilities (PwDs) in designing processes. Energy efficiency strategies like using CFC (chlorofluorocarbons) free equipment, solar heating systems and distributed power generation. For materials and resources, the unique strategies include separation of household waste for efficient waste management. For indoor living environment, the unique strategies are to use low Volatile Organic Compounds (VOC) materials, paints & adhesives for finishing and other indoor construction purposes.

GRIHA

For site planning, the strategies for low impact design and site impervious factors are considered. For water and energy efficiency, the strategies of water quality enhancement and usage of low Ozone Depletion Potential (ODP) materials are taken into account respectively. For Sustainable Building Materials and Solid Waste Management, the unique strategies are to use Bureau of Indian Standards (BIS) recommended waste for construction purposes, reducing the embodied energy of building structure and avoiding post-construction landfill for efficient construction waste management. For occupant comfort and well-being, the unique strategies are maintaining good indoor air quality by using low-Volatile Organic Compounds (VOC) paints and green compounds indoors. GRIHA further includes some important unique parameters which are not accounted in IGBC and LEED. The first is *socio-economic strategies*, second is *performance monitoring and validation* and the third is *construction management*. The *socio-economic strategies* include labour safety and sanitation measures. Design for universal accessibility so that every person is able to access the design features including the PwDs. Also including the dedicated facilities for service staff as design features to enhance user accessibility. Further, increasing the environmental awareness is also taken account. *Performance monitoring and validation* includes using the smart metering and monitoring systems, operation and maintenance protocols and performance assessments for final ratings. *Construction management* include the air and water pollution control, preservation and protection of landscape during the construction period and construction management practices.

LEED

Under site planning, the unique strategies are to discourage development on previously undeveloped land; minimising impact of building on surrounding ecosystems and waterways; controlling storm water run-off; promoting smart transport solutions and reducing pollution caused by different construction processes. For water efficiency, the strategies are aimed to encourage smarter use of water in building's indoors and outdoors. For energy efficiency, the strategies focus upon energy commissioning, efficient designing and construction processes. The strategies pertaining to materials and resources include the reduction of waste at a product's source. There are also unique parameters covered by LEED, which are not covered by IGBC and GRIHA. The first parameter is *awareness and education*, second is *regional priority*, third is *location and linkages* and the fourth is *innovation in design*. *Awareness and education* includes encouraging the homeowners and real estate professionals to provide homeowners, tenants, and building managers, the education tools required for making their home/ building green. *Regional priority* promotes the prioritising and considering regional environmental concerns that are locally most important for every region of the country by offering a project that earns a regional priority credit, one bonus point in addition to any points awarded for that credit. Under *location and linkages*, LEED encourages buildings being built away from environmentally sensitive areas, instead, being built in infill, previously developed, and other sites. LEED promotes structures constructed near already-existing infrastructure, community resources and transits. It also promotes accessibility to open space for walking and physical activities. For *innovation and design*, LEED provides bonus points to projects using new and innovative technologies and strategies (other than what is required for LEED credits or other green building strategies which are not specified anywhere in LEED) to improve the performance of building. Also, to ensure a holistic and integrated approach in the design and construction phase, LEED rewards innovative projects though LEED accredited professionals.

Outcomes

In the above discussion, the common and unique parameters and strategies pertaining to green buildings are discussed for the respective organisations under study. Based on the discussion, concluding the common and unique elements from all the organisations under study, a list of important parameters and strategies which can be beneficial for green building development in Navi Mumbai, is shown in Table 2.

Discussion: Reviewing the Identified Parameters in Context of Navi Mumbai and Indian Scenario

As listed in Table 2, the various green building alternatives have been identified based on the analysis and discussion. These alternatives are categorised under different parameters and strategies. The applicability of these green building alternatives in Navi Mumbai is discussed ahead.

Sustainable Site Planning

Cities create a vividly differential environment from the surrounding areas, hence, effecting the nature and public health (Ramamurthy & Roy, 2019). Navi Mumbai encompasses various naturally sensitive areas *"ranging from low hills with tropical semi-evergreen, tropical moist deciduous, tropical dry deciduous, to marshlands, estuary and mangroves"* (NMMC, 2017). To ensure nature's preservation and public health,green building alternatives of low impact and natural vegetation preserving strategies pertaining to sustainable site planning, become necessary for the city.

Water Efficiency

In India, rapid population growth in urban areas, especially in large urban communities, restricted sources to expand water flexibly, expanded interest and contamination and constrained reuse, have prompted a rising water frailty in urban areas (Shaban & Sattar, 2011). In 2011, urban population in India was 377 million with a domestic water demand of 50,895 million litres per day, it is estimated that by 2050, half of India's population will live in urban areas and will face

TABLE 2: DERIVED LIST OF PARAMETERS AND STRATEGIES

Sl. No.	*Parameters*	*Sub- Parameters*	*Strategies*
1.	Sustainable Site Planning	Low impact design	• Design to mitigate urban heat island effect. • Discourage development on previously undeveloped land and promoting redevelopment and retrofitting practices. • Reducing erosion and light pollution. • Reducing heat island effect. • Controls storm-water runoff.
		Efficient landscaping	• Encourage regionally appropriate landscaping. • Preserving the natural and existing natural vegetation.
		Transport services	• Smart transportation choices. • Electric charging facility for vehicles. • Parking facilities for visitors.
		Usability and accessibility	• Design for differently abled. • Basic facilities for construction workforce. • Green home guidelines, design & post occupancy.
2.	Water Efficiency	Reducing water usage	• Using low-flow and water efficient fixtures, plumbing systems. • Management of irrigation systems and reducing landscape water demand. • Water metering.
		Reusing and Recycling of water	• Rainwater harvesting, roof and non-roof. • On-site water treatment and reuse.
3.	Energy Efficiency	Reducing energy usage	• Using low consumption and efficient appliances, systems, and lighting. • Efficient design and construction measures.
		Green energy and materials	• Use of renewable and clean energy sources generated on-site or off-site. • Solar energy harvesting for uses such as water heating systems. • Distributed power generation.
		Energy management	• Energy commissioning. • Efficient metering and monitoring of energy usage.

(contd. Table 2)

4.	Materials and Resources	Use of low-environmental impact materials	• Utilisation of BIS recommended waste materials in building structure. • Using low ODP materials. • Reused and recycled building materials. • Rapidly renewable building materials & certified wood.
		Local and recycled materials	• Encourage the selection of sustainably grown, harvested, produced, and transported products/ materials. • Using materials with recycled content and reuse of salvaged materials. • Promoting reduction of waste as well as reuse and recycling.
		Waste management	• Organic waste management, post occupancy. • Treat organic waste on-site. • Reduction of waste at a product's source. • Separation of household waste. • Handling of construction waste materials.
5.	Indoor Environment Quality and Sustainable Design	Indoor air quality	• Fresh air ventilation. • Using low-VOC materials and compounds in building interiors to decrease the indoor air pollution. • Using CFC free equipment. • Tobacco smoke control.
		Thermal comfort	• Exhaust systems. • Cross ventilation.
		Acoustics and visual comfort	• Improving acoustics using sound absorbing finishing materials and openings. • Achieving indoor visual comfort requirements. • Providing access to daylight and views through efficient designing measures.
6.	Social Awareness and Socio-Economic Strategies	Socio-economic strategies	• Labour safety and sanitation. • Design for universal accessibility to enable all the users to access all the features of a building. • Dedicated facilities for service staff.
		Awareness and education	• Increase in environmental awareness. • Encourage homeowners and real estate professionals to provide homeowners, tenants, and building managers the education tools necessary for making their home green.

(contd. Table 2)

7.	Performance Monitoring and Construction Management	Performance monitoring and validation	• Smart metering and monitoring. • Operation & Maintenance protocols. • Performance Assessment for Final Rating.
		Construction management	• Air and water pollution control. • Preserve and protect landscape during construction. • Construction Management Practices.
8.	Regional Priority, Location and Linkages	Regional priority	• Promoting and encouraging the projects considering regional environmental impacts.
		Location	• Encouraging buildings being built away from environmentally sensitive areas, instead, being built in infill, previously developed, and other sites. • Rewarding homes built near already-existing infrastructure, community resources and transit.
		Linkages	• Encourage access to open space for walking and physical activity and time spent outdoors.
9.	Innovation	Design innovation	• Encouraging projects that use new and innovative technologies/strategies to improve building's performance and environmental impacts. • Ensuring a holistic, integrated approach to the design and construction phase.
		Innovation in performance monitoring	• Encouraging innovative methods of monitoring the building performance pertaining to green practices.

Source: Derived from comparative analysis.

acute water problems (Ali M. Q., 2018).Also, this water shortage is now compounded with an estimated 20-25 per cent increase in water demand and generation of wastewater for hand washing purpose in these COViD-19 times in the country (Rohilla, 2020).

Navi Mumbai also faces severe water shortage, influencing 1.16 lakh individuals. The daily water requirement of the city is 335 million litres. But, only 305 million litres are provided by NMMC (Verma, 2016). Navi Mumbai consists of several water bodies such as 24 lakes, creek, ponds, wells and so on which are used for various domestic and industrial purposes in the city (NMMC, 2017). However, NMMC remains unable to deal with water shortage. The authority is seeking an alternative water source to decrease the demand from Morbe Dam (major water supplier for the region); also the administration has now asked housing societies to dig bore wells to deal with the shortage of drinking water (Verma, 2016).

These solutions are having certain issues as the Central Ground Water Board (CGWB) says that the groundwater is not suitable for drinking as well as domestic uses (Verma, 2016). The groundwater is also prone to contamination from sewage disposal and excessive pumping may result in sea water intrusion (Verma, 2016). Hence, in Navi Mumbai digging of borewells, cannot be an optimum solution to the water shortage (Verma, 2016). The best solution for the water shortage is to reduce water wastage as recommended by experts (Verma, 2016). Water wastage can be efficiently avoided by practicing green strategies such as using low flow fixtures, managing irrigation practices, water metering, rainwater harvesting, etc.

Energy Efficiency

Concrete buildings are also the major contributors of negative impacts on the environment due to unsuitable use of energy. According to an estimate, heating, cooling, and lighting applications in buildings hold more than one-third of the world's primary energy demand (Yilmaz & Selbaş, 2018). Also, commercial and residential buildings consume 20 per cent to 40 per cent of energy produced globally (Hwang & Tan, 2012). The quantity of CO_2 emissions caused by electricity consumption is directly dependent on the process in which it is generated (TERI, 2013). Using conventional sources of energy results in various kinds of pollution, acid rain, and greenhouse gases (Salameh, 2014). On the other hand, green sources like solar energy technologies can be considered as almost absolutely clean and safe (Wang & Ge, 2016).

In India, coal-based power plants have a major share of almost 60 per cent in electricity generation as in March 2011 (TERI, 2013). In Navi Mumbai the emissions from electricity consumption have increased in the last five years from 1.38 million tonne CO_2 in 2007-08 to 1.98 million tonne CO_2 in 2011-12, almost 1.4 times, with a compound annual growth rate of 9.37 per cent (TERI, 2013). Also, for domestic purposes, the conventional fuels(coal, wood, kerosene, LPG) have become major contributors of PM10 emission load out of total area source emissions by adding 1.29 tonne of PM10 in the environment per day in Navi Mumbai (Maharashtra Pollution Control Board, 2019).

To mitigate these issues, reduction in energy use should be promoted and following environmental impacts of the buildings can be achieved through the application of sustainable sources of energy (Yilmaz & Selbaş, 2018). Also, about 47 per cent of total energy in Indian residential buildings is used for ventilation controls alone (Indraganti, 2011) hence, sustainable designs should be promoted to minimise energy usage.

Materials and Resources

In India, urbanisation, industrialisation and economic growth lead to increase in Municipal Solid Waste (MSW) generation per person, as a result, solid waste management has become a prime issue for many urban local bodies in the country (Kumar, et al., 2017). In 2015, as per Central Pollution Control Board, urban India generated 62 million tonne of MSW which is 450 grams per capita per day. Nearly 82 per cent of MSW was collected, and the remaining 18 per cent consisted of litter. Treated waste was only 28 per cent of the collected waste, and the remaining 72 per cent was dumped openly (Sharma & Jain, 2019). The volume of waste is projected to increase from currently 64-72 million tonnes to 125 million tonnes by 2031 (Ahluwalia & Patel, 2018).The Ministry of Urban Development (MoUD) has recommended all the states to establish recycling facilities for Construction and Demolition (C&D) waste in all the cities having population of above one million to reduce the pressure on natural resources which are getting deteriorated for construction materials, leading to severe impact on the environment (Ministry of Housing & Urban Affairs, 2018).

Navi Mumbai generates around 600 metric tonne of MSW daily, of which nearly 66 per cent is biodegradable, this would translate to around 396 metric tonne of biodegradable waste per day. The remaining 34 per cent of the waste consists of either inert or recyclable materials like metal, glass, paper, plastic, rubber, leather and debris that go back to dumping sites (TERI, 2013). Also, the city generated 7500 metric tonne of C&D waste in the year 2018; all of this waste went untreated to the dumping sites and also no recycling of the waste was done (Maharashtra Pollution Control Board, 2019). Out of total waste generated in the city, 16 per cent goes to the landfills causing CO_2 equivalent emissions of 101258 metric tonne per year (TERI, 2013). These negative impacts to the environment can be curtailed by reducing the waste generation in the buildings; promoting segregation of waste at source for efficient management and treatment of the waste; promoting recycling of the C&D waste and other recycled/ environment friendly materials for construction purposes.

Indoor Environment Quality (IEQ)

People spend on an average 80-90 per cent of their lives inside buildings, hence, buildings must provide a healthy and comfortable environment for individuals (Šujanová et al., 2019); (Nasline, 2017). IEQ of the building has an impact on the health, comfort and productivity of occupants (Haghlesan, 2013). The IEQ problem is more intense in offices, health and education buildings (Özdamar & Umaroğullari, 2018); this results in reduction in productivity of the occupants specially in the office buildings, hence this discomfort has a negative impact on the economy of India (Das, 2015).

Indoor Air Pollution (IAP) is caused by the addition of harmful chemicals/materials in the air indoors; this can be 10 times intense than air pollution outdoors, because enclosed spaces make the pollutants to aggregate (Kankaria, Nongkynrih, & Gupta, 2014). In India, about two million premature deaths occur per year due to negative impacts of IAP, here 44 per cent deaths are caused by pneumonia, 54 per cent by chronic obstructive pulmonary disease (COPD), and two per cent by lung cancer (Kankaria, et al., 2014).

Thermal comfort refers to *"that state of mind which exhibits satisfaction with the thermal conditions"* (Šujanová, et al., 2019). Visual comfort can be defined as "*lighting conditions and views from the workplace of occupant; inadequate lighting, especially glare reduces clear visibility*" (Horr, et al., 2016). The acoustic comfort refers to *"provide appropriate acoustic environment for the designed function of the structure and protecting the occupants from noise"* (Horr, et al., 2016). Poor thermal, visual and acoustic comfort affect the productivity and well-being of the occupants; poor thermal and visual comfort have direct impact on the energy consumption of the buildings (Amirkhani, Garcia-Hansen, Isoardi, & Allan, 2017); (Horr, et al., 2016).

To mitigate the issues of IEQ, sustainable design strategies are to be practiced where "*the traditional strategies (day lighting, solar energy and natural ventilation) are combined with the current innovative technologies, resulting into an integrated system. This system supports user control by focusing on environmental context and with expert mediation for environmental quality and resource responsiveness*" (Haghlesan, 2013).Green buildings use green materials with lower impacts on occupants' health and lower indoor pollution and have rich IEQ than non-green buildings (Ghodrati, Samari, & Shafiei, 2012).

The green building solutions for indoor air quality includes efficient ventilation, air filtration systems to restrain outer air pollutants, use of low-emitting building materials (low ODP materials, CFC free materials), effective management of IAQ through appropriate air handling systems, change in pattern of fuel use and public awareness (Haghlesan, 2013); (Horr, et al., 2016); (Kankaria, et al., 2014); (Šujanová, et al., 2019).

For efficient thermal comfort, the physical adaptation of the environment and design of building must be considered at design stage as alteration of structure is inefficient and expensive post construction; properly designed natural ventilation system provides energy savings considerably from cooling needs (Horr, et al., 2016). To achieve visual comfort, design solutions encouraging daylight harvesting should be considered, daylight harvesting can save 20-77 per cent lighting consumption of buildings and also has positive impact on the health of occupants (Amirkhani, et al., 2017). Acoustic problems need to be addressed at the design stages of the building, hence, it is important to know what will happen indoors and outdoors; strategies to achieve acoustic comfort includes absorption of sound using sound absorbing materials and ceiling tiles, blocking of sound with workstation panels and workspace layout, covering up of sound using electronic sound masking techniques, etc. (Horr, et al., 2016).

Social Awareness and Socio-Economic Strategies

A major role is played by construction sector in economic development (Chavan, 2015). Also, for a successful construction project, safety of the structures and labour is cardinal (Kanchana, Sivaprakash, & Joseph, 2015). Construction is an unorganised sector, hence, the rate of fatal injuries in the construction industry is higher than the national average for all industries (Singh, 2014). Construction labour in India holds 7.5 per cent in the total labour force of the world but contributes to 16.4 per cent of total fatal occupational accidents in the world (Kanchana, et al., 2015). In Navi Mumbai, according to a study, 60 per cent of the workers (sample) have health complications resulted by their work, nearly 15 per cent of the sample had an accident while working and 85 per cent of the labourers did not get any compensation for medical expenses(Naraparaju, 2014). Despite the high number of injuries, 87 per cent of the sample did not receive any safety training regarding their jobs; 86 per cent did not have any safety equipment available during work; also, 96 per cent did not have approach to any insurance policy for accidents and miss- happenings (Naraparaju, 2014).

To mitigate these issues, certain strategies can be beneficial such as organising public medical camps near construction sites, adequate insurance facilities for workers, creating awareness of construction workers' duty and rights, secure safety at construction sites, increasing concern of the workers and staff about safety through constant training for safe operations, regular tracking, scrutiny and safety audits (Chavan, 2015); (Singh, 2014). All accidents and miss- happenings can be avoided by efficient planning and application of safe practices at the site of work (Singh, 2014).

According to Census of India 2011, 2.21 per cent of population has some disability (Smart Cities Council India, 2015). Individuals with different abilities must be able to use buildings, without any difficulty or specific assistance (National Disability Authority, Ireland, 2017). Universal accessibility is to make PwDs live on their own and securing equal access to all in a given physical environment (Smart Cities Council India, 2015); therefore, it covers every individual regardless of age, size and anyone having any other physical condition or disability (National Disability Authority, Ireland, 2017).

So, an accessible building should be the one where there is no barrier for anyone in using all the facilities within (Accessible India Campaign, 2015) following universal design principles referring to design process where user diversity plays the central part so that the buildings' design fulfils requirements of users with varying abilities (National Disability Authority, Ireland, 2017). It should cover optimisations/ adaptations for PwDs in all services such as steps and ramps, corridors, entry gates, emergency exits, parking as well as indoor and outdoor facilities including lighting, signages, alarm systems and toilets (adaptation of toilets for wheel chair users), braille symbols and auditory signals in elevators or lifts (Accessible India Campaign, 2015).

Performance Monitoring and Construction Management

Building performance monitoring is required because usually buildings are unable to perform as designed or estimated, this difference between designed and actual performance is termed as performance gap (Ihasalo & Karjalainen, 2014) which should be minimum as possible. A simple approach for enhancing the performance of building is constant performance monitoring aiming at lowering energy consumption and enhancing IAQ by constant monitoring and analysing problems mostly related to lighting, heating, ventilation and air-conditioning (Ihasalo & Karjalainen, 2014).

The overall sustainability of the project also includes the sustainable construction process of the project (Hwang & Tan, 2012). Selecting materials and construction methods help to reduce energy use of building. Strategies for sustainable construction practices include using materials with low embodied energy[i] (Akadiri, et at., 2012); waste management planning to reduce waste generated during construction; using recycled materials such as concrete aggregates; ensuring minimise construction pollution by managing soil erosion, waterway sedimentation and airborne dust generation; minimising the stress to existing natural environment by conserving natural habitat (Hwang & Tan, 2012).

Regional Priority, Location and Linkages

According to the U.K. Green Building Council, the building industry consumes about 400 million tons of materials a year, most of which have negative environmental effects (UKGBC, 2018). Moreover, research demonstrates that, owing to the "extraction of raw materials," the goods used during a particular construction will often impact the natural environment. Similarly, a range of equipment and services that contract workers and construction companies typically use in the Navi Mumbai, such as on-site chemicals and also the fuel used by diggers and vehicles, will severely *"damage the public health and the climate."* There will be no net depletion in natural resources when construction takes effect, as far as possible. Buildings should not be located on the sites environmentally sensitive for development.

Buildings in neighbourhoods that have been already built eliminates the need for new highways, roads, water pipes and other facilities. This will also promote the revitalisation of the area by the reuse and restoration of current buildings. Historic structures, abandoned land, brown fields and grey areas can be turned into green construction that benefits the local economy and enhances the character of the city (EPA, 2017).

Innovation

("In a period of rapid change, the only ones who survive are those who innovate and create change"- Peter Drucker)

Green building technologies are having increasing popularity in the construction industry worldwide because implementing green building technologies is a way to improve building sustainability efficiency (Chan, et al., 2017). It is a well-known fact that seven per cent of global CO_2 emissions are accounted for the cement industry (Girgin, 2014). Innovative strategies such as replacing the raw material $CaCO_3$ with $MgCO_3$ or manufacturing concrete without cement through 100 per cent fly ash are under progress to reduce this pollution in the huge building sector (Girgin, 2014). Regarding structural systems, the embodied carbon emission to ultimate strength ratios uncovers the significance of using recycled material instead of virgin one (e.g. steel, aluminium) as well as green concrete and masonry blocks by partially replacing cement with waste by-products such as fly ash, blast furnace slag, rice husk ash, etc. (Kuruşcu & Girgin, 2014).

CONCLUSION

The buildings contribute a significant share to the urban environment impacts. As the number grows in India for the construction of buildings, the impact to the environment also increases. The growing cities surrounded by environmentally sensitive areas, like Navi Mumbai, are more vulnerable. In such a scenario, green building and sustainable building alternatives can significantly restrain these negative impacts, enhance the productivity of the occupants and performance of the buildings by promoting environment friendly practices in building construction, operation and maintenance. In this regard, a list of green building alternatives is prepared by analysing the parameters given by different green building rating systems. These parameters are reviewed in the context of Navi Mumbai and Indian scenario for studying the benefits of applicability of these green building parameters in the city. Navi Mumbai is a city of growth, transformations and rich in biodiversity. The rapid growth of population and the process of urbanisation of Navi Mumbai have resulted in an increasing demand for land in the city. It is not growing not only by population but also by changes in spatial dimensions. Hence, Stress on natural resources requires much attention to protect and conserve from degradation due to rapid transformation of natural resources to urban settlements for making the city a better place to live.

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Footnotes

1. High density urban areas which are built using green strategies in design and construction tend to be more energy efficient and cause less pollution. New researches are also revealing that green buildings can be good for health also.

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Endnotes

i Energy consumed in mining, processing, manufacturing and transporting of the material is known as embodied energy (Akadiri, et al., 2012).