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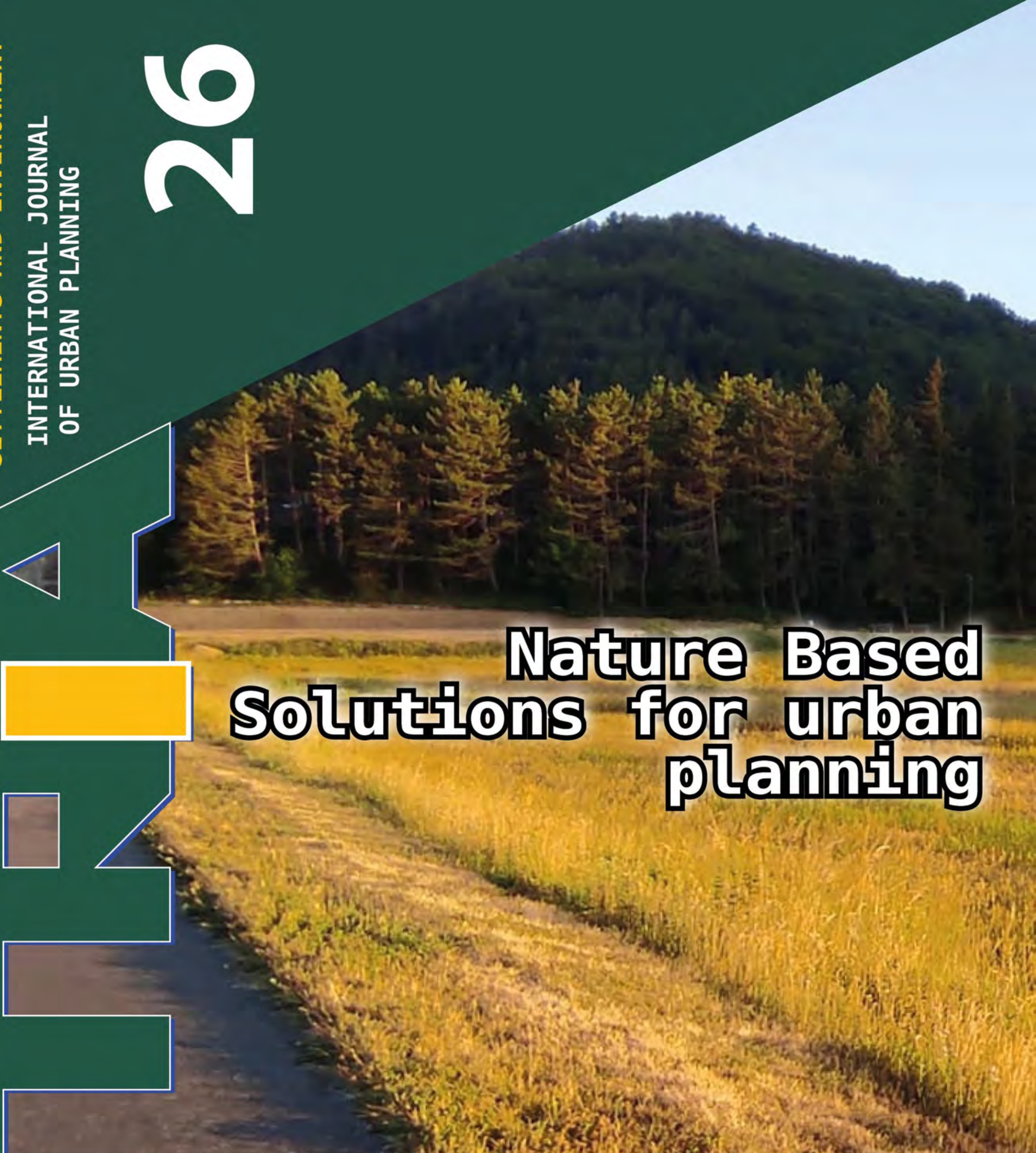

Nature Based Solutions for urban planning

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abstract

Identifying and Reviewing Green Building Alternatives for Navi Mumbai: A Comparative Analysis of Green Building Rating Systems in India

Simranjot Singh, Sanjay Mishra

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 un liveable. 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 research is an attempt to identify and review green building alternatives for the city by studying the various green building parameters and strategies given by different rating organisations

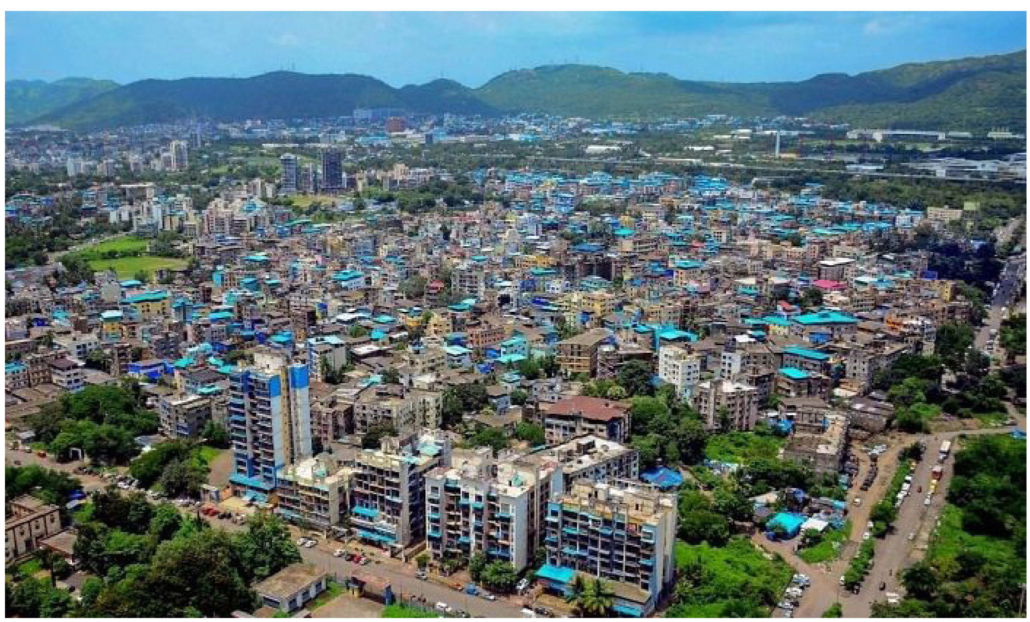

Fig. 1 – Navi Mumbai. Source https://www.freepressjournal.in/

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

Spazi urbani residuali e nuove comunità di pratiche sociali

Il massiccio boom edilizio osservato nelle città indiane negli ultimi due decenni ha portato a una serie di problemi ambientali come inquinamento, isole di calore urbano, deterioramento delle aree verdi e della vegetazione naturale rendendo le città invivibili. Navi Mumbai, la città situata sulla costa occidentale indiana è circondata da vari elementi ecologicamente sensibili sia sulla terraferma che nelle acque. Man mano che la città continua a crescere, anche queste aree diventano vulnerabili, così come la popolazione residente in città. La ricerca è un tentativo di identificare e rivedere le alternative di bioedilizia per la città studiando i vari parametri e le strategie di bioedilizia fornite da diverse organizzazioni di rating nel contesto di Navi Mumbai e dello scenario indiano per lo sviluppo sostenibile della città nel futuro.

Parole Chiave:
edifici verdi, sviluppo sostenibile, isole di calore urbane, vegetazione naturale, aree ecologicamente sensibili

Identifying and Reviewing Green Building Alternatives for Navi Mumbai: A Comparative Analysis of Green Building Rating Systems in India.

Simranjot Singh, Sanjay Mishra

1. Introduction

Buildings account for approximately 19% of all global greenhouse gas (GHG) emissions in the world, and about 31% of global final energy demand (Šujanová, et al., 2019). As the urban population of the world grows, the Green Building concept has become a cornerstone of sustainable development in this period that assumes responsibility for maintaining environmental, economic and social sustainability in the long term (Yoon & Lee, 2003). A green building refers to “the practice of creating structures and using environmentally responsible and resource-efficient processes throughout a building’s lifecycle” (Chan, et al., 2017) and a sustainable project “is designed, built, renovated, operated or reused in an ecological and resource efficient manner” (Akadiri, et al., 2012). Green buildings can also be defined as a structure and method that seeks to minimize the overall impact of the built environment on human health and the natural environment by utilizing 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, utilizing 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 to create sustainable community (Fowler & Rauch, 2006).

2. Introduction to Navi Mumbai

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

3. Research concern

Navi Mumbai is growing with decadal positive growth rate of 88.91 percent 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 industrialization which has been among the prime economic drivers for the city. The population of nodal areas of city are 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% since 2009-10 as shown in Figure 1.

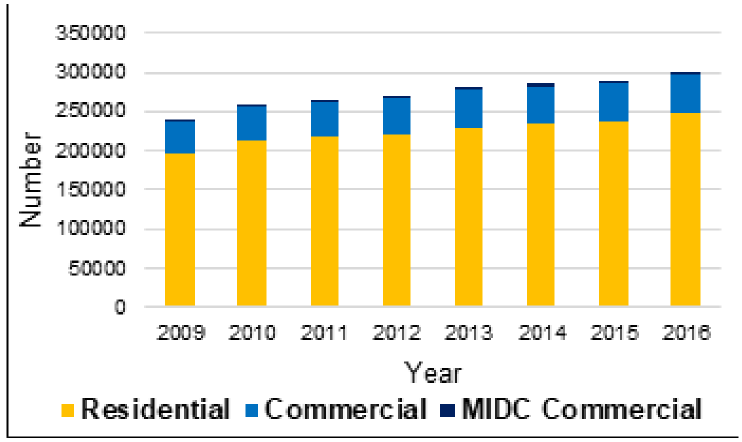

Fig. 2 – Trend of property development over last 8 years in Navi Mumbai.

For the year 2016-17, residential properties recorded highest at 82% of total properties, followed by commercial with 17% and MIDC commercial with 1% share. Also, a huge crisis emerged in the city as buildings are found unsafe to stay in over 53 societies (NMMC, 2017). The scale of urban expansion in Navi Mumbai will continue to be enormous, driven by economic and population growth. 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 impacts on the environment throughout building's life. Using a green rating (assessment) system in the design/build process can produce significant benefits that are not likely to result from standard practices 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.

4. Research Methodology

Different green building rating systems are studied and a list of green building alternatives is identified by analysing various parameters and strategies given by

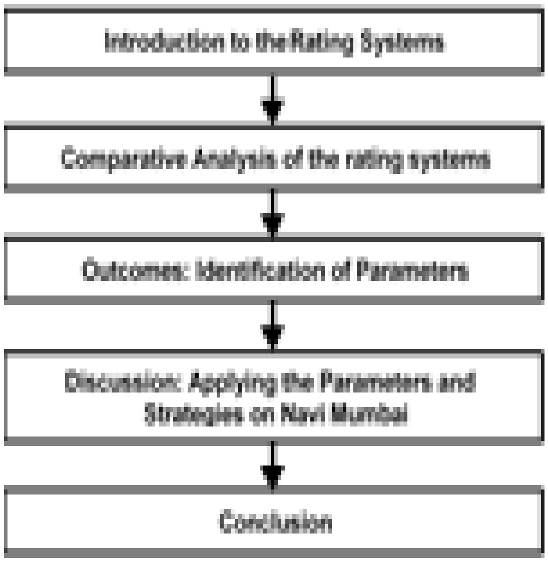

Fig. 3 – Research Methodology (Process Flow).

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 the applicability of the identified alternatives in the city by discussing the issues related to the identified parameters and how green building alternatives are helpful restraining these issues

5. 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, which is developed by The Energy and Resources Institute (TERI) and MNRE as an indigenous building rating system, particularly to address and assess non-air conditioned or partially air-conditioned buildings (TERI, 2016).

The Indian Green Building Council (IGBC) Rating System is a voluntary and consensus-based rating system, for new buildings, which is based on availability of existing materials and technologies. It is a part of the Confederation of Indian Industry (CII) was formed in the year 2001 (IGBC, 2020). IGBC Green New Buildings rating system aims to help design environmentally sustainable buildings through architectural programmes, water efficiency, efficient waste management, energy efficiency, sustainable buildings, and focus on occupant comfort & 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.

6. Comparative analysis

Green Rating for Integrated Habitat Assessment (GRIHA)

The 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 comes out to be common are classified chromatically.

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, concluding all the parameters and strategies which are repetitive/ basic and non- repetitive but still equally important, those parameters and strategies are identified which are cardinal for green development in Navi Mumbai.

Tab. 1 – Table Showing the Common and Unique elements in IGBC, GRIHA and LEED.
Sources: (GRIHA, 2020); (Fithian & Sheets, 2009); (IGBC, 2020); (USGBC, 2017)

IGBC	GRIHA	LEED
Site Selection and Planning	***Site Planning***	***Sustainable Sites***
• Local building regulations. • Soil erosion control. • Basic house-hold amenities. • Natural topography or vegetation. • Heat island effect, non-roof/roof. • Parking facilities for visitors. • Electric charging facility for vehicles. • Design for differently abled. • Basic facilities for construction workforce. • Green home guidelines, design & post occupancy.	• Site Selection. • Low-impact design. • Design to mitigate urban heat island effect. • Site imperviousness factor.	• Discouraging development on previously undeveloped land. • Minimizing a building's impact on ecosystems and waterways. • Encouraging regionally appropriate landscaping. • Controlling storm-water runoff. • Smart transportation choices. • Reducing erosion and light pollution. • Reducing heat island effect. • Reducing construction-related pollution.
Water Efficiency	***Water***	***Water Efficiency***
• Rainwater harvesting, roof & non-roof. • Water efficient plumbing fixtures for reduction. • Managing irrigation and watering systems for landscaping purposes. • Waste water treatment and reuse and water metering.	• Use of low-flow fixtures and systems. • Reducing landscape water demand. • Water Quality. • On-site water treatment and reuse. • Rainwater recharge and recycle.	• To encourage smarter use of water inside and out. • Water reduction, which is typically achieved through more efficient and low flow appliances, fixtures and fittings inside and water-wise landscaping outside. • Rainwater harvesting.
Energy Efficiency	***Energy***	***Energy and Atmosphere***
• CFC-free equipment. • Minimum energy performance. • On-site renewable energy. • Solar water heating system. • Energy saving measures in appliances and equipment. • Distributed power generation. • Energy metering.	• Energy efficiency. • Renewable energy utilization. • Low ODP materials.	• Commissioning. • Energy use monitoring. • Efficient design and construction. • Efficient appliances, systems, and lighting. • Use of renewable and clean sources of energy, generated onsite or off-site.
Materials & Resources	***Sustainable Building Materials & Solid Waste Management***	***Materials and Resources***
• Separation of house-hold waste. • Organic waste management, post occupancy. • Handling of construction waste materials. • Using materials with recycled content and reuse of salvaged materials. • Using local materials for construction and finishing purposes of the buildings. • Rapidly renewable building materials & certified wood.	• Utilization of BIS recommended waste materials in building structure. • Reduction in embodied energy of building structure. • Use of low-environmental impact materials in building interiors. • Avoiding post-construction landfill. • Treat organic waste on site.	• Encourage the selection of sustainably grown, harvested, produced, and transported products/ materials. • Promoting reduction of waste as well as reuse and recycling. • Reduction of waste at a product's source.
Indoor Environmental Quality	***Occupant Comfort And Well-Being***	***Indoor Environment Quality (IEQ)***
• Utilizing Daylighting. • Fresh Air Ventilation and tobacco Smoke Control. • Cross Ventilation and exhaust Systems. • Low VOC Materials, Paints & Adhesives. • Building Flush-out.	• Achieving indoor visual comfort requirements. • Achieving indoor thermal comfort • Achieving indoor acoustic comfort. • Maintaining good indoor air quality for the occupants. • Use of low-VOC paints and other compounds in building interiors to decrease the indoor air pollution.	• Promotes strategies that can improve indoor air. • Providing access to daylight and views. • Improving acoustics.
Innovation & Design Process	***Socio-Economic Strategies***	***Awareness and Education***
• Innovation & Design Process. • IGBC Accredited Professional.	• Labour safety and sanitation. • Design for Universal Accessibility. • Dedicated facilities for service staff. • Increase in environmental awareness.	• Encourage homeowners and real estate professionals to provide homeowners, tenants, and building managers the education tools they need to understand what makes their buildings and surroundings green.
	Performance Monitoring & Validation	***Regional Priority***

7. Review of Analysis

The table 1 identifies the common and unique elements among the listings of various parameters and strategies under GRIHA, IGBC and LEED and establishes a comparison so as to identify the commonalities and differences among them as discussed below:

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 onsite 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.

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 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 house-hold waste for efficient waste management. For indoor living environment, the unique strategies are to use low VOC (volatile organic compounds) 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 ODP (ozone depletion potential) materials are taken into account respectively. For Sustainable Building Materials & 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-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; minimizing 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. Rewards homes built near already-existing infrastructure, community resources and transit. Encourages access to open space for walking and physical activity and time spent outdoors. For innovation and design, LEED provides bonus points for projects using new and innovative technologies and strategies to improve a building's performance beyond what is required by LEED credits or green building considerations that are not specifically elsewhere in LEED. Also, LEED rewards projects using a LEED Accredited Professional to ensure a holistic, integrated approach to the design and construction phase.

8. 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 prepared as follows:

9. Discussion: Reviewing the identified Parameters in Context of Navi

Sr. 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 onsite 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.
4.	MATERIALS AND RESOURCES	Use of low-environmental impact materials	• Utilization 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 house-hold waste. • Handling of construction waste materials.
5.	INDOOR ENVIRONMENT QUALITY AND SUSTAINABLE DESIGN	Indoor air quality	• Fresh Air ventilation. • Use of low-VOC paints and other compounds in building interiors. • Using CFC/ HFC 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.
7.	PERFORMANCE MONITORING AND	Performance Monitoring & Validation	• Smart metering and monitoring. • Operation & Maintenance Protocols. • Performance Assessment for Final Rating.

Tab. 2 – Table Showing the Common and Unique elements in IGBC, GRIHA and LEED. Sources: Derived from comparative analysis

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 categorized 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, quick population growth in urban focuses, especially in large urban communities, restricted sources to expand water flexibly, expanded interest and contamination, constrained reuse and reuse, have prompted a rising water frailty in urban focuses (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 acute water problems (Ali, 2018). Also, this water shortage is now compounded with an estimated 20-25% 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. Navi Mumbai requires 335 million litres of water per day. 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 & 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 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

Buildings are among the major contributors of negative impacts on the environment due to unsuitable use of energy. As an estimate, heating, cooling, and lighting applications in buildings holds more than one-third of the world's primary energy demand (Yilmaz & Selbaş, 2018). Also, commercial and residential buildings consume 20% to 40% of energy produced globally (Hwang & Tan, 2012). The quantity of CO2 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 pollutions, acid rain, and greenhouse gasses (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% 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 CO2 in 2007-08 to 1.98 million tonne CO2 in 2011-12, almost 1.4 times, with a compound annual growth rate of 9.37% (TERI, 2013). Also, for domestic purposes, the conventional fuels (coal, wood, kerosene, LPG) have become major contributor 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% of total energy in Indian residential buildings is used for ventilation controls alone (Indraganti, 2011) hence, sustainable designs should be promoted to minimize energy usage.

Materials and Resources

In India, urbanization, industrialization 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% of MSW was collected, and the remaining 18% consisted of litter. Treated waste was only 28% of the collected waste, and the remaining 72% 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 1 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% is biodegradable, this would translate to around 396 metric tonne of biodegradable waste per day. The remaining 34% 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% goes to the landfills causing CO2 equivalent emissions of 101258 metric tonne per year (TERI, 2013). These negative impacts to the environment can be reduced 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 average 80–90% 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 effects the health, comfort and productivity of occupants (Haghlesan, 2013). The IEQ problem is more intense in office, 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, et al., 2014). In India, about 2 million premature deaths occur per year due to negative impacts of IAP, here 44% deaths are caused by pneumonia, 54% by chronic obstructive pulmonary disease (COPD), and 2% by lung cancer (Kankaria, et al., 2014).

Thermal comfort refers to “that state of mind which expresses satisfaction with the thermal environment” (Šujanová, et al., 2019). Visual comfort can be defined as “lighting conditions and the views from one’s workspace; insufficient light, especially daylight or glare reduces the ability to see objects or details clearly” (Horr, et al., 2016). The acoustic comfort is “the capacity to protect occupants from noise and offer an acoustic environment suitable for the purpose the building is designed for” (Horr, et al., 2016). Poor thermal, visual and acoustic comfort effect the productivity and well-being of the occupants; poor thermal and visual comfort have direct impact on the energy consumption of the buildings (Amirkhani, et al., 2017); (Horr, et al., 2016).

To mitigate the issues of IEQ, sustainable design strategies are to be practiced. “Sustainable design merges the natural, minimum resource conditioning solutions of the past (daylight, solar heat and natural ventilation) with the innovative technologies of the present, into an integrated “intelligent” system that supports individual control with expert negotiation for environmental quality and resource consciousness by focusing on environmental context" (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, et al., 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/HFC 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% 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, et al., 2015). Construction is an unorganized 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% in the total labour force of the world but contributes to 16.4% of total fatal occupational accidents in the world (Kanchana, et al., 2015). In Navi Mumbai, according to a study, 60% of the workers (sample) have health complications resulted by their work, nearly 15% of the sample had an accident while working and 85% of the labours did not get any compensation for medical expenses (Naraparaju, 2014). Despite the high number of injuries, 87% of the sample did not receive any safety training regarding their jobs; 86% did not have any safety equipment available during work; also, 96% 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 organizing public medical camps near construction sites, adequate insurance facilities for workers, creating awareness of construction worker's duty & 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% 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 construction of green building is part of sustainable construction” (Hwang & Tan, 2012). Selecting materials and construction methods helps to reduce energy use of building. Strategies for sustainable construction practices include using materials with low embodied energy (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; minimizing 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 be located on portions of the site that are not environmentally sensitive to development.

Building 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, brownfields 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 growing 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 7 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). In view of structural systems, the embodied carbon emission to ultimate strength ratios reveal the importance of recycled material utilization 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).

10. 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 scenario, green building and sustainable building alternatives can significantly restrain these negative impacts, enhance the productivity of the occupants and performance of the building by promoting environment friendly practices in building construction, operation and maintence. In this regard, a list of green building alternatives is prepared by analysing 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 urbanization 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.

Endnotes

1 High-density urban areas—especially those built using green methods in design and construction—can be more energy efficient and pollute less. New research is also revealing that green buildings can be good for health too.

2 Navi Mumbai City Population Census 2011 | Maharashtra. (2017). In Census2011.co.in. https://www.census2011.co.in/census/city/368-navi-mumbai.html.

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

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