Green Infrastructure Entities- A Study of Indian and International Cities

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Abstract

Cities are places for humans and countless other species. With increasing city limits, urbanization has meddled with the life of several organisms; creating an unhealthy balance. A green city is planned by scrutiny of the impact of development on the environment and mankind. This not only assures a better future but also connects people to nature. This paper highlights approaches towards the creation of liveable cities, segregated into three categories – Greens, Water, and Sustainability. Further divisions of these categories are done based on green infrastructure techniques prevalent across the globe today. The purpose is to refurbish the underdeveloped regions into smart cities through sustainable infrastructure; which will provide a good quality of life, better environmental impact, etc. The paper aims to analyze and compare case examples for each parameter through the medium of national (Indian) and international case studies. The comparison stresses the fact that India, as a developing nation, can implement these methods in its cities. The paper also deduces that there are cases where Indian cities can be an inspiration to the world. Degeneration of nature knows no political boundaries. Thus, every country has a legitimate stake in environmental practices and must pledge to create greener cities.

Highlights

1. Highlight importance of Green Infrastructure in cities of today and future.
2. Division of green infrastructure methods into: Green, Water, and Sustainability.
3. Citing examples of Indian and International cities for impact of green infrastructure.
4. Comparison of case studies to pave the way ahead for development of Indian cities.

1. Introduction

Green infrastructure, the name itself suggests that the infrastructure was made to either protect or increase the growth of greens in the city. It is a very positive approach towards the environment and urban development. The elements of green infrastructure are cost-effective and viable for an extensive period. It encourages multifunctionality. For example, a piece of land can have multiple benefits - plantation on a terrace can act as a kitchen garden as well as help to reduce the temperature in the building. Green infrastructure promotes sustainable and resource-efficient development. Taking the example of wastewater treatment, if done efficiently; can further be put to use for agriculture or industrial purposes. Green infrastructure has a vast number of environmental features that can be applied from the smallest of the built forms to the largest of cities. It is designed to enhance and benefit human society considering social, economic, and environmental impact. It is a concept of urban planning counting on ecosystem services of green infrastructure. Green infrastructure can be implemented in every corner of the city. Some of the green infrastructures are the green roof, an urban agglomeration, urban canopy, rainwater harvesting, stormwater management, etc. The advantages of green infrastructure are listed as follows: (United States Environmental Protection Agency, n.d.).

1.1 Benefits of green infrastructure

Environmental benefit - Green infrastructure plays a vital role in protecting the environment from harmful effects by reducing pollution, lowering the temperature, bringing rain, etc. Improving biodiversity will provide habitats for distinct species. Water quality can be raised by the implementation of rainwater harvesting and rain gardens. By incorporating green infrastructure in the city, it will not only benefit humans but also nature.

Social benefits - The design and beauty of the landscape can contribute to the identity of the city's character. Trees can provide shelter in public spaces and reduce the urban temperature. Green cover attracts tourism and other outdoor activities which encourages more social gatherings.

Economic benefits - Increasing the number of greens in the city may also help the citizens economically. Due to low temperature on building surfaces, it diminishes the cooling demand which results in decreasing energy needs. The life expectancy of the building increases as green infrastructure will protect it from high temperature, helps in lowering maintenance costs, etc. Green streetscape and landscape enhance the aesthetic and ethical qualities. Property values also increase in the areas with a good number of trees (Global Designing Cities Initiative, n.d.).

1.2 Importance of green

Green cities help people to connect with nature and provide ways to conserve biodiversity. Green can reduce stress, which leads to mental and physical wellbeing. It makes the environment aesthetically beautiful, increases biodiversity, improves air and water quality, insures water storage, etc. To accomplish this necessity of a green city, green infrastructure like an urban canopy, reuse of treated water, waste management, sustainability, solar energy, recreational places, etc. are implemented.

2. Methodology

The research approach influences the benefits of green infrastructure and the welfare of the city. This paper provides an outline of distinct parameters of a green city and its necessity. After a comprehensive analysis of each of the parameters, they are compared in the form of national (Indian) and international case studies. Cities have been chosen where the variables were best suitable and practiced uniquely. Some of the infrastructure which makes a green city is given in the below table, where the shaded names are the repetitive cities that are used in two or more parameters.

Table 1
List of parameters and its national and international case studies

(Source: Author)

Sr. No.	Elements/ components of Green city	National case study	International case study
GREENS			
1	Urban forest	Hyderabad	Curitiba
2	Urban agriculture	Kerala	America
3	Agri tourism	Assam	San Diego
4	Green pockets	Bangalore	Hong Kong
5	Connected greens	Chandigarh	Copenhagen
6	Central Park	Jaipur	New York
7	Biophilic buildings	Chennai	San Diego
8	Shaded streets	Delhi	Sweden
WATER			
9	Sponge city	Kochi	China
10	Bioswales	New Delhi	Michigan
11	Rain water harvesting	Odisha	Thailand
SUSTAINABILITY			
12	Blue green infrastructure	Visakhapatnam	Stockholm
13	Sustainability	Amravati	Curitiba
14	Rapid transit	Kolkata	Curitiba
15	Roundabouts	Bihar	Indonesia
16	Elevated walkways	Mumbai	Paris
17	Renewable energy	Gujarat	China
18	Solid waste management	Gandhinagar, Indore	USA

3. Parameter Analysis

The selected parameters for this paper were derived from a literature study related to ecological, sustainable, natural perspective and are further divided into 3 main categories: Green, Water, and Sustainability.

3.1 Green parameters

- Urban forest-** Urban forestry is defined as the planting, care, and maintenance of vegetation in urban dwellings. It is a collection of trees, plants, and Woody plantations. Urban forests benefit ecologically, like cleaning the air, water, etc; which are essential for the basic lifestyle of a person living in town. It also helps to enhance biodiversity, reduce atmospheric pollutants, increase the amount of oxygen, reduce noise pollution, prevent soil erosion, etc (Feder, 2019).
- Urban agriculture-** Urban agriculture or urban gardening is the process of growing, refining, handling, and distributing food in the surrounding urban areas. Animal husbandry, aquaculture, beekeeping, horticulture is also included in urban agriculture (Miller, 2020). Small zones like vacant plots, gardens, terraces, etc where crops are grown and provide a source of income to the dwellers are also included in urban farming (Medici et al., 2021).
- Agritourism-** The tourist travels and stays around farming activities like in villages or farmlands and practices small-scale food production or animal husbandry for entertainment or education. They practice agriculture and sustainable conservation methods by participatory approach. (Khamung, n.d.)
- Green pockets-** A public open space with abundant greenery is often located near residential areas, offices, schools, recreational places, etc. There are countless benefits of having green pockets in the City; it can relieve stressful life, conserve energy, reduce air pollution, enhance surrounding beauty, increase property value, etc (Marie, 2020).
- Connected greens-** It includes green networks, corridors, and linkages in a city which are generally a fragmentation of biodiversity. This has different social as well as environmental benefits like landscape beauty, public access, recreational places, etc (Urban Green Networks, Corridors and Linkages, n.d.).
- Central Park-** Central Park, the main city park is a large green area that has lots of trees, plants, and lawns; used for recreational purposes. It provides equal access to all the areas with higher facilities, infrastructure, and amenities compared to neighborhood parks (Baird, 2017)
- Biophilic buildings-** Biophilic design incorporates natural lighting, ventilation, green roof, and green facade for a productive and healthy built environment for people (14 Patterns of Biophilic Design, 2014).

8. **Shaded streets-** Roads are covered by the shadow of the trees and provide relief to the people by reducing the temperature. It adds a good amount of tree cover to the city. It might not be necessary that streets can be covered only by shadows of trees, it might also be covered by built form (Pataki et al., 2021).

3.2 Water parameters

9. **Sponge city-** A city that has the capacity and management of infrastructure systems to store and collect rainwater is defined as a sponge city. The area in the sponge city absorbs the rainwater, naturally filtered by sand, soil, pebbles, and rocks. It also increases the groundwater level which is later extracted through Urban and peri-urban wells (Hamidi et al., 2021).
10. **Bioswales-** Bioswales are deliberated to transport stormwater runoff. This design minimizes the period of conveyance of water in the swale and removes pollutants from water. Bioswales store and treat the stormwater before plunging into the watershed (Bioswale, n.d.)
11. **Rainwater Harvesting-** With the growing population, water demand is also increasing which results in depletion in groundwater levels. Thus, there is a need to replenish the groundwater and use alternate methods to harvest water. Rainwater harvesting is the method of capturing the rainwater instead of allowing it to flow off (Sivanappan, 2006).

3.3 Sustainability parameters

12. **Blue-green infrastructure-** A combination of water elements like rivers, canals, ponds, etc., and green elements like trees, lawns, fields, forests, etc. make up a term blue-green infrastructure in green infrastructure. A city should be a composition of blue as well as green infrastructure to have a balanced and sustainable life for the residents (Bioveins | What Is Green and Blue Infrastructure? n.d.)
13. **Sustainability-** Sustainability implies fulfilling the demand of the residents without negotiating the needs of upcoming generations. The characteristics of a sustainable City are public transportation, walkable neighborhood, green buildings, food production, water conservation, public green space, waste management, etc (Sustainable Cities, n.d.).
14. **Rapid transit-** Rapid transit is the means of transportation that is faster and easily accessible in the city such as Metros; which are used as local transit in metropolitan cities (Rapid Transit, n.d.).
15. **Roundabouts-** A roundabout is a circular intersection where roads coming from multiple directions meet in the center and vehicles go round in the same direction. Some roundabouts are designed incorporating the aesthetic beauty, flora, sculptures, and statues showing the identity of the place (What Is a Roundabout? n.d.).
16. **Elevated walkways-** It is a pedestrian green walkway that connects two or more buildings or structures. It is located at a certain height to avoid disrupting the vehicle movement beneath (Elevated Walkway Definition, n.d.).
17. **Renewable energy-** The energy which is generated from a non-exhaustible source is known as renewable energy. Storing solar energy, retrieving the wind energy, generating tidal energy, etc are approaches to reduce the use of fossil fuels (What Is Renewable Energy? - Definition, Types, Benefits and Challenges, n.d.).
18. **Solid Waste Management-** Waste management implies managing the waste produced from its inception to its final disposal which includes the collection of waste, transport facility, segregation, treatment, and monitoring and regulation of the process. This method is useful for the city to prevent irregular waste disposal which leads to health issues, land pollution, water pollution from industrial waste, etc (Nathanson, n.d.)

4. Case Studies

The chosen parameters were further compared with national and international case studies.

Table 2
Comparison of case studies

(Source: Author)

Sr. No.	Parameter	National case study	International case study	Performance in the city
1	Urban forest	Trees and forests play a vital role in maintaining healthy, liveable, and sustainable cities and towns. Hyderabad has been renowned as the 'Tree city of the world' in 2020. Telangana government has increased the tree cover from 25.16–33% in the state. Increasing the ratio of the urban forest in the city and its management will help to ensure better living conditions for residents in the future. Hyderabad's objective is to rejuvenate the degraded forest and forest blocks around the city and develop it into urban forest parks. This approach not only makes a clean, green, and smart city but also provides a healthy living environment. (Hyderabad Wins Global 'Tree City' Status, 2021)	This city in Brazil is one of the greenest cities which has successfully executed large-scale tree planting. The city planted about 140000 trees in 3 years. A large amount consists of araucaria trees which provide shade as well as habitats to certain animals and birds. Under the city's Plant Production Department, the hazardous trees were identified and removed, and 2 more new trees were planted in their place. This program helps to increase the amount of healthy and useful trees in the city (Curitiba City Hall, 2016).	Trees are the life of the city. The Cities would be incomplete without vegetation, thus urban forest acts significantly in Hyderabad as well as Brazil. Both are growing rapidly which also invites problems like pollution, increased temperature, etc, thus this forest provides solutions to many of the city's problems complementing a different variety of trees with medical advantage and aesthetic beauty.
2	Urban agriculture	A new variety of farming and gardening emerges in Kerala because of its unpredictable rains and floods; it is a wise and safe way of growing food on terraces. People grow vegetables and fruits on their terraces. Though it is a small-scale project, it is seeking much attention from people and results in awareness in society. Sustainable agriculture fulfils the requirement as well as helps in food security, high nutrition, income generation, and climate change of the city (World Bank, 2013).	Many American cities have been practicing urban agriculture since the 1800s. Urban agriculture in America is one of the routes to economic development as it offers the development of workers, enhanced neighborhoods, environmental benefits, etc. Thus, America focuses more on commercial or urban farms where food sales practices in form of a sustainable agricultural business rather than social enterprise (Schaffstall, 2019)	Agriculture is one of the most efficient uses of the land. Kerala is famous for its tea, coffee, pepper cardamom, and cashew plantation. This is the basic source of living for the people. Like so many cities over the world perform these activities as it provides strong financial support to the city.
3	Agritourism	Majuli, the world's largest river island, is situated in India. Many tourists are attracted to this beautiful island full of greens. Tourists live in cottages made of bamboo, eat tribal food of the village, and live the lifestyle of a villager. Planting bamboo is the foremost activity in this bamboo village. Agritourism is a part of the economy of the localities. Travelers also explore forests, beaches, and pleasant views on all four sides of the island (Saravanan & Todd, 2018).	Agriculture and tourism are two large enterprises in San Diego. Increasing local tourism and the agriculture industry resulted in Agritourism becoming an important segment. The flower fields in Carlsbad have a temperature suitable for flowers and their blossoms attract thousands of tourists yearly; the city captures revenue through it. Over 200000 people annually are attracted to this field during the spring season (Lobo, et al, 1999).	The most important characteristic of agritourism is that it preserves the rural culture and lifestyle. It also provides the long-term sustainability of the farms as well as gives an opportunity to tourists to experience a new and different lifestyle.
4	Green pockets	Bangalore is blessed with a pleasant climate, scenic gardens, parks, and natural lakes. The city has about 333 green buildings and a total of 227.92 sq km. of green space. The city is home to several water reservoirs, a botanical garden, biodiversity park, butterfly park (special breeding area for insects), National Park (Bannerghatta), and many small neighborhood and plot-level gardens. In this way, the city is full of green pockets along with a green belt and agricultural land in the periphery (Saini, 2014).	About 40% of Hong Kong is sheltered with public green spaces which is an upstanding scenario. The residential area covers only one-third portion while the rest has large parks and gardens. Some gardens are located within walking distance from the tram stations. There are temples, Bonsai trees, a Rock Garden, plazas, promenades, pagodas, pavilions, fish ponds in these green pockets. Similar activity on a neighborhood scale should be necessary to enhance the environmental beauty in the residential area (Lau, et al, 2012).	Having recreational and green spaces around the residence keeps humans fresh and healthy. Also, it can be a habitat for many of the species. Green pockets are an imperative element in today's city of concrete structures.
5	Connected greens	Chandigarh is the first planned city in India which is benefitted from an architecture and environmental perspective. The landscape of the city has a leisure valley (a series of parks and gardens)- the main attraction of the city. This is designed to keep the residential area away from noise and pollution of traffic as well as increase the plantation and flora (Bedi et al., 2020)	The master plan of Copenhagen is also known as the finger plan as it replicates a palm resting on the compact City center. It integrates forests and lakes, agricultural landscapes, rivers, streams, etc. The linear shape makes traffic and transportation easy and quick. The area between the fingers represents the greens and the fingers represent the districts. These fingers connect the city to the environment. It is an extended path of vegetation that maintains the linkage of the city (Bartwal, 2017).	Very few cities have the concept of a connected green network as it can restrict urban expansion. But it is necessary to stop the urban sprawl to save from eroding the agricultural land. This belt gives a connection to the entire city.

Sr. No.	Parameter	National case study	International case study	Performance in the city
6	Central Park	The Pink City of India, Jaipur is also complemented by the green color of lushing trees in Central Park of the city. Being Jaipur, one of the tourist attractions, the central park is also appreciated exceedingly. Localities utilize it for jogging, exercise, and get together. The Park also displays a 206 feet high Indian national flag- the biggest in the country. Musical fountains during sunset are also one of the focus points. This Central Park has increased the appearance of the city locals as well as outsiders (Pawan, 2019)	Manhattan, a borough of New York has the largest and most predominant public park with an area of about 840 acres. The Park observes highly varied terrain with flat grassy land and gentle slopes. The Park also features some beautiful vistas, an art museum, zoo, ice rink, three ponds, one amphitheatre, recreation grounds, fountains, and tons of small sculptures. It is the world's largest central park with excellent accessibility (Bawatneh, 2018)	Parks are necessary recreational places in any neighborhood, but the city-level park has its importance. Central Park of New York has a unique, historic, and scenic landscape. Central Park attracts the population of the entire city resulting in the highest number of facilities in the park. It has become a famous landmark and character of the city.
7	Biophilic buildings	Olympia Tech Park is an IT park in Chennai which is a perfect example of Biophilic buildings. It is the heart of the city. It implies several eco-friendly and energy-saving techniques. The building is incorporated with methods like rainwater harvesting on the roof and used later. Power is generated by using renewable resources like solar rooftop and wind energy. There is also a provision of recycling the waste and reusing the grey water for flushing and irrigation purposes to achieve zero discharge. It is awarded the title of one of the biggest gold LEED-rated buildings in the world. (Raheja, 2018)	An excellent example of biophilic design is the building of California State University, San Marcos where 2540 sq. ft. of the live roof was built which fulfils the requirements of the university like aesthetic design, stormwater management, energy, and flora. This roof was made in an arid climate and partially covered by vegetation which helps to reduce the urban heat island effect, increase rainwater storing capacity, etc. The biophilic design is made for the building to make it self-sustainable and to make maximum use of natural resources (Andrews III, 2014).	The buildings are designed with an amalgamation of architecture and nature. It reduces the maintenance of the building and promotes efficient building design. These buildings are made by integrating sun and wind directions, green roofs, green façade, etc. Increasing these buildings in the city will also increase the amount of flora.
8	Shaded streets	Delhi has designed a planned network with highly connected roads with pedestrian sidewalks and bicycle tracks. It is covered under the shadow of a lane of trees beside. The landscape of streets helps to improve the overall life of an area and make it attractive, aesthetic, and user-friendly. Thus, Delhi is pacing towards making their streets pedestrian and cycle-friendly as well as reduce the traffic congestion on the roads. (Kaur, 2019)	There is a live main Street in Stockholm namely Gotgatan where the built form including offices, shops, restaurants serve the sides of the street. It is a popular street in the city for shopping and entertainment. The heights of the buildings on the sides are more than the width of the street which keeps the street shaded and enhances the shopping and entertainment activities. (Global designing cities initiative, n.d-b)	Shades of the trees seem more pleasant in summer. Trees along roadsides have many benefits; they help to increase the tree cover in the city, as well as reduce the temperature and provide shade to pedestrians and motorists.
9	Sponge city	Kochi is located in a coastal area which results in affecting the city by a disaster like a flood. To improve this condition, the irrigation and agricultural department planned to reduce the intensity and frequency of disasters by implementing the sponge concept in the city. Urban areas have been identified with a greater number of wetlands and permeable spaces which will absorb the rainwater and reduce the intensity of floods. Today, Kochi has the potential and ability to tackle floods and harvest rainwater (Times of India, 2020).	Out of 351 cities of China, 62% of cities have suffered from water clogging on streets due to excessive rainfall. Wuhan was one of the most prone cities to flood and water clogging. Thus, it is one of the pilot Cities under the program where 70% of rainwater is collected, treated, and later used for irrigation purposes. One of the successful examples is the garden Expo Park in Wuhan where rainwater is collected, retained, and used to water the plants (Ulku, et al, 2018).	Floods, heavy rains etc make a huge destruction in vulnerable cities, thus in this situation if cities behave like a sponge then land can absorb the water, increase the ground water level and also can be used later for many purposes. In this way, cities will be protected from disasters as well as make proper use of water.
10	Bioswales	Mostly, all Indian cities are water-stressed and face water crisis. To conserve the water resources, New Delhi is planning an approach towards sustainability through stormwater management, bioswales, permeable paving, rain gardens, etc. They have integrated it along the transport line as a part of the infrastructure. These swales collect the rainwater and stormwater; the soil above will absorb the water leaving the pollutants behind and hence it will offer good quality of water to the watersheds. Thus, New Delhi has implemented a creative and useful idea to make bioswale work with transportation (Gupta, 2019).	Earlier lakes, rivers, and streams were heavily polluted in Michigan. But over the last decade, there was an improvement in these water resources. Bioswales have become a key element to protect the surface water by decreasing stormwater runoff. Bioswales in parking grounds restrict the pollutants from cars and prevent them from flowing into waterways. It filters the pollutants, and then allows the water to merge with the watershed. This is a very positive approach to filter the surface water as well as increase the amount of plantation on the streets (Gibb, 2015).	Many areas in the cities face waterlogging. This is due to the accumulation of rainwater in the streets and the lack of water management techniques. Therefore, bioswales on roadsides, dividers, or in the parking area will be protected from waterlogging.

Sr. No.	Parameter	National case study	International case study	Performance in the city
11	Rainwater Harvesting	Odisha faces high temperature in summer inspite of high rainfall, which results in groundwater depletion. To solve this problem, rainwater harvesting is implemented in Joda town due to its low-cost harvesting technique. They have incorporated these technologies in the catchment area to capture and retain the runoff of rainwater. The pipe network is in such a way that water gets collected and empties in percolation tanks which increases the ground water level and rest of the water flows in the nearest watershed. This water is later used in agriculture, industrial and raw use (Krishna et al., 2020).	This method is majorly used in rural areas due to population growth, inaccessibility, contamination, and lack of water supply. Rainwater storage vessels are used in Thailand like jars for households and tanks for settlement. Rainwater is collected on the roofs of the household and through a pipe, water is glided in the tap. The runoff from ground and road catchment is used for livestock, irrigation, and nurseries. (Visvanathan et al, 2015).	It is one of the best methods to conserve rainwater; and can be used in many ways like drinking, domestic, agriculture, industrial, etc. It is very useful in drought-prone cities. It is also used in rural areas to avoid the cost of water.
12	Blue-green infrastructure	Visakhapatnam is blessed with five large water bodies, forests, and agricultural land. The city has worked on its blue-green city plan to increase the proportion of blue and green land use in the city. In terms of blue infrastructure, the focus was made to increase the number of lakes, reservoirs and for green, agricultural land was increased to make productive use of it. The city has proven a good example of a balance of blue and green infrastructure with providing huge benefits like employment generation, industries, tourism, environment, etc (Mukherjee and Madapala, 2020).	It is one of the greenest and cleanest cities of the world - 40% land of the city consisting of parks and recreational areas- more than a thousand parks, seven nature reserves, one City National Park (Stockholms Stad, 2013). As a part of blue, there are 24 beaches, water bodies like ponds and lakes consisting of 10% of the surface area of Stockholm. Every resident lives within a 300m radius of the green area. Flora enhances the beauty of the green city (Ali, 2013).	When there is a balance of blue and green infrastructure in the city, then it functions more efficiently. It helps to enhance resilience to climate change and also increases the interaction between mankind and nature.
13	Sustainability	Amravati is one of the most suitable cities in the world and hopes to be the new capital of Andhra Pradesh catering to a large number of populations. This ongoing project aims for sustainable activities like all buildings having power generation from solar panels. Bicycle networks, electric vehicles will enhance transportation. Recycled water will be used in irrigation. The central business district will have hospitals, schools, banks, hotels and is expected to create about 4 lakh jobs. It also includes recreational places like cultural and sporting facilities. 60% of the city is covered by green space and water. The city almost covers all the parameters of a sustainable city (Lo, 2018).	Curitiba is one of the reputed cities for its sustainability, urban planning, operative transport system, environmental protection, pedestrian-friendly, and waste management system. There is a program called 'garbage that is not garbage', where 70% trash is recycled by people themselves. People residing in areas that are unreachable by trucks, bring their garbage bags to the centre of the neighborhood and exchange it and get bus tickets, food and agricultural products in return. Children get chocolates, toys in exchange for the trash. Paper recycling saves 1200 trees per day. New lakes have been proposed in the city to overcome seasonal floods. City has an integrated and sustainable approach with long-term planning (Soltani & Sharifi, 2012).	People like to live in a place where chief amenities like bus stations, gardens, shops, hospitals, schools etc are near their residence. Thus, this parameter is a crucial part of any city to make it a smart city. Amravati – the developing city in India is incorporating every possible, sustainable and comfortable infrastructure to provide a better lifestyle to the people residing there. Whereas Curitiba is incomplete without its integrated transportation: it makes it easy for people to travel within the city along with many other sustainable infrastructures.
14	Rapid transit	Kolkata was the first city to have a metro in India. Earlier Kolkata faced many challenges due to transport like congestion, excess energy consumption in urban mobility, climate change, safety etc. To counter this, the Kolkata metro project was introduced in 1984. It has 2 operational lines of about 32 km stretch with underground, on ground and elevated stations. A smart card is provided for daily users. There are about 40 metros with more than 700,000 daily ridership. Average speed is noted to be 55-60 km /hr. The city has proved itself by raising transport connectivity through the Kolkata metro rail project (Kundu, 2018).	In Curitiba, 80% of the population use the Bus Rapid Transit System efficiently. The city is discouraging the use of private transport and increasing the use of cycle and public transport to the maximum. The integrated transport system of Curitiba plays an important role. First is a tube system (handicapped-friendly) that is connected to BRTS, further connected to feeder city bus service and finally ends in cycling stands. Today 200 km of roads in Curitiba have cycle tracks which are expected to reach 408 km of bicycle infrastructure by 2025 (Cidco smart city, 2017).	Transportation is an instrumental part of the smart city. It enhances the quality of city life, reduces carbon emissions and most importantly convinces people to travel in public transport. Usually, the foremost reason for less use of public transport is that it is time-consuming, and thus rapid transit in the city is surely valuable.
15	Roundabouts	Urban areas face heavy traffic especially on highways where goods vehicles are mixed with local traffic at junctions and congestion is likely to occur. This invites many negative effects like air and noise pollution, accidents, and delay. The Pandit Jawaharlal Nehru roundabout in Patna is the perfect example of a floral roundabout which indicates the love of Pandit Jawaharlal Nehru towards flowers. It has about 40 m diameter and is blessed with flourishing, fresh, grassy, and leafy plantations. (Pandit Jawahar Lal Nehru Roundabout - Wikimapia, n.d.)	This roundabout is one of the most recognized landmarks of the city, also called 'the welcome monument'. The statue placed in the centre depicts two bronze statues of man and woman welcoming mankind in a waving gesture. The beauty of the statue is enhanced by the fountain on its all side. This can be included in blue infrastructure- the roundabout and fountain are so huge, enough to be a lake. The atmosphere becomes cooler surrounding the roundabout, attracting locals to gather around it (Fajar, 2013)	Growing greens in roundabouts is another helpful way to increase vegetation in the city. Those roundabouts with larger diameters can also act as gregarious places. It also increases the aesthetic value of the streetscape. Generally, in international cities, we can find a wider variety of roundabouts.

Sr. No.	Parameter	National case study	International case study	Performance in the city
16	Elevated walkways	Talking about skywalks, Mumbai is at the top controversial for its elevated walkways. MMRDA has constructed 36 skywalks of a total length of 17 km in Mumbai and outskirts. It shifted a good amount of people from busy rail to daily walkers. Skywalks connect certain destinations like a residential area, bus stop, commercial building, markets, railway station, etc. Mumbai has enough skywalks but needs to be filled with vegetation. People should initiate and grow greens on the walkways to make it alluring. This will come up with good support in reducing the pollution in the city (Rao, 2014).	Paris is home to the most beautiful parks in Europe. Along with this, it is also fortunate to have elevated walkways. One of them was made in the mid-19th century from an abandoned viaduct. It is the most cherished landmark of Paris. It is made over the crossroads with facilities like a staircase and lifts. It is a garden along with a pool area on the viaduct full of dense trees and plants which attract the gathering of people. (Brunton, 2017).	Generally, walkways are found above the roads to avoid the busy traffic underneath. Incorporating vegetation in these walkways will augment its beauty. This can be also made to connect several buildings with transport stations to save travel time.
17	Renewable energy	Gujarat has installed a capacity of 10730 MW of renewable energy i.e., 28% of total capacity. The state has the longest coastline in India which leads to the potential of wind power. 80% of the renewable energy in Gujarat is generated by wind energy. Biomass generates 1800 MW of electricity from crop residue and 140 MW from the forest. This energy is used in cooking. There are a total of 77 solar plants commissioned of capacity 891 MW. Gujarat is heading continuously to produce more and more energy from renewable energy resources (Vibrant Gujarat, 2014).	It is the world's largest solar power plant in the desert with a capacity of 2.2GW. It provides power to cities in East and South China which includes Shanghai and Beijing. This energy is used in running street lights, supply of power in residential and public sectors, etc. China is set to maximize the consumption of renewable energy and boost the economy of the country. This case study shows the productive use of desert where the temperature is maximum and utilizing that temperature for the betterment of the city (Bellini, 2020).	Renewable energy from different sources have tremendous benefits like it will help to reduce the amount of greenhouse gas in the atmosphere, cut energy demand, reduce the usage of fossil fuels, etc. maximum use of renewable resources is a major step in moving towards sustainability.
18	Solid Waste management	Gandhinagar A sustainable township in Gandhinagar called GIFT city has all the parameters of a liveable city - one of them is solid waste management. This township acquires Swiss technology where a smart solid waste management system is used to collect the waste from the buildings and send it to the waste collection center through vacuum suction pipes at 110 -140 km/hr speed. This waste is recycled and transformed into organic manure and also used in power generation. This entire system is computerized- from the collection of the waste from buildings to the recycling of the waste in the centers (Balan, 2015). Indore With the increasing population, solid waste management has become a significant character in urban dwellings. Indore has an excellent municipal solid waste management system along with other parameters of a liveable city. The city was declared the cleanest city in India for the 4th consecutive time in 2020. A well-organized system is followed in the city to maintain municipal solid waste where the process includes: generation of waste collecting, transporting, and disposing it in the Indore city. There are various policies introduced by the government to manage waste efficiently. (Singh, 2021)	The first step towards the sustainability of roads is to reduce the waste then reuse the waste. A similar method is adopted by Colorado in the USA where millions of discarded tires were recycled using liquid nitrogen which made the tires brittle. Then the scrap was pulverized into a fine powder and later used in products like paint, coatings, etc. Decomposition of used tires is a very difficult task, but the city of Colorado has implemented an exceptional technique to utilize the rubber waste in the form of paints and coatings (Miller & Spoolman, 2021).	Proper garbage collection and disposal is a crucial infrastructure in the town. It prevents waste stack up and maintains hygiene in the area. This can be done effectively with low cost to add a sustainable infrastructure in the city.

5. Conclusions

Today, many cities are adopting the concepts and methods of green infrastructure for city development and making them sustainable, liveable, and eco-friendly. The four pillars supporting a green city are energy, greenery, infrastructure, and land use planning. Cities developed based on these pillars become better support for not only humans but also the other ecosystem involved. The development of cities also contributes a large amount to the process of climate change. This paper discusses the different methods of the green city concept and how it can be incorporated in the cities. The parameters include green building design, use of eco-friendly infrastructure, incorporating green spaces, and promoting green products, etc. Green infrastructure reduces the toxic substances released in the air, caused due to emissions and other construction and industrial activities. In a green city, several types of natural resources are regarded, safeguarded, and stretched out to assist city inhabitants. These green zones are either effectively utilized as grassland, parks, gardens or are

deserted from their past use such as certain empty plots of land, which unfortunately are transformed into dumping grounds. Eco urban areas have been developed and undertaken in various instances. The development of these areas, not only covers a wide cluster of philosophical but also natural objectives essential for the sustenance of life. Expansion of city limits, urbanization, and quick populous development lead to particular issues such as air and water contamination, environmental degradation, shortage of housing, infrastructure, education, and transportation.

This paper tries to explain the use of green infrastructure in cities and its benefits. The use of green infrastructure provides an opportunity for recreational places, promotes community identity along with other countless profits. The benefits of the green city also include rich biodiversity, decrease air pollution, ensure water shortage, reduce noise pollution, cools down temperatures, decreases the effect of climate change, etc. Distinct elements that are a part of the green city are explained through the means of comparison between national (Indian) and global case studies. The analysis in this paper indicates that Gandhinagar, Bangalore, Kerala, Chandigarh are the most prominent green and sustainable cities in India. In the case of international case studies, the analysis indicates that Curitiba, China, Copenhagen, Melbourne, San Diego is liveable as well as recognized as green cities in the world. To deduce, green infrastructure will also be utilized as a tool to inform the citizens of the respective city about how green infrastructure helps to grow the green, sustainable and liveable city. The analysis of the urban forests of Kerala and Curitiba indicates Curitiba has large-scale tree plantations while Kerala is rapidly stepping towards increasing the ratio of the urban forest in the city through the adoption of methods like urban agriculture and horticulture. In the case of the United States of America, the citizens practice rooftop planting and are transforming lands into community gardens, kitchen gardens, etc. Furthermore, Agritourism has been boosted in the last few years where people like to take a break from the city life and live a village-like lifestyle. Majuli and San Diego are excellent examples of Agritourism, where individuals feel connected to the natural beauty of the earth where man has intervened the least. Apart from the concrete jungles that the cities of today have become, having green recreational places in the form of green pockets is essential for a city. The infrastructure of Bangalore city has included green building techniques, water reservoirs, parks, and gardens. Hong Kong has incorporated plazas, promenades, pagodas, temples, etc. as a part of green pockets. Comparing the two of them in terms of the diversity and functioning of green spaces, the city of Hong Kong has more such spaces and functions associated with the creation of green pockets. Other examples of these spaces are the connected greens of Chandigarh and Copenhagen. Having a glance at the master plan of both the cities, Chandigarh seems to have a better-connected network of vegetation with recreational activity. This is more preferable to having the districts connected and vegetation surrounding all these districts together. Central Park of New York has been recognized the world over for its vast area, huge greenery, and various recreational activities. Another parameter associated with green infrastructure is green buildings. These are generally found in international countries, and such a concept of design is upcoming in the Indian sub-continent. Yet, Chennai, a city in India is also stepping towards the approach of green buildings. One of the important features of eco City is the shaded streets which are analyzed by the case study of two cities: Delhi and Stockholm which manifest that street can get shelter from trees as well as built form.

Water is the backbone of any City. Without water, a city cannot function. On the other hand, an abundance of water in the form of floods can also destroy the city. Thus, harvesting and water conservation is an essential practice. The Sponge City concept was introduced by China to prevent floods which gained success and thus the same concept is being followed by Kochi to protect the city from disasters. Bioswales, rain gardens, and biorientation are the techniques incorporated in some of the national and international cities like Delhi, Michigan, Pune and Melbourne to reduce the amount of surface water runoff, filter it and use to increase the groundwater level. While rainwater harvesting is a method to store rainwater and use it later. In Thailand, only rural areas practiced this method but an excellent example of the same is presented by Joda township, in Odisha, where the entire neighborhood helps to store rainwater including roofs, roads, buildings, landscape, etc. This township is planned brilliantly from this perspective. Along with the use of freshwater, we should also look to reuse the water where the water is used for agriculture, industrial and aquaculture purposes.

The next chief constituent of a green city is sustainability which can be incorporated through many ways including blue-green infrastructure where a city needs to have a balanced ratio of blue (water) and green (vegetation). Stockholm gains the higher ranking for having 40% of land full of greens and 10% off the water. It also benefited from natural beauty. In the case of Visakhapatnam, the city also has the presence of large water bodies but here, the green part includes agricultural land and forest which focuses more on employment generation. The major characteristic of sustainability is resource and energy conservation, waste reduction, ease of accessibility and transportation, green design, etc. Curitiba is one of the most reputed cities including all the characteristics of sustainability like rapid transport, adequate open space, recycling, etc. When compared with India- Amravati is focusing on its plan to be the most sustainable city in the world and hopes to be the new capital of Andhra Pradesh. Looking into the transportation sector, the Kolkata metro is foremost for its rapid transit. Every city should have adopted the approach of integrated transport for smart and easy transit. Roundabouts and raised islands are an essential part of traffic flow, almost present in every City- but the aim is to use this part of the land also as green by planting vegetation or any infrastructure connecting this roundabout to be a part of a green city. Similarly for elevated walkways, this type of infrastructure can also improve sustainability as well as increase the greens in the city. On one side Paris is an example of converting an old viaduct into a walking breath. On the other side are the skywalks of Mumbai which are fully efficient but have no aesthetic and green beauty. By planting shrubs on this skywalk can provide shelter, cool temperature as well as people's attraction. Renewable energy generated from wind, sun, biogas, tides etc. play a major role in the sustainability of the city. China has the largest Solar Power plant with great capacity and like other more countries like Israel and Singapore etc are focusing on desalination plants, thermal energy power plants, etc. Indian states like Gujarat are giving no less competition to them by generating 28% of total capacity from renewable resources. This is a very positive approach to reduce the use of fossil fuels. Another parameter of sustainability is solid waste management. In the early decades, the majority of the countries were dumping the waste on either land or ocean rather than recycling. Today, we have multiple methods to recycle almost everything. Colorado is an illustration where small-scale recycling of rubber is done whereas an Indian city in Gandhinagar has made an amazing smart solid waste collection process connecting the entire township. Thus, this shows a comparison of distinct parameters of green sustainable city. It demonstrates that for some variables international cities are superior, while the incorporation of some infrastructure techniques should be influenced from Indian examples and case studies.

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Figures

Figure 1
Benefits of green infrastructure (Source: Article name- Green Infrastructures: A Framework to Apply a Multiscalar and Transectoral Approach in Planning.)