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Holistic Integrated Approach of Designing a Satellite Town: Introducing Theories of Environmental Parameters Like Pollution Free, Circular Economy and Sustainability

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Abstract

Urban regions are quite challenging to restore the quality of environment at the global level as well as posing serious threat to climatic changes. This fact is demonstrated on the grounds that around 70% of the carbon footprint is contributed from the urban sector. The authors of the present study have attempted to design a satellite town of population 50,000, partly to dilute the population density of main urban town and partly to make the satellite town as ideal to facilitate the migration of population from the main urban town. An effort has been made in the present study by the authors to address the issues of environmental degradation along with issues governing circular economy, sustainability, tourism hotspots, and perfect ecosystem. The satellite town is designed to infuse the concepts of urban air ventilation, balancing albedo effect, urban heat island effect, optimization between concreting and non-concreting urban surface area and adequate carrying capacity of roads. To develop satellite towns, urban forestry along with zoological parks and environmentally compatible residential towers with green roofs and solar panel coupled with parking spaces, schools, colleges, green parks, government institutions, hospitals, commercial areas, stadiums and water reservoirs to catch rainwater. Besides, water sports activity also has been designed along with an adventure club and circular toy train all along the periphery of the satellite town to attract the tourists. The solid waste and sewage generated shall be treated at the environmentally compatible site to transform into valuable resources, which shall be used for raising urban forestry and promoting green spaces. The reservoir water shall be treated with specified aquatic organisms. The present study aimed at holistic design in terms of overall environmental issues, circular economy, sustainability and tourism.

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INTRODUCTION

Urban sectors face serious challenges like air pollution, water pollution, degradation of biodiversity species, deforestation, and decline of biodiversity. In addition to it, there are more issues like efficient waste management, traffic congestion, inadequate public transportation, rising greenhouse gas emissions, urban heat island effect, limited

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greenspaces and increasing socio-economic disparities. These challenges contribute to worsening the living conditions and severe strain on the green infrastructure. As urbanization is increasing at a rapid pace, cities are facing significant challenges on the global scale. Economic growth, social development, innovations, energy and natural resources are the main drivers of urbanization. The expansion of cities contributes approximately more than 70% of the world's carbon emission which is the main factor for climate change.

In many developing nations like India, Nigeria, Kenya, Ethiopia, Bangladesh, Indonesia, Brazil, Mexico and more, the population is tremendously increasing and intensifying the pressure on the existing infrastructure and natural resources. The challenges are unplanned urban expansion, pollution, inadequate waste management and inefficient energy consumption faced by the cities. Policies promoting green buildings, renewable energy adoption, and circular waste management systems are gaining momentum. The government has taken up various smart city projects whose prime focus was sustainability, innovation, and energy efficiency. Designing satellite towns that integrate renewable energy, urban forestry, and eco-friendly transport options not only address urban overcrowding but also aligns with the national goals of reducing emissions and creating a greener economy. These towns can serve as blueprints for balancing growth with environmental stewardship.

LITERATURE REVIEW

It is reported that out of total 30 most polluted cities of the world there are 22 Indian cities [1]. As per an observation by WHO that India is considered as the 5th most polluted cities, based on its carbon emission and concentrations of particulate matter [2]. Henceforth, it has become a necessity to reconsider the urban planning processes into more performance based planning [2]. A big contributing factor being Urban Heat Island Effect, adversely affecting human comfort, energy management, urban planning and other issues [3]. Thus, one of the most essential components being urban air ventilation which reduces the exposure to air pollutants and provides thermal comfort which guarantees a better sustainable and resilient urban space [4].

As observed, the lack of proper policy initiatives in urban spaces has resulted in environmental degradation and simultaneously increase in carbon dioxide emissions [5]. Thus, the reduction of carbon dioxide emissions has become one of the prime aims for the sustainable and green world through different influential factors such as the use of renewable energy, various technological innovations and economic growth [5].

The various reports stated that two thirds of the global population expected to reside in cities by 2050 thereby resulting in challenging pressure on resources, materials, housing and transport sectors. Cities contribute 70% of greenhouse gas emissions (GHG) globally [6]. With the significant consumption of food coupled with increasing housing and transport, it became hotspots for both urban material and carbon footprints [7].

It is interesting to note that 32% of greenhouse gas (GHG) emissions are generated by food production and 33% by buildings. The increasing pressure of urbanization, population growth, and urban sprawl contributes to the overburdening of infrastructure, depletion of natural resources, and environmental degradation, highlighting the need for sustainable urban development solutions [8]. Collecting waste and its disposal is one of the greatest challenges urban societies face today. At the same time, minimizing waste production is going to be vital for reducing GHG emissions, due to the reduction of direct emissions in the form of methane. The term "circularity" refers to several strategies to keep resources and materials in close loops of production and consumption, such as reducing, reusing, recycling, and renting rather than owning things [9]. In a circular economy, the goal is to retain and optimize the value of products and materials through different means. Some studies, concerned with the environmental impact of circularity measures, demonstrate that the substantial reduction of CO_2 and other GHG emissions is possible through appropriate policies for effective materials management, eco-design, and reuse [10–12]. It is important that strategies implemented at urban scale can have a significant impact on climate change [13].

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DESIGN OF A SATELLITE TOWN: A CASE STUDY

The present study is oriented towards environmentally compatible satellite towns wherein special emphasis has been laid on zero pollution, sufficient urban air ventilation, optimizing concrete to non-concrete urban surface areas, transformation of waste into usable products, infusion of urban forestry and zoological park, water conservation and tourism.

The satellite town is designed for a population of 50,000 and the residential accommodation is designed by developing residential towers to the tune of 111 in numbers. Each residential tower shall have 15 stories, and each story shall have 6 flats. It is assumed that each flat has 5 people to accommodate, which would mean that 450 people should be accommodated in 90 flats in each tower. There will be 111 towers to accommodate the entire population of 50,000. Each tower should have green roofs and solar panels along with a small garden attached to it and an adequate parking facility. The design calculation in respect of the above statement along with estimated number of cars and scooters with extent of parking space needed is also calculated as per Tables 1–3.

Area of Satellite Town

The total satellite town area is 4200000 m^2, out of which open space would be 2500000 m^2 and built up or concreting area is 1700000 m^2. The above area is calculated by taking WHO ideal figure of 50 m^2/person as open space and by assuming 60:40% as open and built up are used for the design of satellite town. The calculation is reflected in Table 1.

Number of Flats and Towers

The number of flats and towers are calculated as per Table 2, and the picture of tower is shown in Figure 1.

Solid Waste Management

Solid waste and sewage generation have also been calculated with a view to transforming these wastes into usable products. This will facilitate the concept of circular economy and sustainability and eliminate the problem of pollution in the satellite town of 50000. The Table 3 reflects the total solid waste generated (Degradable and non-degradable) along with byproducts in the form of biofuel and power, and Table 4 shows the estimated sewage generation.

Number of Estimated Cars and Scooters

The estimated number of four and two and four wheelers are given in Table 5. It would be seen from Table 5 that around 1000 cars and an equal number of scooters are expected to be available in the satellite town. Similarly, 20 school buses and 30 transport buses are expected to be available. In addition, to the above, 200 tourist cars and 50 tourist buses are expected to come daily to the satellite town for which adequate parking spaces have been designed and reflected in Table 6.

Table 1. Area of satellite town.

Total proposed population	Proposed open area	Proposed built-up area	Proposed total area	Proposed circumference of the town
50,000	25,00,000 m^2=2.5 km^2	17,00,000 m^2=1.7 km^2	42,00,000 m^2=4.2 km^2	73,00,000 m=7.3 km.

Note: Let it be considered that, Open Area per person =50 m^2 and the ratio of the Proposed Open Area: Proposed Built-up Area=60:40, If we consider the master plan of the satellite town to be a circle, then area of the circle =4.2 km^2 and the proposed radius of the town=1.16 km=1,60,000 m.

Table 2. Showing Number of Flats and Towers.

Number of units in 1 tower	Total population in 1 tower	Proposed total number of towers
50,000	25,00,000 m^2=2.5 km^2	17,00,000 m^2=1.7 km^2

Note: Let it be considered that, 1 floor of a Tower =6 units of flats and Number of floors in 1 Tower =15, Also assume, that1unit of flat=5 persons.

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Residential Towers

Figure 1. Shows the proposed number of flats and towers calculations.
Source: Simon photos, Tsuen Wan, Hong Kong.

Table 3. Solid wastes and byproducts produced.

Total solid wastes to be generated (kg/day)	Total degradable wastes to be generated (kg/day)	Total non-degradable wastes to be generated (kg/day)	Total biofuel to be produced (l)	Total power to be produced
50,000	7500	42,500	910.78=911 l	0.075 MW=75,000 W

Note: Let it be considered that, Solid waste to be generated per person =1 kg/per person/day, Total Degradable waste to be generated =85% of the total solid waste to be generated and Total non-degradable waste to be generated =15% of the total solid waste to be generated. Also, Total Biofuel to be generated=Total degradable waste to be generated (in tons/capita/day) ×21.43 and Total Power to be generated =Total non-degradable waste to be generated (in tons/capita/day)/100.

Table 4. Sewage generation.

Total water consumed per person (l/day)	Total water consumed (l/day)	Total sewage generated	Total volume of sewage to be handled by the sewage treatment
135	67,50,000	47,25,000=4725 m^3	1.5×4725=7087.5 m^3=7088 m^3

Note: As, Total water consumed by the total population =50,000×135 l/person/day, Total Sewage generated=0.7×Total water consumed by the total population and Total Volume of Sewage generated to be handled by the Sewage Treatment Plants =1.5× Total Sewage Generated.

Table 5. Estimated cars, scooters and buses.

Population	Total cars (5 persons/car)	Total scooters (5 persons/scooter)	School bus	Transport bus
50,000	1,000	1,000	20	30

Parking Space Required

The parking space required for car, scooter and buses are being calculated and given in Table 6 and picture of different parking spaces are shown in Figure 2. It is evident from the said Table 6 that 25000 m^2 area is provided for vehicular parking at different places.

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Figure 2. Showing parking spaces.
Source: Pixabay pictures.

Table 6. Estimated area of parking space.

Vehicle Type	Total numbers	Parking space (m^2)
Local Cars (3×5 m=15 m^2)	1000	15000
Local Scooters (1×2 m=2 m^2)	1000	2000
Local School Bus (10×5 m=50 m^2)	20	1000
Local Transport Bus	30	1500
Tourist Cars	200	3000
Tourist Buses	50	2500
Total	2300	25000

Details of Residential Towers and Their Blow Ups

In terms of proposals for residential areas, 65 m high towers of 15 floors are being proposed. Each floor would be having 6 units of flats, with each unit being a 3 BHK (BHK: Bedroom, hall and Kitchen) apartment of floor area 350 m^2 each. The space between the two proposed residential towers has been maintained to the minimum of at least 1.5 times the height of the towers, which is 97.5 m to be exact. The distance between the towers is proposed to provide sufficient air corridors so that the winds can enter the satellite town without any sort of barriers.

The airstream entering the proposed town crosses the 50-m-wide green belt which is being proposed adjacent to the boundary of the town, providing a cooling effect which results in a comfortable environment throughout the town, as shown in Figure 3. Henceforth, allowing an acceptable amount of space in between the two residential towers and letting the wind pass through a surrounding green belt of 50 m is sufficient for proper air ventilation within the city coupled with cooling effect. This will reduce the urban heat island effect, urban energy and water consumption and allow transporting the air pollutants quickly with effective dispersion leading to safe air quality of the city. It can be seen from Figure 3 that 118 m space provided between two residential towers is utilized by providing 4-lane roads, Pedestrian walking street, cycling track, gym, children parks, coupled with green spaces resulting in beautiful, attractive layout and excellent appearance to attract tourists and residents living in towers.

Water Conservation

An attempt has been made to conserve the rainfall in the satellite town of an area of 42,00,000 m^2. The average rainfall is assumed as 400 mm per year where the satellite town is proposed to be situated. The amount of total rainfall in the satellite town would be 1680000 m^3. If 40% of this rainfall is effectively collected through well designed drains along with providing adequate slope to the water reservoirs. The capacity of water reservoir would be 672000 m^3 to hold the rainwater plus additional storage of 10% to provide clear space on the top of water level in the reservoir. Thus, the total designed capacity of the reservoir would be 739200 m^3.

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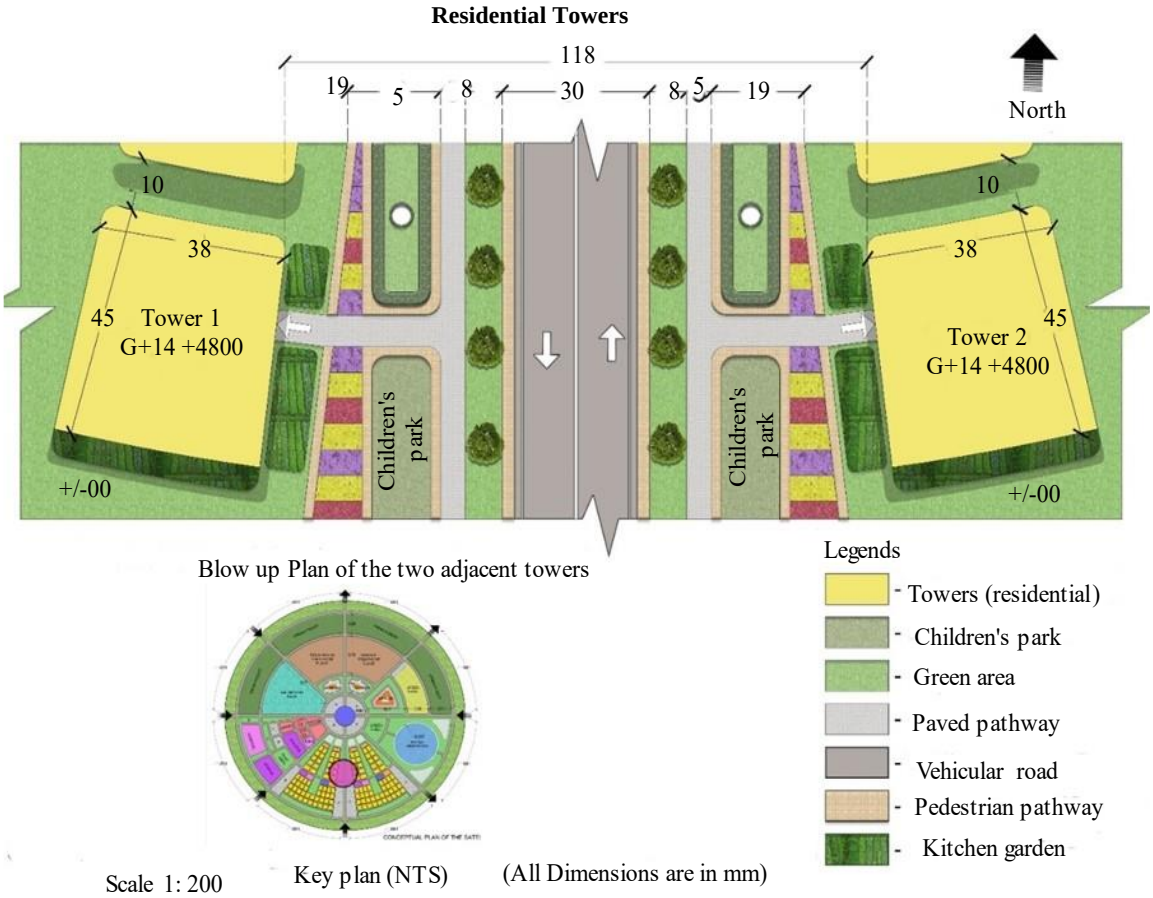

Figure 3. Showing layout of residential towers, 4-lane road, pedestrian walking street, cycling track, gym, children parks, coupled with green spaces.

Assuming the depth of reservoir as 10 m, the area of the reservoir would be 73920 m^2 which would mean that the radius of the reservoir would be 153 m and the circumference of the reservoir would be 2×3.14×153=961 m. Table 7 shows the rainwater reservoir calculations. It is also proposed that Singhi, Tilapia and carps' fishes and frogs and tortoises should be added in the reservoir to keep the water clean and provide the economic outlook based on selling these fish in the market. Moreover, well-designed and attractive boats should be provided to cater for the tourists and to provide additional economic and sustainability benefits, a 5 m width road with green space on both sides of the road shall be provided all around the periphery of the reservoir. The water available in the reservoir shall be provided to all the flats in the towers, schools, colleges, government institutions, commercial activities and water sports throughout the year. The diagram of the reservoir is shown in Figure 4.

Commercial Areas

The satellite town is also provided with an attractive commercial area wherein 15 storied high rise commercial tower is proposed. The commercial building shall be constructed in a radius of 100 m at the center of the satellite town. Number of hotels, restaurants, shopping centers, corporate offices, gym, cinema halls, conference rooms, indoor games activities, swimming pools etc. are a prominent part of the proposal on a large scale, so that the needs and requirements of the residents and the tourists are being fulfilled. The entire commercial building shall be air-conditioned and having descent ventilation. Around the commercial building, 30 m width circular roads shall be provided and beyond it 20 m width parking space shall be provided to park the vehicles. Such an attractive facility shall be able to attract the economy and to provide sustainability for the effective management of satellite town. The typical diagram of the commercial area is reflected in Figure 5.

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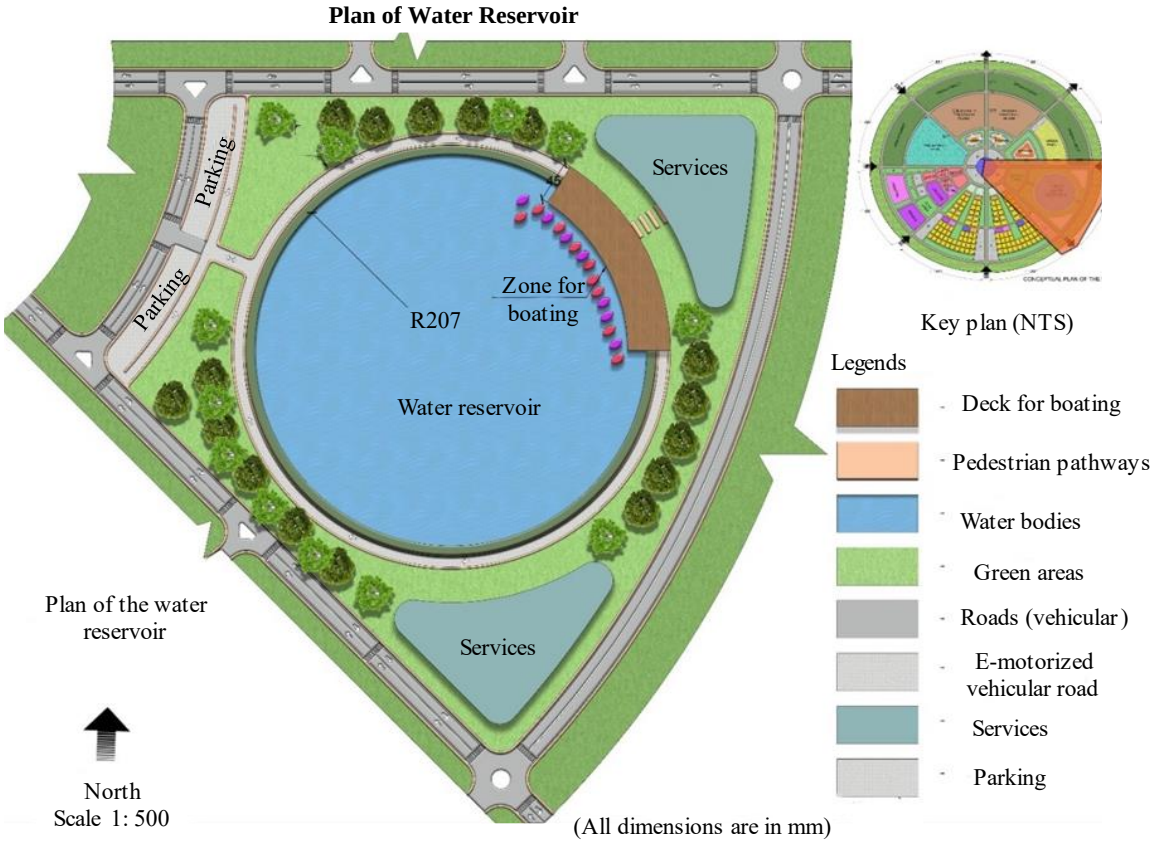

Figure 4. Showing plan of water reservoir.

Table 6. Rainwater Reservoir Calculations.

Amount of rainfall within the proposed town (m^3)	Average rainfall (m^3)	Amount of rainfall drained through from the paved areas (m^3)	Amount of rainfall to be collected in the reservoir (m^3)
42,00,000	400	21,00,000	16,80,000

Note: As, Amount of Rainfall=40 cm/year. Total Amount of Rainfall within the proposed town=0.4× Total proposed Area in sq.m, Amount of Rainfall drained through the paved surfaces=40% of the Total Amount of Rainfall joining the reservoir.

Figure 5. Showing High rise commercial tower.
Source: Published on September 7, 2023, Fujifilm, X100V.

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Institutional Areas

A separate institutional area has also been designed with green spaces where different government offices shall be provided. These offices include electricity board, water works, police chowki, administrative offices, forest office, Municipal office etc. All these offices should have green roofs and solar panels to provide an environmentally compatible institutional area.

Schools and Colleges

Schools and colleges are also provided in an isolated and calm area along with small gardens and playgrounds with green roofs and solar panels. Residential accommodation shall also be provided for the outside students separately for schools and colleges with all facilities. A typical school or college building is shown in Figure 6.

Urban Forestry

Urban forestry refers to the process of managing and taking care of trees, green covers and forests in an enclosed urban space. It incorporates certain practices whose primary aim is to promote health and sustainability of trees and green covers of urban spaces. Thus, urban forestry plays a very important role in the improvement of the quality of life of towns and cities, mitigation of various environmental challenges and notable contribution to a more sustainable urban area. The objectives of urban forestry are mainly listed here below:

- Environmental Conservation.
- Air Quality Improvement.
- Temperature Regulation.
- Biodiversity Enhancement.
- Stormwater Management.
- Community Health.
- Economic Benefits.
- Carbon Sequestration.

Here are some trees that are commonly used in urban forestry in India:

- Neem: *Azadirachta indica*
- Mango: *Mangifera indica*
- Banyan: *Ficus bengalensis*
- Sacred fig: *Ficus religiosa*
- Champak: *Michelia champaca*
- Flame of the forest: *Butea monosperma*
- Golden shower tree: *Cassia fistula*
- Pride of India: *Lagerstroemia speciosa*
- Singapore cherry: *Muntingia calabura*
- Gamhar: *Gmelina arborea*
- Sita Ashoka tree: *Saracaasoca*

School Building

Figure 6. Showing school building and playground.
Source: Creator: Tom Sibley Credit: Getty Images.

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Trees play a vital role in urban forestry by providing shade, cooling and habitat provision. They also help to improve air quality and reduce pollution. When choosing trees for urban forestry, it is important to consider native species, as they help to support local ecosystems and avoid the introduction of invasive plants. A typical urban forest is shown in Figure 7.

Water Sports

- Swimming is one of the most accessible water sports: all you need is a swimsuit, body of water and maybe some goggles.
- Roller Coaster.
- Canoeing.
- Rowing.
- Stand-Up Paddle boarding.
- Surfing.
- Wakeboarding.

Figures 8 and 9 show amusement park with water sports.

Greenbelt Around the Satellite Town

A 50 m width green belt is proposed to be developed all along the periphery of the satellite town. Such a green belt will have tall trees and a pedestrian walkways at the center of this belt to provide pure nature feel. The green belt will also facilitate cooling the air passing to the satellite town and may also reduce energy consumption due to cooling effect. Within this greenbelt, at every500 m, there shall be a small picnic spot in the form of a rock garden, natural pond, and a small children's park. Each adventure spot should have a mobile cafeteria to provide snacks for the visitors. Figure 10 shows the green belt surrounding the satellite town.

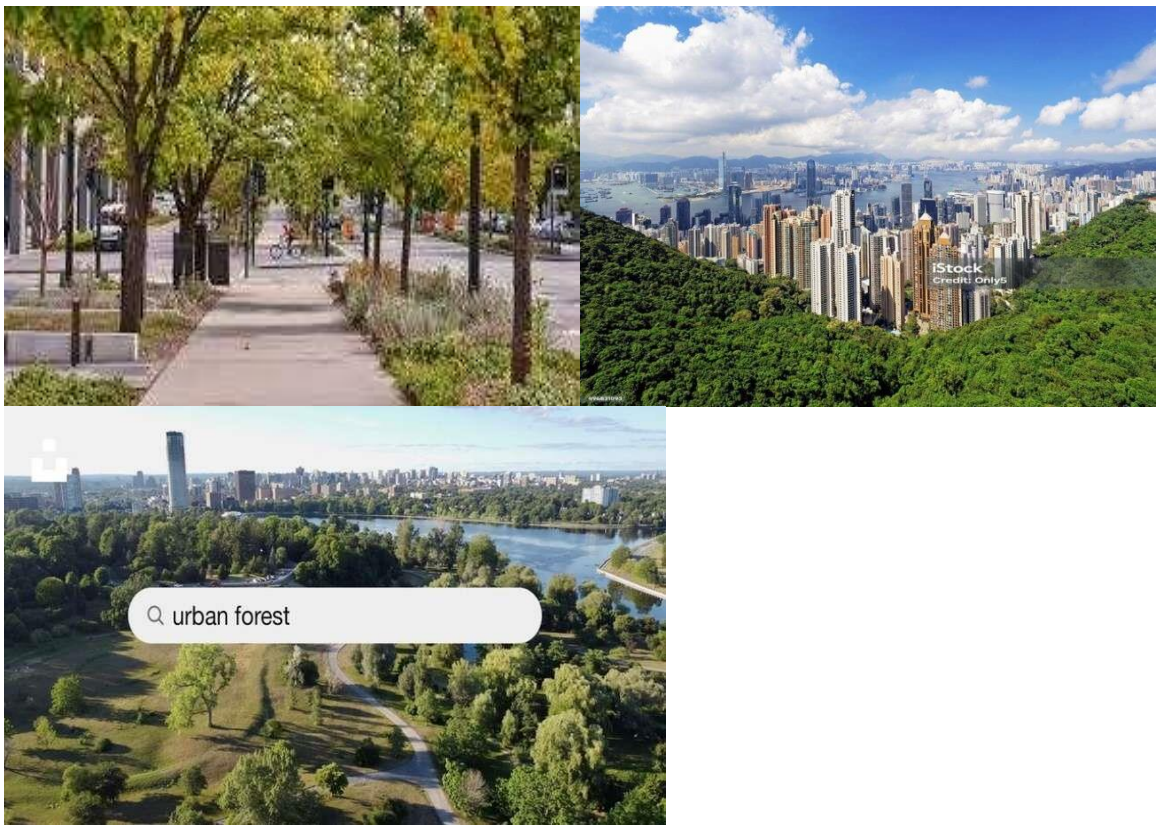

Figure 7. Showing typical urban forest
Source: 5 benefits of urban forests: college of natural resources news.

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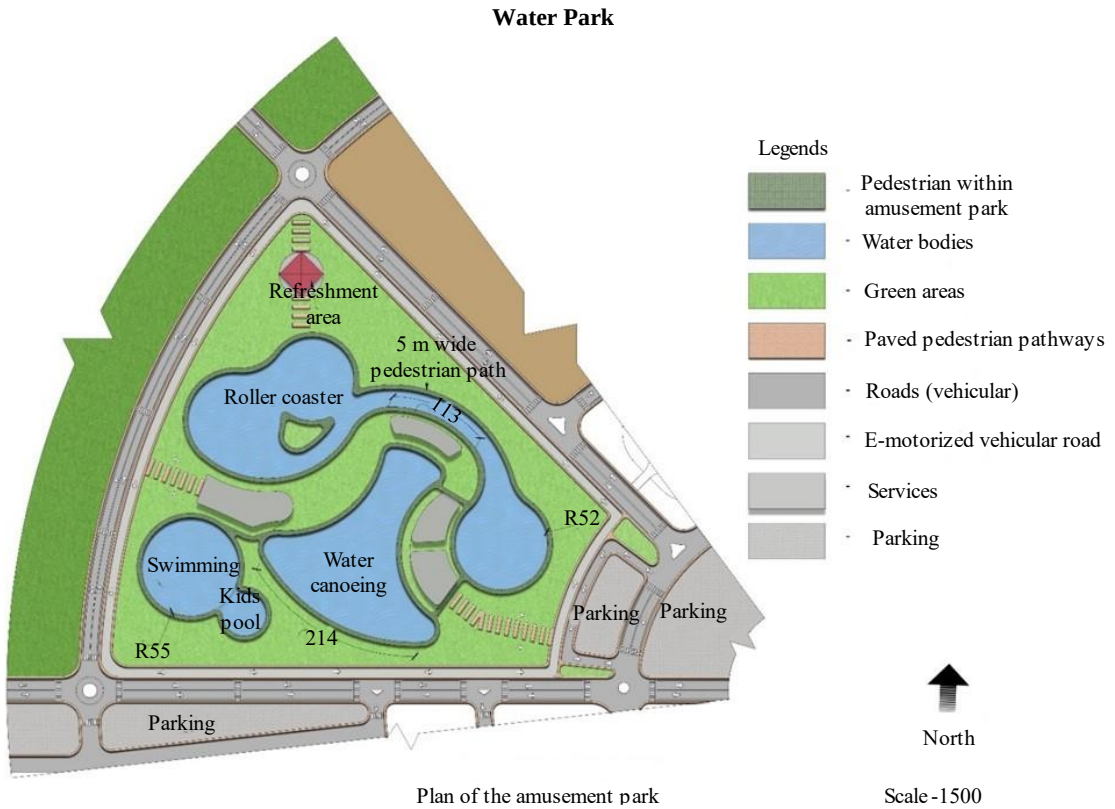

Figure 8. Showing amusement park with water sports.

Figure 9. Showing the water sports.
Source: Setting Up a Successful Water Park in India: Arihant.

Zoological and Amusement Park

Zoological park shall also be developed in an area of 216300 m^2 where wildlife in the form of tigers, lions, giraffes, snakes etc. shall be kept. Moreover, different types of birds and aquatic animals like parrots, silver bill, myna, pigeon, hippopotamus, crocodile, water snakes, fishes, Dolphin, shall also be kept. Such a zoological park is proposed to be designed with excellent greenery and food park to attract the tourists. Such a zoological park would promote tourism, attract the economy and provide sustainability as shown in Figure 11.

Circular Toy Train

A circular toy train is designed all around the satellite town in a stretch of 7.3 km with stoppage at residential towers, institutional areas, water reservoir, zoological and amusement park, water sports,

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etc. Such a circular toy train will attract tourists and promote the circular economy of the tourists and add to the circular economy of the town leading to sustainability. A typical diagram of the circular train is shown in Figure 12.

LAYOUT PLAN OF SATELLITE TOWN AND AREA ALLOCATION

The layout plan of satellite town is shown in Figure 13 in which all the features listed and explained are reflected. The areas of each feature are also reflected in Figure 13.

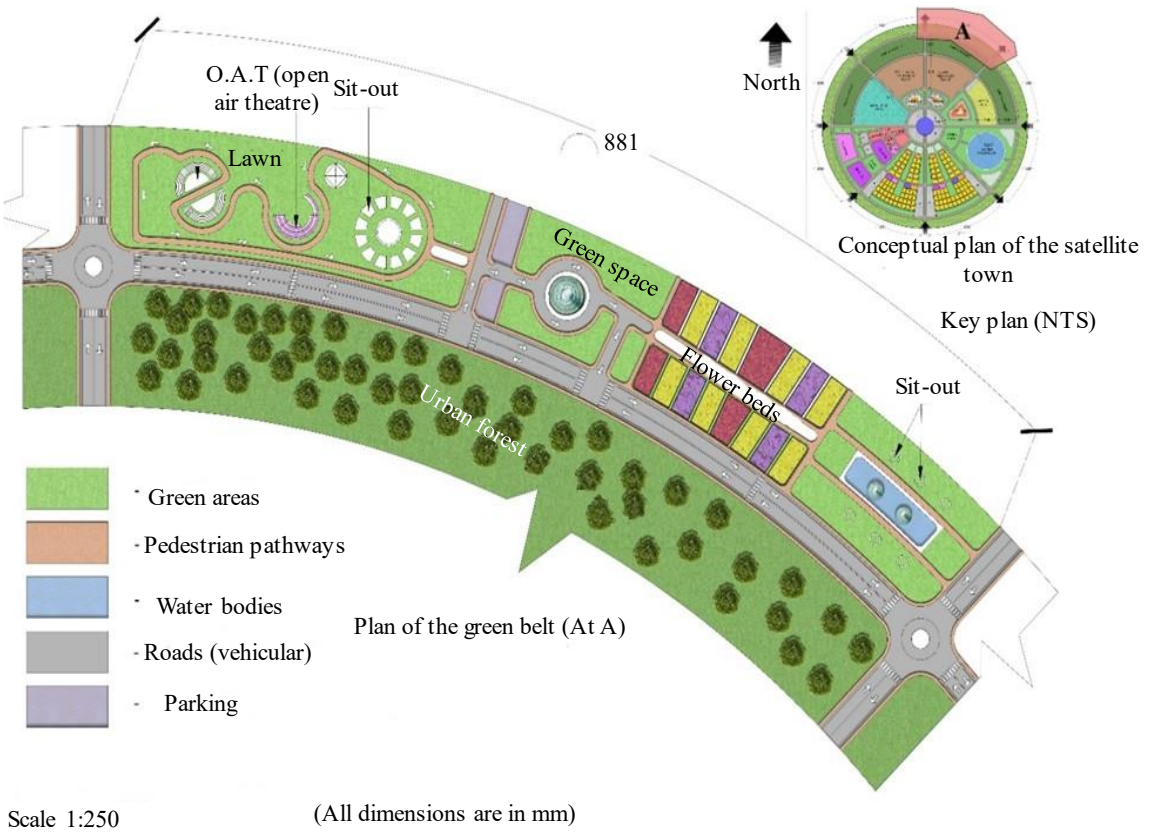

Figure 10. Showing the Green Belt surrounding the Satellite Town.

Figure 11. Showing the Zoological and Amusement park.
Source: 178,820 Amusement Park Stock Photos.

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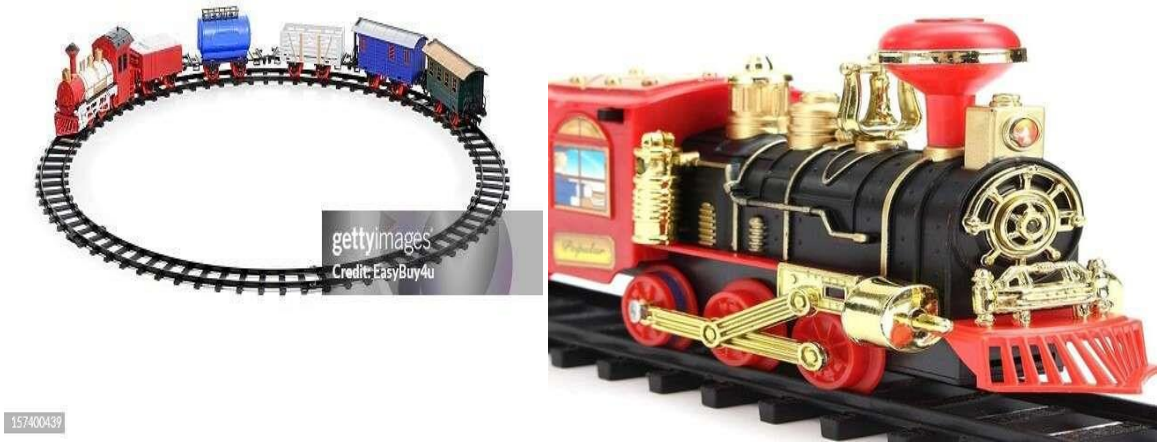

Figure 12. Showing the circular toy train
Source: Getty Images.

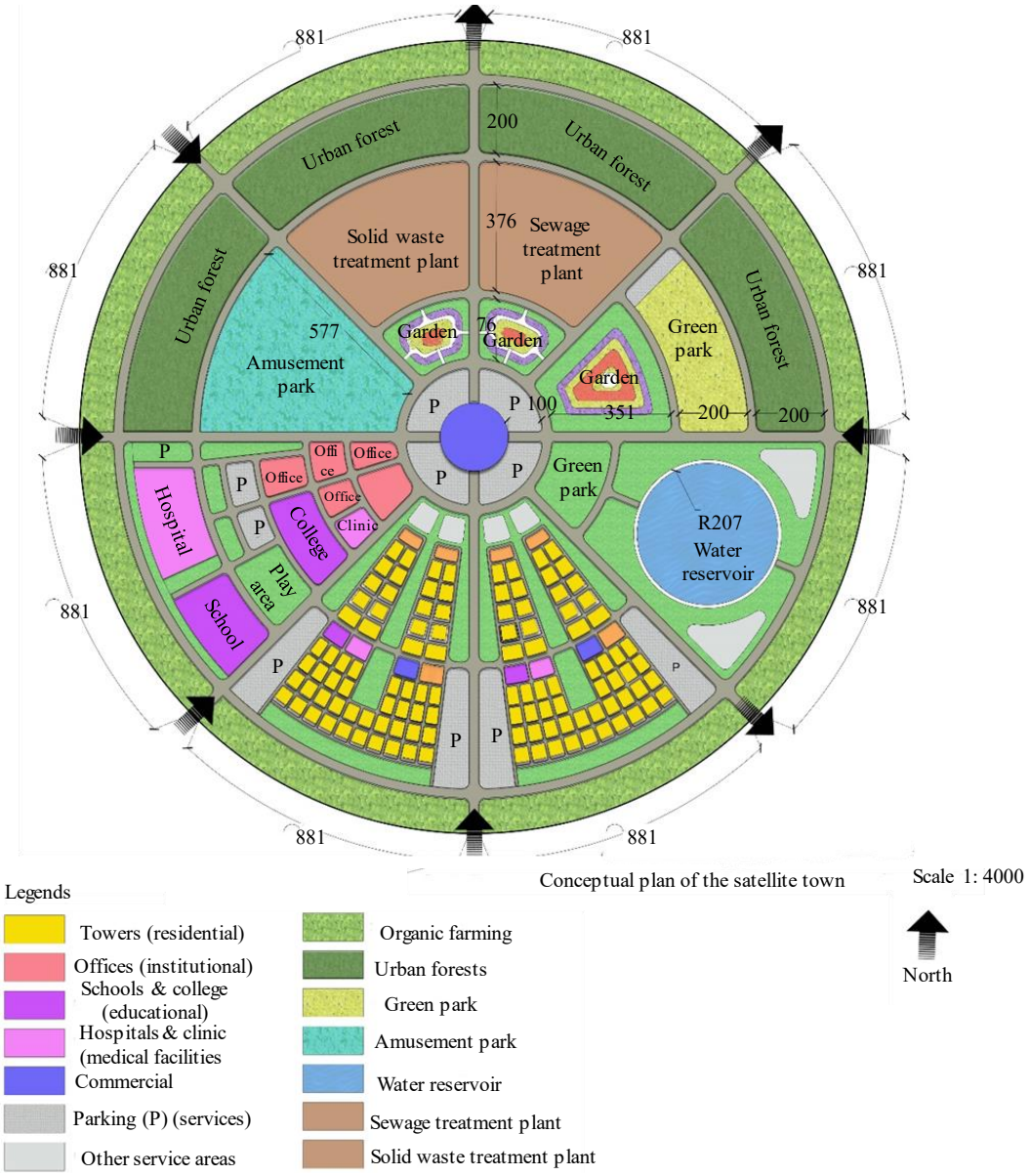

Figure 13. Showing the layout plan of satellite town.

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CONCLUSION

The present research work is oriented towards integrated approach of designing a satellite town while infusing concepts of different environmental parameters, pollution free, circular economy coupled with sustainability.

Adequate open space has been kept by adopting the WHO ideal criteria of 50 m^2/per person and 60:40 as ratio of open to concrete area. Special emphasis has been laid on transformation of waste into value added products like energy, fuel pallets, biogas and compost and application of treated sewage for raising the urban forestry and green infrastructure. The satellite town is designed to infuse the concepts of adequate urban air ventilation, urban heat island effect, environmentally compatible zoning, and optimization of concreting to non-concreting urban surface area coupled with vertical to horizontal spread of the town. The entire satellite town is designed to have an effective rainwater conservation mechanism by providing storm water drains and collecting the rainwater in a big reservoir. This reservoir is designed to have boating facilities, walk away all around the periphery of reservoir, aquatic species to clean the water in the reservoir, and other tourist attraction tools. Such a reservoir would not only be able to cater the demand of drinking water and other usage but will also encourage the infusion of circular economy thereby providing sustainability.

The satellite town under reference is designed to have effective urban forestry in place where green infrastructure is designed, green roofs and buildings are designed, 50-m width green belt kept all around the periphery of satellite town, parks and gardens and green belt provided on both sides of road network. Such an infusion of urban forestry would be able act as a scavenging system to absorb air pollutants, noise, and odor along with providing cooling effect to take care of urban heat island effect, resulting in an increase in energy and water consumption. Such a designed system would not only facilitate carbon neutrality but will also provide a circular economy coupled with sustainability. The entire study under reference by the authors reflects circular economy by designing and putting in place water sports, water reservoir, commercial activities, toy trains, green buildings and roofs, adventure parks, and so forth, thereby having sustainability.

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