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Significance and Importance of Subterranean Architecture for Hot Climates in India

[*1]Ar. Syed Zain Mohammed and [2]Dr. Yashaswini Somashekar

[*1]Master in Architecture, Department of Urban Design, School of Planning and Architecture, University of Mysore, Mysore, Karnataka, India.

[2]Assistant Professor, Department of Urban Design, School of Planning and Architecture, University of Mysore, Mysore, Karnataka, India.

Abstract

In India's hot climate, subterranean architecture provides a creative and sustainable way to deal with the problems of resource scarcity, urbanization, and climate change. This design strategy makes use of the earth's natural thermal insulation qualities to produce energy-efficient areas that require fewer artificial cooling systems. Subterranean buildings reduce the effects of intense surface heat by using passive cooling strategies like natural ventilation and geothermal energy to maintain consistent interior temperatures.

This idea is especially pertinent to India, where environmental resources and urban infrastructure are under stress due to the country's dense population and high temperatures. Stepwells and haveli courtyards are examples of traditional architectural designs that can be combined with underground architecture to create contemporary public, commercial, and residential spaces. These designs use solar tubes, skylights, and biophilic components to improve natural lighting and psychological comfort, ensuring livable and aesthetically pleasing environments.

This allows us to investigate the planning and building of subterranean structures that combine environmental harmony with practicality. It makes use of the insulation and protection that the soil naturally provides to create sustainable and energy-efficient habitats. From commercial and residential spaces to cultural and military installations, the concepts and conceptual designs can be used for a variety of reasons. Subterranean architecture tackles issues including scarce land, severe weather, and urban overpopulation by fusing cutting-edge engineering methods with aesthetic concerns. It is a developing trend in sustainable development that might provide creative ways to maximize resilience and spatial efficiency while reducing environmental effect.

Keywords: Subterranean architecture, contour study, feasible design, urbanisation, a new vision for New Delhi, new India vision with subterranean architecture.

1. Introduction

In regions with extreme heat, traditional architectural methods often fall short of providing adequate comfort without relying heavily on energy-consuming technologies such as air conditioning. Subterranean architecture offers an alternative approach, leveraging the earth’s natural insulation properties to create spaces that maintain cooler temperatures even in hot climates. This paper examines the principles of subterranean architecture, its historical applications, and its potential as a sustainable solution for modern design challenges in hot climates. Drawing on case studies from arid regions, it evaluates how underground structures can optimize thermal comfort, reduce energy consumption, and foster sustainability. Furthermore, the paper explores the design considerations, material choices, and modern adaptations necessary to implement subterranean architecture effectively in the 21st century.

Climate change and the increasing prevalence of extreme weather conditions have made energy-efficient architecture more critical than ever. In hot climates, conventional above-ground buildings are vulnerable to overheating, necessitating the use of air conditioning systems that consume vast amounts of energy. This paper proposes that subterranean architecture offers a compelling alternative by taking advantage of the earth's natural temperature regulation to maintain comfortable indoor environments with minimal energy input.

2. Design Considerations for Subterranean Architecture in Hot Climates

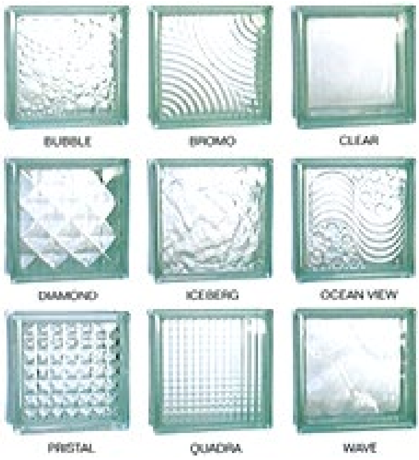
While subterranean architecture offers numerous advantages, it is not without its challenges.

Site Selection and Soil Conditions: Choosing the right location is crucial. The soil type, water table, and seismic activity of the site must be carefully evaluated to ensure stability and longevity. In hot climates, dry and compact soils are often preferred for their insulative properties.

Ventilation and Air Circulation: One of the potential drawbacks of subterranean spaces is poor air circulation, which can lead to issues like humidity buildup and poor indoor air quality. Designing an effective natural ventilation system is critical. This often involves integrating courtyards, light wells, or chimneys to allow fresh air to circulate while maintaining thermal insulation.

Water Management: Water infiltration and drainage are key concerns in subterranean architecture. In hot climates, while rainfall may be infrequent, the potential for flash flooding or water accumulation still exists. Designers must incorporate proper drainage systems and waterproofing techniques to prevent moisture from entering the structure.

Material Selection: Materials used in subterranean architecture should complement the thermal properties of the design. Earth-based materials like adobe, rammed earth, and stone are often favored for their thermal mass, which can further enhance the passive cooling effect. In modern applications, insulated concrete forms (ICFs) are also commonly used.



Source: *Glass Blocks*

Fig 1: Construction Material as Glass Bricks for Lighting.

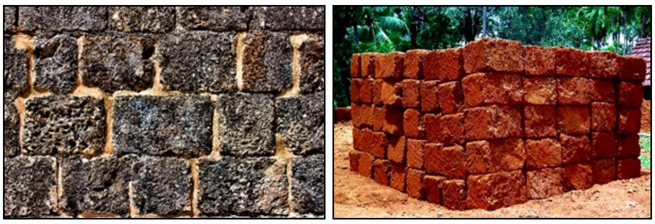
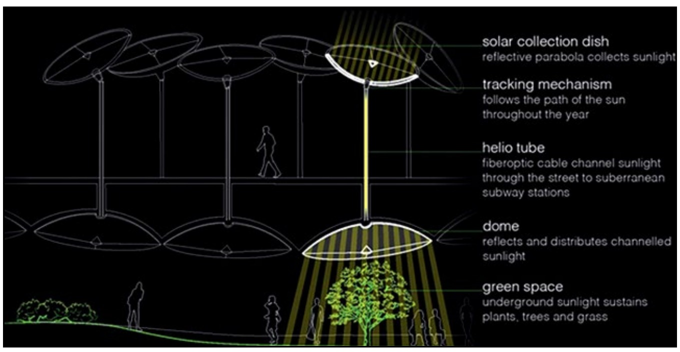


Fig 2: Construction Material as Natural Laterite Stone as a resource in India for thermal cooling.

Integration with the Landscape

Subterranean structures can be designed to seamlessly blend with the natural landscape. By minimizing visual disruption and reducing the building's ecological footprint, these structures can contribute to the preservation of the surrounding environment.



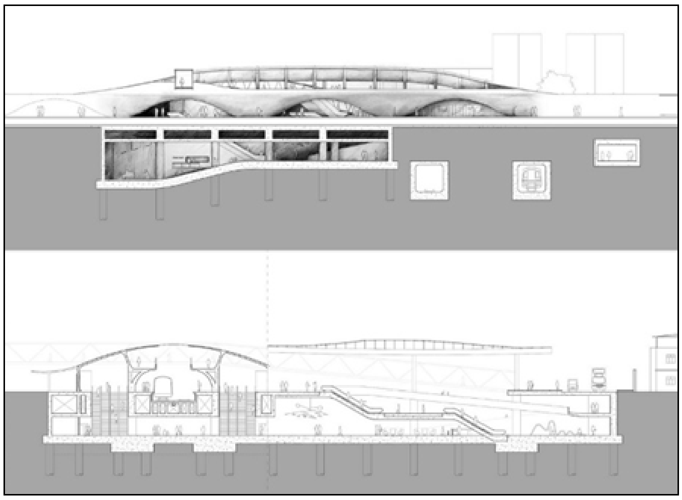
Source: *Ecosapien Project in New York.*

Fig 3: The Lowline Underground Park in New York.

3. Modern Applications and Potential for Sustainability

In the context of increasing global temperatures and the need for sustainable architecture, subterranean design offers significant potential. In addition to passive cooling, subterranean homes can reduce the urban heat island effect and promote biodiversity by preserving natural landscapes. With the development of new materials and construction techniques, the challenges of air circulation and moisture management can be overcome, making subterranean architecture a viable solution for modern cities in hot climates.

Moreover, subterranean architecture can contribute to *Net-Zero Energy Buildings (NZEB)* by minimizing energy use and maximizing natural temperature regulation. By integrating modern renewable energy systems such as geothermal heating and cooling, photovoltaic panels, and green roofs, subterranean structures can significantly lower their carbon footprint.



Source: *Presidents Medals Art in City*

Fig 4: Sectional Illustration along the Platform for Kowloon Tong Interchange & Tate Museum by Yvonne Lo
Article source: www.presidentsmedals.com

Subterranean architecture, rooted in ancient traditions, offers a sustainable and energy-efficient alternative for construction in hot climates. By leveraging the natural thermal properties of the earth, these structures can maintain comfortable indoor environments with minimal reliance on mechanical cooling systems. As climate change continues to pose challenges for urban design, subterranean architecture has the potential to play a crucial role in reducing energy consumption, lowering carbon emissions, and creating resilient, sustainable communities.

For future research and application, it is essential to explore innovations in materials, construction techniques, and ventilation systems that can address the unique challenges of subterranean architecture, making it an even more practical solution for widespread use in hot climates.

Subterranean architecture for hot climates is a fascinating area of study, especially when focusing on passive cooling strategies and how underground spaces can moderate extreme temperatures. Here's how you might approach such a thesis, including potential key sections and topics that can be explore,

Subterranean structures naturally reduce heat gain because their exposure to sunlight is minimized. However, in hot climates, south-facing openings can allow for controlled solar gain during winter months when passive heating is desired.

Earth Berming (placing earth around the exterior of the building) can provide both insulation and protection from solar radiation.

In hot climates, water management is crucial. Underground homes can integrate water recycling systems, rainwater harvesting, and even graywater systems to maintain a sustainable water supply.

Green roofs on subterranean or semi-subterranean buildings can enhance insulation, reduce heat island effects, and manage stormwater. In hot climates, careful plant selection can further aid in cooling.

Designing subterranean architecture for hot climates requires a deep understanding of how to leverage the earth's natural insulation, optimize passive cooling, and ensure comfort without relying on excessive mechanical systems.

By taking advantage of the temperature difference between subterranean and above-ground air, stack ventilation can be used to create airflow. Warm air rises and can be vented out through openings at higher elevations, while cooler air flows into the structure.

Integrate chimneys or solar chimneys that enhance stack effect by heating air within a vertical shaft, promoting upward airflow and drawing cooler air into the subterranean rooms.

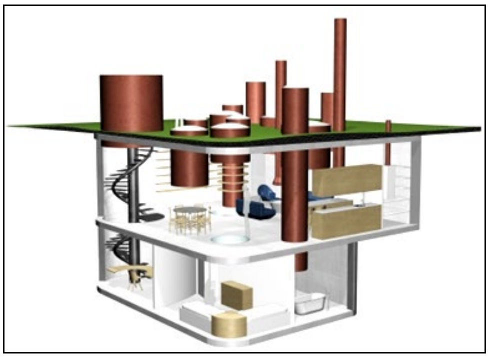
Stone, Adobe, and Concrete These materials can store heat during the day and release it slowly at night, helping to regulate temperature inside subterranean spaces. Thick walls made of these materials absorb excess heat during the day, keeping interiors cool. At night, the stored heat is slowly released, reducing temperature fluctuations. Incorporate high thermal mass materials into the walls and floors of subterranean structures to take full advantage of passive cooling and heating, reducing the need for active systems.

The design of subterranean architecture in hot climates hinges on harnessing the natural thermal properties of the earth, optimizing passive cooling strategies, and integrating modern sustainable technologies. From earth beaming and natural ventilation to light wells and green roofs, these strategies reduce the building's dependence on mechanical systems while ensuring comfort in extreme temperatures. The key is to balance traditional passive methods with contemporary technologies to create spaces that are both energy-efficient and comfortable year-round.

4. Passive Cooling Systems in Subterranean Architecture for Hot Climates

Passive cooling systems are critical in subterranean architecture, especially in hot climates where energy-efficient, sustainable cooling is a priority. The concept revolves around maximizing natural processes like ventilation, thermal mass, and evaporative cooling to maintain comfortable indoor temperatures without relying on mechanical systems. Here's a detailed look at various passive cooling strategies for subterranean architecture.

When buildings are constructed underground or partially buried, the surrounding earth acts as a natural insulator. The temperature a few meters below the surface is relatively stable, often cooler than the air temperature in hot climates. This thermal buffering significantly reduces temperature fluctuations inside the building. In most hot climates, the earth remains at a constant temperature of about 15°C to 20°C (59°F to 68°F), much cooler than surface temperatures. Subterranean structures can harness this stable environment to avoid the intense heat experienced above ground.



Source: *Office–Alireza Taghaboni + Dayastudio*

Fig 5: Sectional Illustration for conceptual Under Houses by French Architect Paul Coudamy Article source: Coudamy design.

Subterranean structures are not exposed to direct sunlight, which significantly reduces heat gain compared to above-ground buildings. This minimizes the need for cooling systems even during peak summer heat.

In subterranean architecture, passive cooling systems play a central role in ensuring thermal comfort, especially in hot climates. By harnessing the earth's natural insulating properties, leveraging thermal mass, promoting airflow through stack and cross ventilation, and incorporating evaporative cooling features, subterranean structures can achieve comfortable indoor temperatures with minimal reliance on mechanical systems. Integrating these passive techniques not only reduces energy consumption but also aligns with sustainable, climate-responsive design principles.

4.1. Earth as a Natural Insulator and Thermal Mass

Insulating Properties of Soil: When buildings are constructed underground or partially buried, the surrounding earth acts as a natural insulator. The temperature a few meters below the surface is relatively stable, often cooler than the air temperature in hot climates. This thermal buffering significantly reduces temperature fluctuations inside the building.

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Thermal Mass: High thermal mass materials (like stone, concrete, or adobe) absorb heat during the day and release it slowly at night. In subterranean architecture, the earth itself serves as a massive thermal mass, absorbing excess heat and releasing it when the surrounding air cools.

The thermal mass of the earth moderates indoor temperatures, keeping them cooler during the day and preventing overheating by dissipating the stored heat overnight. This ensures a more consistent and comfortable indoor climate throughout the day and night.

4.2. Natural Ventilation and Airflow

Stack Ventilation: Stack ventilation relies on the principle that hot air rises. When warm air is allowed to escape through high openings or vents, cooler air is drawn in through lower openings, creating a natural airflow. This can be particularly effective in subterranean buildings where cooler air from the ground level is pulled into the interior spaces.

Subterranean homes can incorporate vertical ventilation shafts or solar chimneys to enhance the stack effect, drawing cooler air from shaded or underground spaces.

Cross Ventilation: Cross ventilation involves placing openings on opposite sides of a space to allow air to flow freely from one side to the other, flushing out warm air and bringing in cooler air.

Subterranean buildings can be designed to take advantage of prevailing winds. Openings should be positioned in alignment with the dominant wind direction to enhance the natural cooling effect.

Rooms and corridors should be arranged to facilitate the movement of air from cooler exterior spaces through the interior.

In subterranean courtyards, wind can be captured and funneled into living spaces, cooling the interior without mechanical systems.

Windcatchers (Badgirs): Windcatchers or badgirs, are a traditional Persian passive cooling method used for centuries in desert climates. These tall towers capture cooler wind at higher elevations and channel it down into subterranean spaces. As the cool air enters, it displaces warm air, which exits through another vent.

Modern Integration Windcatchers can be combined with subterranean architecture to enhance airflow and cooling. By positioning the structure to capture prevailing winds, they can provide continuous air circulation.

Subterranean homes in places like Yazd, Iran, utilize windcatchers in conjunction with qanat water channels to cool the air before it enters the living spaces.

5. Evaporative Cooling in Subterranean Spaces

Water Features for Cooling: Evaporative cooling occurs when warm air passes over a water surface and evaporates, lowering the temperature of the air. In hot and dry climates, incorporating water bodies like pools, fountains, or underground streams can help cool the surrounding air.

Integrating shallow pools or reflective water surfaces in central courtyards or atriums within the subterranean structure can cool the air before it enters the living spaces.

Air channels that run over water or through moist, shaded areas can provide a cooling effect when the air is funneled into the building.

The qanat systems in Iran, where underground water channels are used in combination with wind towers to cool the air, serve as a prime example of how evaporative cooling can be integrated into subterranean architecture.

Humidity Control: While evaporative cooling is effective in hot, dry climates, it increases humidity. In subterranean spaces, it's important to ensure that moisture is controlled to prevent dampness and mold growth.

Evaporative cooling systems should be paired with effective ventilation to manage moisture levels and prevent air stagnation.

Subterranean courtyards with water features could include open ventilation shafts to ensure a continuous exchange of air, keeping humidity at manageable levels.

Light Wells for Daylighting and Cooling: Vertical shafts that bring natural light into subterranean spaces can also contribute to passive cooling. By allowing sunlight in during cooler parts of the day, light wells can reduce the need for artificial lighting while maintaining a comfortable indoor temperature.

Light wells can also serve as ventilation shafts, allowing warm air to rise and escape while cooler air is drawn into the subterranean space.

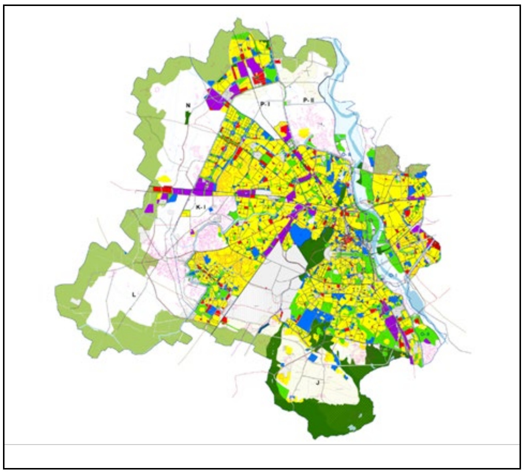
Light wells should be strategically placed in shaded or partially shaded areas to minimize excessive heat gain. Reflective materials can be used within the light well to direct light without increasing temperatures.

Implementation of Subterranean Architecture in India a Case Study on Delhi

6. Introduction to the Precinct

Delhi experiences hot summers from April to June, with temperatures sometimes reaching 45°C. The monsoon season runs from July to September, bringing high humidity and heavy rainfall. Autumn from October to November is warm and dry. Winters from December to February can be cold, with temperatures dropping below 0°C at times. Spring from March brings warmer weather. The climate greatly affects shelter structures, with flat roofs and heat-reflecting walls being common.

Implementing subterranean (underground) architecture in Delhi could be a strategic solution to the city's many challenges, such as population density, space constraints, extreme weather, and environmental sustainability. Underground spaces can provide cooler, more stable environments, reduce land usage, and present unique opportunities for energy-efficient building. Here's a look at key considerations, challenges, and potential applications for subterranean architecture in Delhi.



Source: *Zoning & Land use Maps of Delhi*

Fig 6: Zoning

Fig 7: Land use Maps of Delhi

7. Demographic Trends

Delhi is one of the fastest growing cities in the country. Due to rapid pace of urbanization, the landscape of Delhi has undergone a change from a rural majority to urban. The rural to urban area change during the last three censuses in Delhi is depicted in the below table.

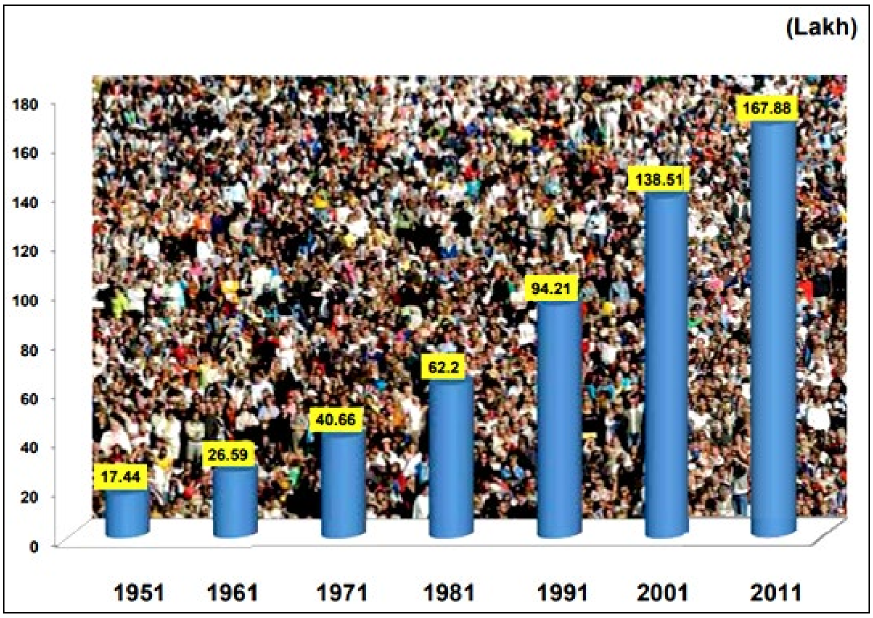
Table 1: Area-rural and urban

S. No.	Classification of Area	1991		2001		2011	
		Km²	%	Km²	%	Km2	%
1.	Rural	797.66	53.79	558.32	37.65	369.35	24.90
2.	Urban	685.34	46.21	924.68	62.35	1113.65	75.1
3.	Total	1483.00	100.00	1483.00	100.00	1483.00	100.00

Source: *Census of India, 1991, 2001 & 2011*

The growth in the urban area during 2001-2011 was observed at 20.44 percent. This pace of urbanization has reduced the number of villages in Delhi from 300 in 1961 to 165 in 2001 and 112 in 2011. The number of urbanized villages has increased from 20 in 1961 to 135 in 2011. The number of census towns has increased from 3 in 1971 to 29 in 1991 and 110 in 2011. Thus, more and more rural villages of Delhi are being declared as census towns in each successive Census, resulting in decreasing rural population and rural areas in Delhi.

8. Population



Source: *Census of India 1991, 2001, 2011*

Fig 8: Population Density Analysis from 1951 to 2011 for Delhi, India.

The Population Census is the only source providing comprehensive data on population characteristics carried out decennially by the Govt. of India in collaboration with states. The first synchronous census in India was held in 1881. The latest census, 15th in the series, was conducted in 2011.As per this census, the population of Delhi, as of 1st March, 2011, was 16.78 million as against 13.85 million on 1st March, 2001. According to Census 2011, about 97.50 per cent of the population of Delhi lives in urban areas and the remaining 2.5 percent in rural areas. This urban population includes the population of 110 census towns in the 2011 Census. As per the Revenue Department record, these census towns are located in the rural area of Delhi and they are not a part of the notified urban area of Delhi.

8.1. Household Size

The number of persons living together in one house is commonly called household size. As per 2011 Census, there were 3340538 households in Delhi. The average size of a household in Delhi was found to be 5.02. It indicates that in one house, there are more than five persons. More than one half of the households had more than five members during the year 2011. The distribution of households by size in Delhi in 2001 and 2011 are presented in the table below.

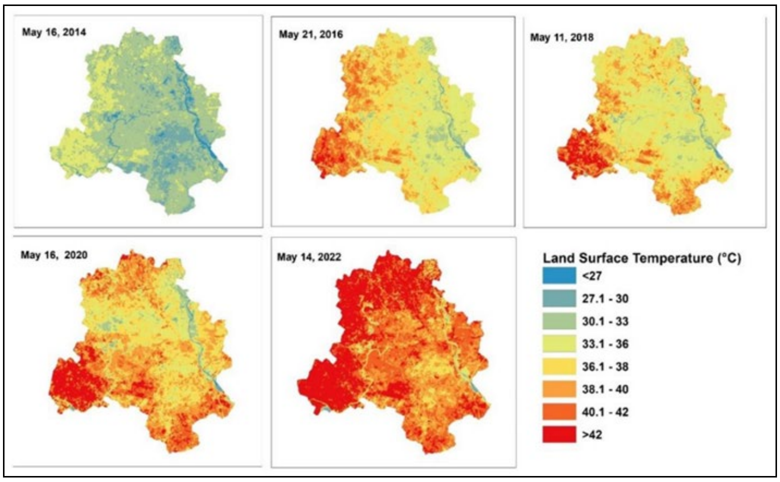
Table 2: Distribution of households by size in Delhi-2001 & 2011

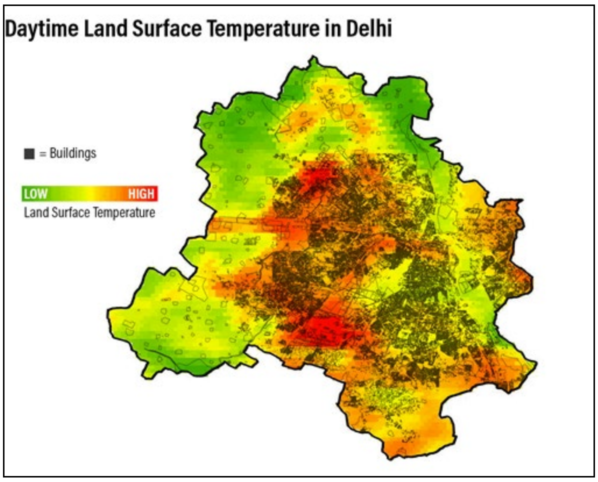
S. No.	Size of Household	No. of Household	Per cent of total No. of Household		
		2001	2011	2001	2011
1.	One member	99786	123106	3.90	3.70
2.	Two members	206925	252370	8.10	7.60
3.	Three members	295216	428403	11.56	12.80
4.	Four Members	544289	803065	21.31	24.00
5.	Five Members	506711	681142	19.84	20.40
6.	Six to Eight Members	680065	853773	26.63	25.60
7.	Nine or more members	221157	198679	8.66	5.90
8.	Total Households	2554149	3340538	100.00	100.00

Source: *Census of India 1991, 2001 & 2011*

8.2. Climate & Temperature

Delhi's subtropical semi-arid climate with extreme temperatures, high pollution levels, and seasonal variations, architectural designs must prioritize thermal comfort, sustainability, and resilience.





Source: *CSE analysis of Landsat 8 satellite image from USGS Earth Explorer website for 2014, 2016, 2018, 2020 & 2022*

Fig 9: Representation of Temperature in Delhi from 2014 to 2022 **Fig 10:** Representation of Day Time Temperature in Delhi, India

Climatic Challenges

Extreme Temperatures

- Summers often exceed 45°C (113°F), causing heat stress.
- Winters can drop below 5°C (41°F), with dense fog reducing visibility.

Air Pollution

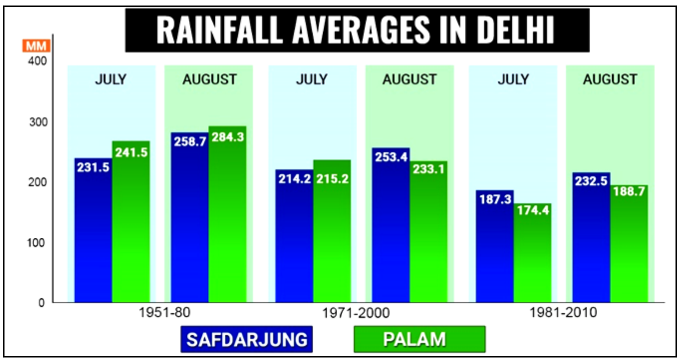
- Among the most polluted cities in the world.
- Pollution peaks in winter due to crop residue burning, industrial emissions, and vehicular pollution.

Urban Heat Island Effect

- The dense urbanization exacerbates heat stress, especially during summer.

Water Scarcity and Flooding

- Over-reliance on monsoon rains leads to water shortages in dry months.
- Heavy monsoon rains can overwhelm drainage systems, causing flooding.

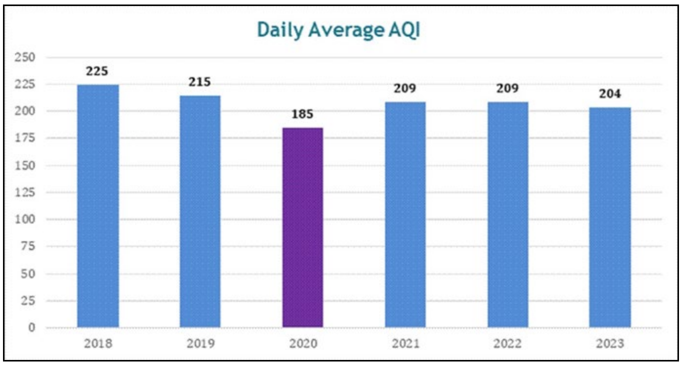


Source: *DNA India, Skymetweather*

Fig 11: Representation of Rainfall in Delhi from 1951 to 2010.

Table 3: Air Quality Index

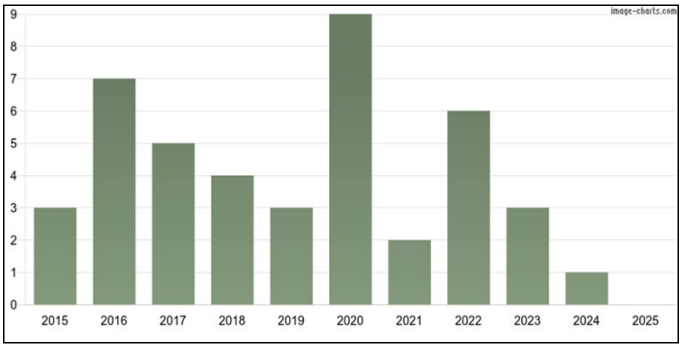
Year	2018	2019	2020	2021	2022	2023
Daily Avg. AQI	225	215	185	209	209	204



Source: *Gov Press Release frame page*

Fig 12: Analytics of Rainfall during 2018 to 2023 in Delhi

Seismic Activities



Source: *Earthquake List*

Fig 13: Analytics showing the Earthquake report of nearing states to Delhi, India

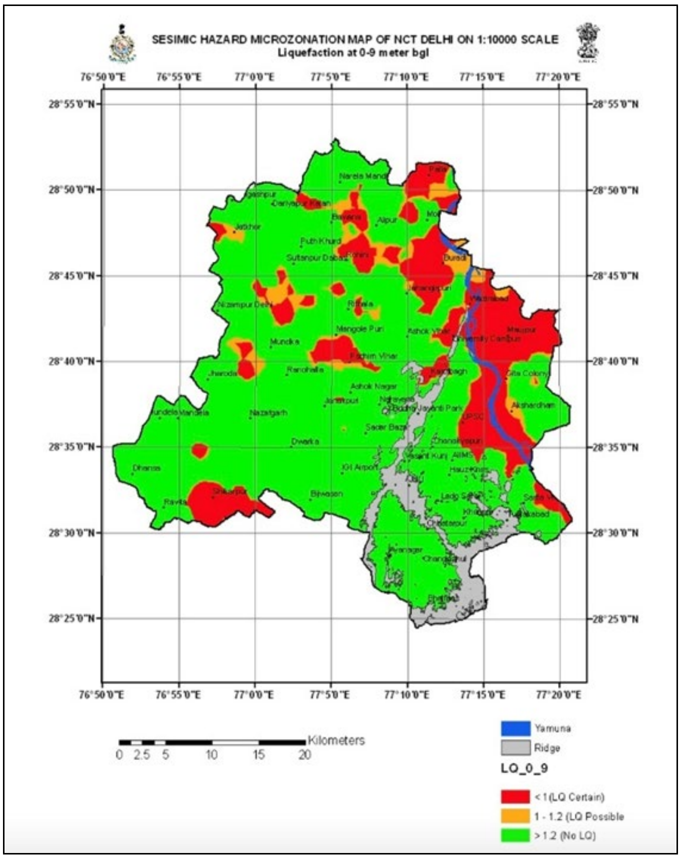


Fig 14: Seismic Hazard Micronization Map of Delhi, India.

The table below visualizes the distribution of all earthquakes that occurred within 300km of Delhi in the past 10 years. No earthquakes with a magnitude of 6 or above have occurred near Delhi during this time. Usually, higher magnitudes are less common than lower magnitudes. Small earthquakes with a magnitude below 4 on the Richter scale have been omitted from this overview.

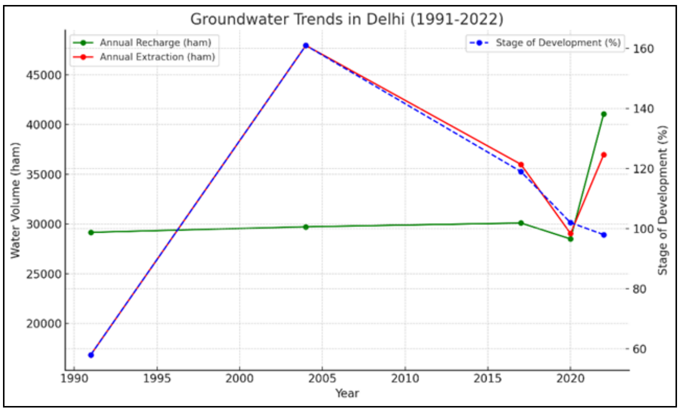
Water Table

The graph above illustrates the groundwater trends in Delhi from 1991 to 2022. It includes:

Annual Recharge (green line): Represents the volume of water naturally replenished.

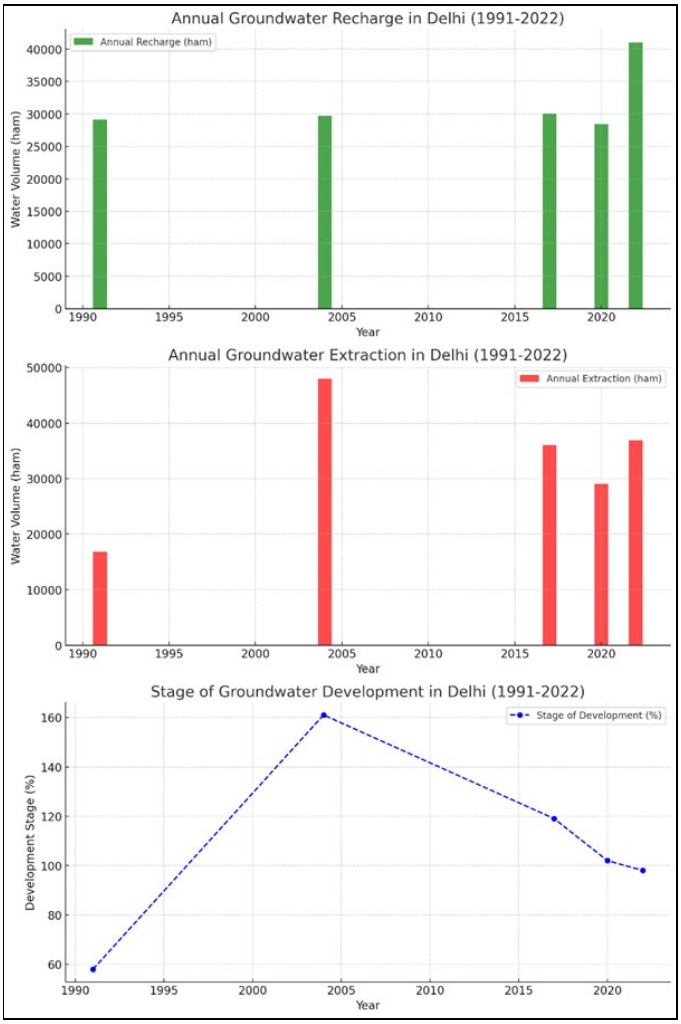
Annual Extraction (red line): Shows the volume of water extracted.

Stage of Development (blue dashed line): Indicates the percentage of groundwater extraction relative to recharge, providing insight into sustainability.



Source: *Delhi Jal Board.*

Fig 15: Line graph showing Water Table from 1990 to 2020 for Delhi, India.



Source: *Delhijalboard.*

Fig 16: Analytics of Groundwater Recharge from 1990 to 2020 in Delhi, India.

9. Vision for "Underground Delhi"

This subterranean concept can transform Delhi into a futuristic, sustainable, and livable megacity. By integrating modern design, sustainability, and cultural sensitivity, "Underground Delhi" offers a blueprint for addressing the challenges of urbanization while preserving the city's historical essence and environmental resources.

Expanding the "Underground Delhi" concept can incorporate additional elements that cater to the city's growing needs and challenges while enhancing urban functionality and livability.

9.1. Underground Eco-Districts

Develop **self-contained eco-districts** underground, designed as live-work-play environments. These districts can include:

Residential Quarters: Modern apartments with natural lighting systems (skylights, solar tubes) and vertical gardens for oxygenation and aesthetics.

Commercial Hubs: Underground shopping streets, restaurants, and co-working spaces designed with vibrant interiors to promote psychological well-being.

Community Amenities: Schools, fitness centers, clinics, and daycare facilities integrated into subterranean spaces for convenience.

These eco-districts can be powered by renewable energy, incorporate zero-waste systems, and have state-of-the-art water recycling plants, reducing the environmental footprint.

9.2. Underground Transportation Expansion

Delhi's population relies heavily on public transport, and subterranean architecture can significantly expand this infrastructure:

High-Speed Transit Corridors: Dedicated underground routes for **high-speed trains** connecting Delhi with NCR regions such as Gurgaon, Noida, and Ghaziabad, reducing surface congestion.

Integrated Multimodal Terminals: Spaces where metro, bus, auto-rickshaws, and electric vehicles converge. For instance, beneath busy hubs like Sarai Kale Khan or ISBT Kashmere Gate, reducing the strain on surface traffic.

9.3. Climate-Controlled Subterranean Markets

Building on the concept of traditional Indian bazaars, subterranean markets can be developed in areas like Chandni Chowk or Lajpat Nagar. Features could include:

Central Cooling Systems: Maintaining comfortable temperatures year-round.

Artisan Zones: Dedicated spaces for local craftspeople to promote Delhi's traditional arts and crafts.

Food Courts: Offering a mix of street food and fine dining in controlled environments, free from pollution.

9.4. Advanced Water Management Systems

Delhi faces significant water challenges, including scarcity and urban flooding. Subterranean architecture can address these through:

Rainwater Harvesting Reservoirs: Large underground tanks to store rainwater during the monsoon season, which can then be purified and used for drinking, agriculture, or industrial purposes.

Floodwater Redirection Channels: Underground flood tunnels and reservoirs can divert excess monsoon water to prevent waterlogging in areas like **I.T.O.** and **Minto Bridge**.

Groundwater Recharge Systems: Percolation wells built into underground structures can replenish Delhi's depleting aquifers.

9.5. Subterranean Educational and Research Facilities

Establish cutting-edge underground educational and research campuses:

Universities and R&D Centers: Facilities for advanced research in areas like climate change, sustainable urban planning, and technology development.

Think Tanks and Innovation Hubs: These spaces can serve as incubators for start-ups focused on urban and environmental challenges.

Cultural Institutions: Underground archives, libraries, and museums for preserving Delhi's rich historical and literary heritage, designed to protect sensitive materials from environmental damage.

9.6. Underground Waste Management Facilities

Subterranean spaces can house waste processing and recycling plants, minimizing the environmental impact on surface areas:

Waste-to-Energy Plants: Use underground plants to convert organic waste into biogas or electricity.

Automated Waste Collection Systems: Pneumatic tubes beneath the city could transport waste directly to processing facilities, reducing the need for garbage trucks.

9.7. Subterranean Energy Solutions

To support Delhi's growing energy needs sustainably:

Geothermal Power Stations: Underground geothermal facilities to generate clean energy.

Battery Storage Facilities: Large-scale subterranean battery systems to store renewable energy, like solar or wind, for use during peak demand.

Underground Power Grids: Minimized surface disruption and enhanced safety against extreme weather events.

9.8. Subterranean Smart Cities

Integrate Delhi's underground infrastructure into a smart city framework, leveraging IoT and AI technologies:

Smart Monitoring Systems: Sensors for air quality, temperature, water levels, and seismic activity in underground spaces.

Dynamic Ventilation Systems: Adjust airflow and filtration based on real-time pollution or CO2 levels.

Wayfinding and Navigation: Digital signages and augmented reality (AR)-based navigation systems to help people move through complex underground networks.

10. Subterranean Architecture as a Concept for Delhi: "Underground Delhi"

The concept "Underground Delhi" envisions a multi-layered subterranean infrastructure that integrates seamlessly with the city's existing fabric. This proposal leverages the benefits of underground architecture to address Delhi's challenges like urban congestion, heat, pollution, and sustainability, while preserving its rich cultural heritage and green spaces.

Potential Benefits of Subterranean Architecture in Delhi

10.1. **Climate Resilience & Space Efficiency:** Delhi experiences extreme heat in summer and cooler winters. Underground structures are naturally insulated, providing a stable internal temperature that reduces the need for heating or cooling.
As the capital city, Delhi has limited land area, and subterranean architecture could offer a way to build more without occupying the already scarce surface space.

10.2. **Reduced Urban Heat Island Effect Enhanced Energy Efficiency:** By moving some buildings and infrastructure underground, there is potential to reduce the urban heat island effect caused by large above-ground structures and paved areas.
Underground spaces are better insulated from external temperatures, which can significantly reduce energy use for climate control, making subterranean architecture environmentally friendly.

10.3. **Multi-Tiered Subterranean Zones:** The concept divides the underground space into functional zones to optimize use and minimize disruption:

- **Top Layer (0-10 meters below ground):** Retail spaces like underground shopping malls and markets.
  Pedestrian pathways and cycling tracks connecting major hubs.
  Small-scale public facilities such as libraries, co-working spaces, and cafes.
- **Middle Layer (10-30 meters below ground):**

Source: *AI gen Images by Author*

Fig 17: AI generated image showing underground facilities, compiled by the Author

Transportation infrastructure, including metro extensions, underground bus terminals, and parking lots.
Utility corridors for water, gas, electricity, and broadband cables.
Cultural and recreational spaces like underground museums, art galleries, and performance venues.

- **Deep Layer (30-50 Meters Below Ground):**

Data centers and high-tech hubs benefiting from cooler underground temperatures.
Emergency shelters and storage spaces.
Subterranean reservoirs for water conservation and rainwater harvesting.

Fig 18: AI generated image showing proposed underground facilities, compiled by the Author.

Source: *AI gen Images by Author*

Fig 19: AI generated image showing Sectional underground facilities, compiled by the Author.

10.4. Energy-Efficient and Sustainable Design

Geothermal Heating and Cooling: Utilize the Earth's stable underground temperature to regulate indoor conditions, reducing energy consumption.
Solar Tubes and Light Wells: Harness sunlight and direct it into subterranean spaces, creating well-lit and vibrant environments without relying entirely on artificial lighting.
Green Roofs and Terraces above Ground: Maintain greenery at the surface level while providing insulation to underground spaces.

10.5. Cultural Integration

Preservation of Heritage Sites: Subterranean structures will avoid heritage zones like Old Delhi's monuments, ensuring that the city's history is preserved.
Design Inspired by Local Aesthetics: Use Mughal-inspired geometric patterns, arches, and natural materials to blend tradition with modernity in underground spaces.
Interactive Spaces: Underground museums and galleries could showcase Delhi's history, art, and culture, creating immersive educational experiences.

Fig 20: Conceptual Design for Urban Underground Project by Maquinnext Architects, Spain

Source: *Maquinnext development Project*

Fig 21: Conceptual Design balancing Nature and Built for Urban Underground Project by Maquinnext Architects, Spain

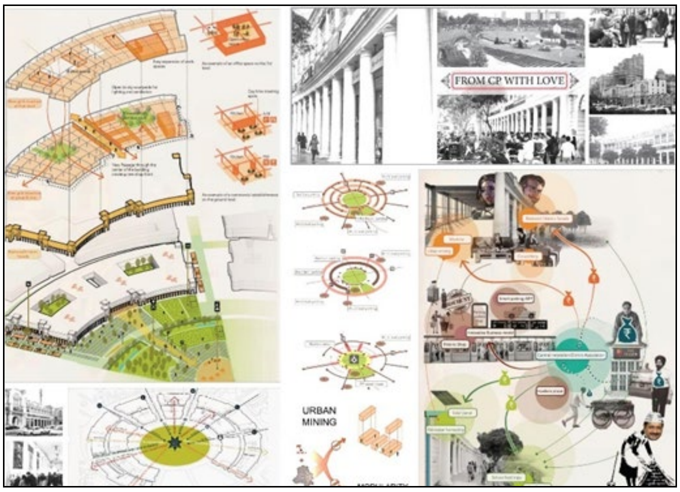
10.6. Climate Resilience

Flood Management Systems: Integrate underground floodwater channels and reservoirs to prevent waterlogging during monsoons and manage groundwater recharge.
Pollution-Free Zones: Subterranean spaces with advanced air filtration and ventilation can provide refuge from Delhi's poor air quality during peak pollution periods.
Urban Heat Island Mitigation: By relocating heat-producing infrastructure underground, the surface temperature of the city can be reduced.

10.7. Applications and Examples

Underground Urban Mobility Hub

A multi-modal transit center near **Connaught Place**, where metro, buses, and pedestrian pathways intersect. The hub could include underground parking, shops, and eateries, easing surface congestion.



Source: *Building Delhi's Future by Anjali Singh*

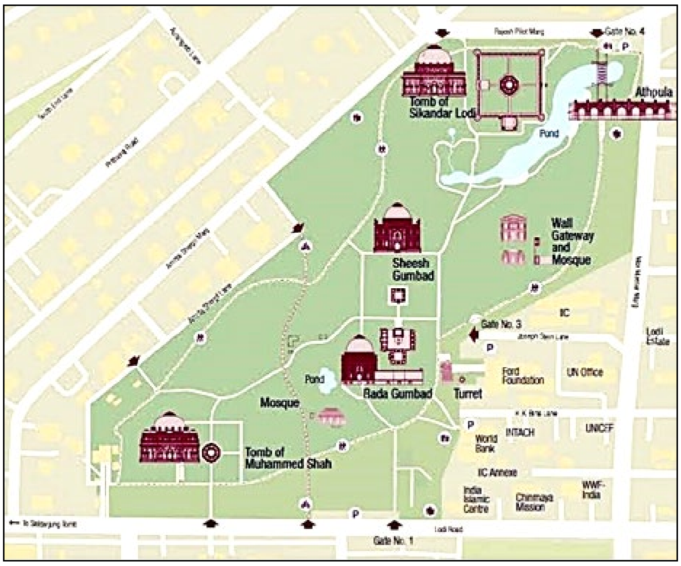
Fig 22: Award winning Conceptual Design for Cannaught place in Delhi, India.

Source: *Building Delhi's Future by Woobin*

Fig 23: Award winning Conceptual Design for Cannaught place in Delhi, India.

Underground Cultural Corridor

Create a cultural corridor beneath Lodhi Gardens, connecting it to an underground art museum and auditorium. These spaces would celebrate Delhi's rich history while minimizing environmental disruption.



Source: *Wordpress by Amanjul*

Fig 24: Imagery showing thehistorical importance, their impact on the development of the Indo Islamic Architecture and their role in many different eras of Delhi, India.

Source: *Conceptual by Oasis Designs Architects*

Fig 25: Conceptual design proposed for LODHI ROAD & LALA LAJPAT RAI ROAD JUNCTION by Oasis Design Inc, New Delhi, India.

Subterranean Green Parks

Develop underground green parks with skylights in areas like Nehru Place, where open recreational spaces are limited. These parks could double as flood shelters during emergencies.

Sustainable Housing Solutions

In densely populated areas like Karol Bagh, partially subterranean residential complexes can be built to reduce the pressure on surface land while maintaining access to natural light through courtyards and skylights.

Source: *Master Plan SNC Realty*

Fig 26: Conceptual Site Plan for Fairfox EON Karol Bagh in Delhi by SMC Real Estate Advisors Noida, India.

Source: *Conceptual View SNC Realty*

Fig 27: Conceptual view for Fairfox EON Karol Bagh in Delhi by SMC Real Estate Advisors Noida, India.

11. Implementation: Zone-Wise Development

The implementation of "Underground Delhi" can proceed in stages, focusing on specific zones:

Phase 1: Pilot Projects in Key Areas

Connaught Place: A cultural and commercial subterranean hub, featuring shopping, parking, and underground pedestrian walkways.

Pragati Maidan: Expansion of convention centers and exhibition spaces underground, complementing above-ground infrastructure.

Phase 2: Expanding to Residential and Industrial Areas

South Delhi (Saket, Hauz Khas): Subterranean residential units and eco-districts.

East Delhi (Anand Vihar): Underground logistics hubs and transit-oriented developments.

Phase 3: Comprehensive Integration

Linking all subterranean zones with transportation corridors, utilities, and smart systems for seamless operation.

11.1. Design Considerations for Safety and Livability

Psychological Biophilic Design: Incorporate biophilic elements, such as green walls and water features, to enhance mental well-being in underground spaces.

Emergency Preparedness: Equip spaces with fireproof materials, multiple exits, and disaster evacuation protocols.

Accessibility: Ensure spaces are universally accessible with ramps, elevators, and tactile pathways for people with disabilities.

Biophilic and Green Elements

Vertical Gardens: Incorporate indoor and outdoor greenery to improve air quality and aesthetics.

Green Roofs: Design surface-level green roofs to mitigate the urban heat island effect and provide recreational spaces.

Natural Materials: Use local, sustainable materials such as stone, clay, or bamboo to blend with traditional Indian aesthetics.

11.2. Economic Impact and Opportunities

Job Creation: Subterranean construction and maintenance projects can generate thousands of jobs in engineering, design, and technology.

Revenue Generation: Underground markets, transit hubs, and eco-districts can drive economic growth by attracting businesses and tourism.

Cost Savings: Long-term savings through energy efficiency, reduced surface infrastructure wear-and-tear, and optimized land use.

12. Vision for a Sustainable Future

"Underground Delhi" represents a visionary approach to urban development, combining tradition with innovation. By embracing subterranean architecture, Delhi can evolve into a global model for sustainable urban living, balancing the pressures of rapid urbanization with environmental preservation and cultural heritage. This approach not only redefines how we think about city spaces but also prepares Delhi for a resilient and adaptive future.

Strategies in Design

Designing subterranean spaces in hot climates requires a thoughtful integration of environmental, cultural, and functional elements to maximize sustainability, livability, and efficiency. The following strategies can enhance a sustainable feasible design

Passive Design

Earth Sheltering: Utilize the insulating properties of soil to regulate temperatures naturally, reducing reliance on mechanical cooling.

Thermal Mass: Design thick walls and floors to store and release heat gradually, maintaining stable indoor temperatures.

Ventilation Shafts: Incorporate vertical shafts to enable stack ventilation, promoting airflow and reducing heat buildup.

Geothermal Energy: Implement ground-source heat pumps for efficient cooling and heating.

Focused Water Management

Wastewater Segregation and Collection

Separation of Streams: Segregate wastewater into blackwater (from toilets) and graywater (from sinks, showers, and washing machines).

Graywater can be treated and reused.

Blackwater requires advanced treatment.

Piping Networks: Design separate pipelines for graywater and blackwater, minimizing cross-contamination.

Graywater Recycling

Filtration Systems: Treat gray water using multi-stage filtration systems, including sand filters, activated carbon filters, and UV disinfection.

Use treated gray water for irrigation of green roofs, walls, and courtyards.

Employ it for non-potable uses like toilet flushing and cleaning.

On-Site Wastewater Treatment

Constructed Wetlands: Utilize vegetated wetlands as natural treatment systems to filter wastewater and improve water quality.

Decentralized Treatment Units: Compact systems for on-site treatment of wastewater, suitable for subterranean projects.

Sequential Batch Reactors: Flexible, automated systems ideal for treating varying wastewater loads efficiently.

Stormwater and Wastewater Integration

Combined Systems: Design systems to integrate stormwater with treated wastewater for recharge into underground aquifers.

Retention Basins: Use underground basins to store treated wastewater and rainwater for future use during dry seasons.

Energy Recovery

Biogas Generation: Convert organic waste in blackwater to biogas using anaerobic digesters, powering lighting or HVAC systems.

Heat Recovery: Extract heat from wastewater to preheat fresh water, reducing energy consumption.

Example Implementation Layout

Surface Level: Green spaces irrigated with treated graywater. Stormwater collection points.

Upper Subterranean Levels: Graywater recycling units integrated into service zones.

Middle Levels: Blackwater treatment plants with anaerobic digesters and bioreactors.

Lower Levels: Storage tanks for treated wastewater and biogas generation units.

Lighting Solutions

Solar Tubes: Install light tubes or fiber optics to channel natural sunlight into underground spaces.

Skylights: Design strategically placed skylights with shading devices to balance light and heat ingress.

LED and Biophilic Lighting: Use energy-efficient lighting that mimics natural daylight to enhance comfort and reduce energy usage.

Energy Efficiency

Renewable Energy Sources: Use solar panels on the surface to power underground spaces.

Energy Recovery Systems: Employ systems to recover and reuse waste heat or energy.

Efficient HVAC: Optimize heating, ventilation, and air conditioning systems with smart sensors and controls.

Integration with Nature

Green Roofs and Walls: Install vegetation on roofs or walls to improve thermal performance and air quality.

Underground Farming: Create hydroponic or aquaponic farming systems in subterranean spaces for food production.

Biodiversity Preservation: Design projects to minimize disruption to local flora and fauna, incorporating native species into landscaping.

Safety and Disaster Preparedness

Fire Safety: Use fire-resistant materials and design escape routes with fire suppression systems.

Structural Integrity: Incorporate advanced engineering techniques to withstand seismic activity and soil pressure.

Emergency Systems**:** Install robust communication, lighting, and evacuation systems.

Strategies for Conceptual Layout in Planning:

Surface Level: Green parks, community plazas, solar panels, and skylight installations.

Upper Subterranean Levels: Shopping centers, cultural hubs, restaurants, and green spaces with natural lighting.

Middle Levels: Office spaces, libraries, and recreational areas with geothermal cooling.

Deep Levels: Utility spaces, water reservoirs, data centers, and storage areas.

From the conceptual picture we can have a glance at the following

Cross-sectional layout showing levels and functional zones

Source: *AI generated by Author*

Fig 28: AI generated image showing Section for Water Treatment & Water Storage for underground facilities, compiled by the Author.

Ventilation and passive cooling systems.
Skylight and lighting integration.
Water management system, including rainwater harvesting and drainage.
Surface-level green integration with subterranean architecture.

Fig 29: AI generated image showing Sectional for Lighting for underground, compiled by the Author

Source: *AI generated by Author*

Fig 30: AI generated image showing Sectional for Lighting & Green spaces for underground, compiled by the Author.

13. Conclusion

Subterranean architecture offers a compelling solution to address the growing challenges of urbanization, climate change, and resource scarcity, particularly in regions with hot climates like Delhi and other parts of India. By leveraging the natural insulating properties of the earth, underground structures provide a sustainable alternative to traditional construction, reducing energy consumption for cooling and enhancing thermal comfort. This architectural approach also optimizes land use, preserves above-ground ecosystems, and minimizes urban sprawl.

Furthermore, integrating advanced technologies, such as passive cooling systems, renewable energy sources, and innovative water and wastewater management strategies, ensures the long-term viability of subterranean developments. Case studies from across the globe demonstrate the feasibility of such designs in varying contexts, emphasizing the importance of tailoring solutions to local climatic and cultural conditions.

However, the successful implementation of subterranean architecture requires addressing specific challenges, including high construction costs, public perception, and potential environmental impacts. Comprehensive planning, interdisciplinary collaboration, and community engagement are essential to overcome these hurdles and realize the full potential of underground spaces.

In conclusion, subterranean architecture is not just an innovative design strategy but a necessity for sustainable urban development. Future research should focus on refining construction techniques, assessing long-term impacts, and exploring new applications to fully integrate subterranean architecture into the urban fabric of modern cities.

14. Acknowledgement

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