

# UNDERGROUND SPACE DEVELOPMENT AS A CATALYST FOR URBAN GROWTH

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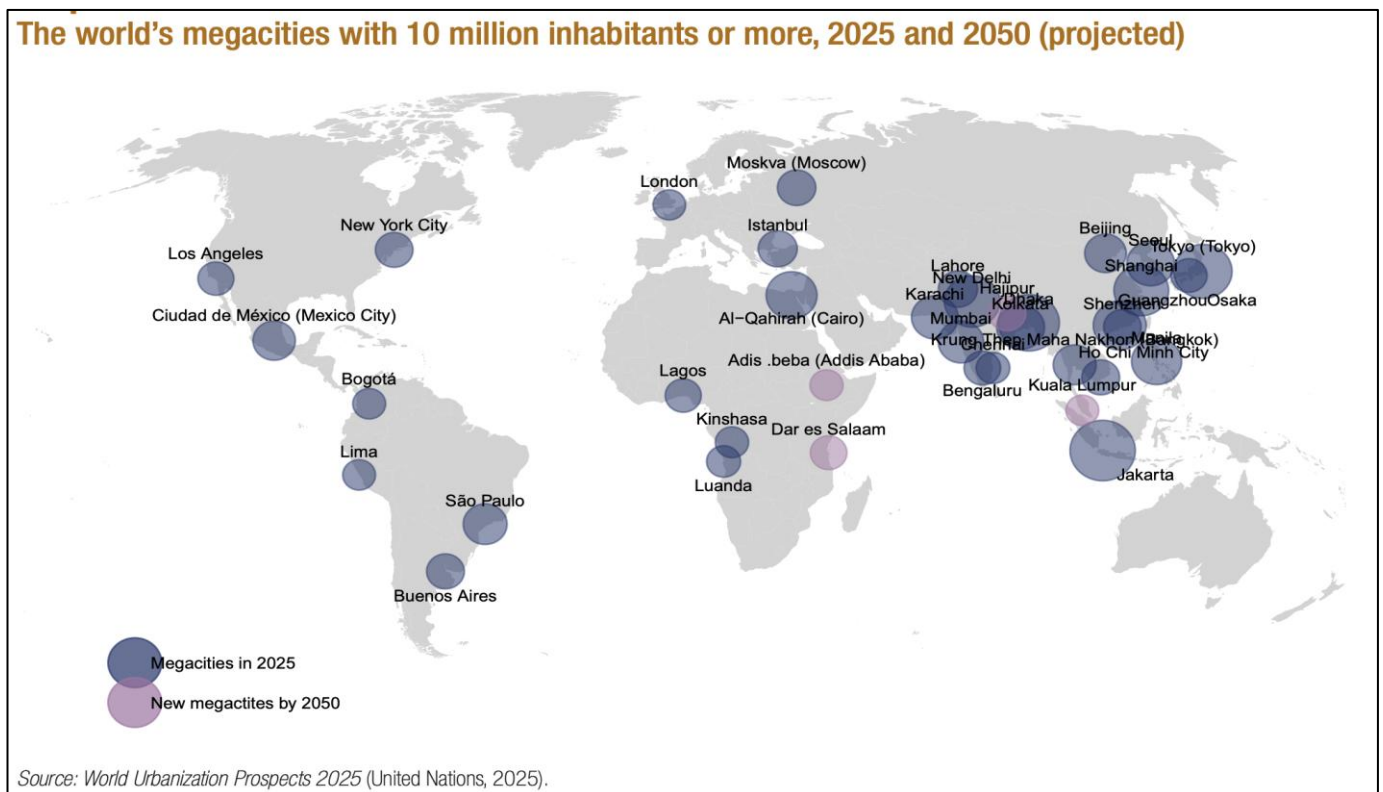
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**ABSTRACT:** As global urbanization accelerates and surface land becomes increasingly scarce, cities worldwide are recognizing underground space as a critical resource for sustainable development. This paper examines how strategic utilization of subsurface environments serves as a catalyst for urban growth, drawing on historical precedents, contemporary case studies, and emerging planning paradigms. The analysis demonstrates that underground space development, when properly integrated into comprehensive urban planning frameworks, can transform city structures, enhance economic vitality, improve environmental sustainability, and provide resilient infrastructure. However, success requires overcoming significant challenges including policy development, technological innovation, equity considerations, and interdisciplinary coordination.

## 1. INTRODUCTION: THE UNDERGROUND IMPERATIVE

### 1.1 THE URBAN CHALLENGE

The 21st century confronts humanity with unprecedented urban growth. By 2030, an estimated 60% of the global population will reside in urban areas, with over 100 cities surpassing five million inhabitants. In 2018, thirty-three megacities—each exceeding ten million residents—collectively housed more than 500 million people. This trend continues unabated, creating super megacities that strain existing infrastructure and consume limited surface space at alarming rates. Figure 1 shows a map of mega cities in 2025 and the expected growth by 2050.



diminishing surface availability, the logical solution lies beneath our feet, yet most cities lack comprehensive policies for underground space utilization as integral components of urban planning.

## 1.2 DEFINING UNDERGROUND SPACE

Urban underground space planning has rapidly evolved from experience-based approaches to evidence-based and data-driven methodologies, driven by needs for human-centric design, low-carbon development, enhanced resilience, and alignment with sustainable development goals. The subsurface represents what researchers increasingly call "the final frontier" of urban development, offering marked potential to address spatial problems, enhance sustainability, and build resilient cities.

## 2. TRANSIT DEVELOPMENT TRANSFORMATIVE POWER

### 2.1 SUCCESS STORIES

The New York City subway system provides compelling evidence of underground infrastructure's transformative power. At the end of the 19th century, New York's population concentrated in lower Manhattan within walking distance of local light industry and places of business, making it among the world's highest density cities due to geographic confinement. Between 1913 and 1940, massive subway construction—290 route km (180 route miles) including twelve bridge and subaqueous tunnel crossings—integrated Queens, Brooklyn, and the Bronx with Manhattan. Figure 2 shows the impact of Flushing Line on urban development in Queens in New York.



1917 Courtesy of NYC Transit – T. Jablonski



2025 Google Earth

Figure 2 – Urban development following the construction of the Flushing Line in New York

This underground expansion opened new lands for affordable, low-density housing for middle-class and working-class families while providing fast, convenient workplace access. Rural outer borough areas transformed into tree-lined boulevards with single and two-family homes, apartment houses, open parks, institutional facilities, and recreational areas. These transformations brought local commercial enterprises and industry, forming mini-societal areas within the larger metropolis. By 1940, when the initial system neared completion, New York's population reached approximately 7.5 million, similar to today's 8.5 million residents. The system provided connectivity and prosperity with over 5.5 million daily riders at its highest level in 2019. No one can imagine New York City without its subway system—it sustains the city's economic and physical vitality.

Research examining urban rail transit effects on city growth in forty Chinese cities demonstrates positive impacts on population, Gross Domestic Product (GDP), and employment rates. Similar examples worldwide illustrate subway systems' role in urban development and neighbourhood connectivity. Washington DC Metro, Toronto's subway system, London Underground, Seoul Metro, Hong Kong Subway, Beijing Metro, and the recent Paris Metro expansion have all catalysed successful urban development and economic growth. A recent study conducted by Dallas Rapid Transit concluded that

urban development within a ½ km (quarter of a mile) of a transit station would generate over \$18B in direct economic impact over the life of the facility.

## **2.2 LEARNING FROM FAILURES**

Not all underground transit stories succeed. Professors John Landis and Robert Cervero's in 1999 study "*BART and Urban Development*" revealed that the Bay Area Rapid Transit (BART) system achieved one major success—developing San Francisco's commercial hub maintaining its pre-eminence as the business and financial centre in Northern California—but missed opportunities in the metropolitan area, failing to trigger reinvestment in downtown Oakland, Berkeley, or Richmond. They concluded that rail transit benefits for urban development are not automatic but require collaboration among transit agencies, local governments, and private developers to overcome policy, design, and financing obstacles. Similar failures are also encountered in other cities when transit projects faced challenges by small businesses during and beyond construction, causing commercial displacement and altering neighbourhood commercial landscapes. These findings underscore that underground development's impact depends heavily on implementation proper planning, implementation strategies, community engagement, and supportive policies.

## **3. SUSTAINABILITY AND RESILIENCE BENEFITS**

### **3.1 ENVIRONMENTAL ADVANTAGES**

Underground space utilization offers substantial environmental benefits. Placing lesser facilities—parking, transportation, utilities, storage—underground frees surface land for higher purposes: residential, commercial, institutional, and recreational facilities including parks and green spaces. This multiuse approach enhances quality of life and provides environmental and economic benefits to users and society.

The underground space is inherently sustainable. It provides isolation from the elements reducing power consumption and carbon footprint. Natural thermal isolation by the surrounding earth provides uniform, moderate temperatures year-round, reducing climate control needs and associated costs and environmental impacts. Underground facilities improve air quality by removing vehicles from streets, reduce congestion, and minimize noise and vibration, creating better surface quality of life. Studies demonstrate that urban underground space presents a strategic approach for sustainable development, with significant carbon reduction potential through geothermal resources. The use of the underground space improves the local and global ecological cycle.

### **3.2 RESILIENCE AND LONGEVITY**

Underground facilities demonstrate superior resilience to natural disasters. Earthquakes, hurricanes, tornadoes, thunderstorms, and floods have lesser impact on subsurface structures protected from the elements. Seismic event impacts are far less severe—structural oscillation and amplification effects for underground structures substantially decrease compared to surface or above-surface structures.

Underground facilities prove more cost-effective considering life-cycle costs and triple bottom line analysis, as design life for all underground facilities exceeds 100 years. Many existing operating tunnels demonstrate this longevity—the Thames Tunnel in London was constructed in 1843, and the London Underground first opened in 1863.

## **4. UNDERGROUND SPACE AS THE THIRD DIMENSION IN URBAN PLANNING**

Underground space provides opportunities for better urban development through holistic planning that benefits from three-dimensional space integration above and below the surface. This creates opportunities for more efficient urban land use while developing less dense, more desirable surface environments with additional open spaces and outdoor recreational facilities.

For example, building an underground sports arena or shopping centre while developing the area above for outdoor recreation or green spaces allows multiple land uses. These developments often extend several levels below the surface with various functions at different depths—transit connections, underground parking, commercial levels, services, and connections to office buildings and adjoining developments. For example, Montreal's Underground City (La Ville Souterraine) exemplifies efficient

underground space use. See Figure 3. This network comprises 29 kilometres (18 miles) of tunnels and underground space spread over 12 square kilometres (3,000 acres), demonstrating how extensive subsurface development can enhance urban functionality while preserving surface environments.



Figure 3 – Montréal “Underground City.”



Figure 4 Utilidor in Amsterdam carries multiple utility lines SOURCE: Courtesy H. Admiraal.

Another efficient underground space application is utility corridors (utilidors), where various utility services are organized in planned underground spaces rather than placed arbitrarily by different utility owners. This prevents impacts on other utilities and surface traffic, businesses, and the public when repairs or replacements are needed. Amsterdam's utilidor system demonstrates this concept's effectiveness in reducing surface disruption and improving infrastructure coordination. See Figure 4.

## 5. INTERNATIONAL PLANNING APPROACHES

In recent decades, many major cities in the world started placing many of its facilities and urban services underground and developing real underground cities. But often not in an overall urban planning strategy. A report prepared by ITA/ITACUS/ISOCARP entitled “*Think Deep: Planning, development and use of underground space in cities*” addressed the needs and the challenges of integrating underground space planning with urban planning dealing with the third dimension of space planning. However, very few cities have adopted a comprehensive policy of underground space planning.

### 5.1 CHINA'S COMPREHENSIVE STRATEGY

China's urban underground space planning has evolved to encompass multiple development goals including sustainability, resilience, intelligence, and livability. Tianjin provides an exemplary case where accelerating urban development and underground space utilization entered rapid development stages. In 2004, the city conducted extensive research documented in “Comprehensive Utilization of Underground Space Planning in Tianjin Central City (2006-2020),” aligned with the City Urban Master Plan.

Underground space planning was prepared at macro, and micro levels corresponding to underground space use. The master plan distributes underground space in multiple layers—shallow (10m), middle (20m), and deep (30m)—with space allocations based on utilization for parking, services, utilities, commercial activities, and transportation. Underground space planning guidelines are used to incorporate underground space into the urban regulatory planning system, and to guide the urban construction as a basis for urban management. Currently, Tianjin's central city underground space construction area exceeds 15 million square meters, focusing on shallow and middle layers. Figure 5 shows underground space planning concept for Tianjin.

With nine subway lines totalling 470 kilometres (294 miles) completed, the city focuses on developing transportation urban hubs and public centres integrating surface planning with underground space utilization. This approach has been adopted by other Chinese cities including Beijing and Shanghai.

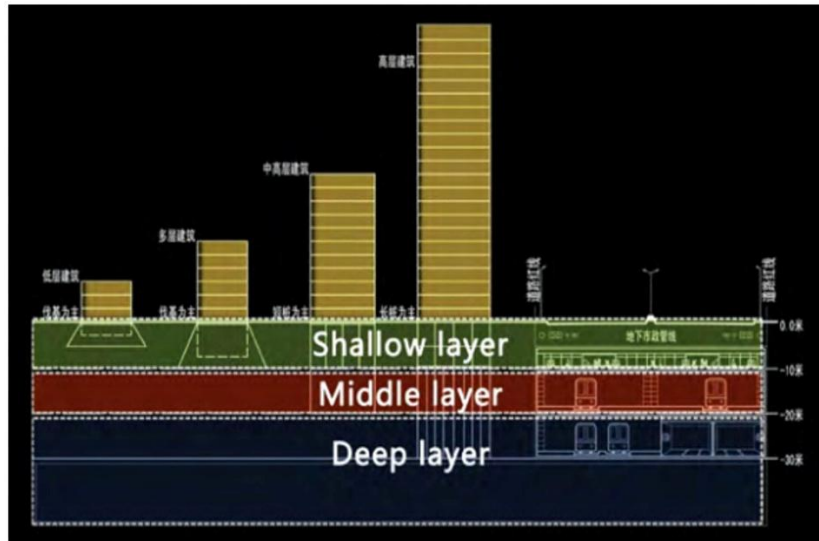


Figure 5 Tianjin underground surface planning allocates different levels for different facility types

## 5.2 HELSINKI'S UNDERGROUND MASTER PLAN

Helsinki has developed an underground master plan for its entire municipal area, with decision-making history described comprehensively. The city began this work in the 1980s and has maintained an underground space allocation plan ever since. On average, under each 100 square meters of surface area in Helsinki, there is one square meter of underground space, with substantial resources remaining for future needs. One of its goals is improving densification and efficiency by moving large-scale functions underground—such as wastewater treatment plants, coal and oil storage, and parking—Helsinki frees up prime surface land for residential and commercial development. Another goal is dual use of the space. Many facilities, such as swimming pools and sports halls, serve as recreational centres during peacetime but are designed to be converted into high-grade civil defence shelters within 72 hours. Figure 6 shows the underground swimming pool convertible to emergency shelter.



Figure 6 Underground Swimming Pool in Itäkeskus which can be converted into an emergency shelter if necessary. (Courtesy of ILKKA VÄHÄÄHO, City of Helsinki)

Helsinki's Underground Master Plan has legal status, reinforcing systematic construction quality and information exchange. The master plan controls locations and space allocations for new, large underground facilities, traffic tunnels, and interconnections while safeguarding existing spaces. Helsinki possesses over 200 kilometres of technical maintenance tunnels, with 60 kilometres being utility tunnels used by multiple operators, housing transmission lines and pipes for district heating, cooling, and electricity since 1977.

### 5.3 5.3 SINGAPORE'S STRATEGIC APPROACH

Singapore's underground space planning exemplifies innovative urban development in response to severe land constraints. With only 730 square kilometers of territory, this island nation has developed one of the world's most comprehensive strategies for subterranean development, treating underground space as a critical national resource. The cornerstone of this approach is the Underground Space Master Plan, launched in 2019 by the Urban Redevelopment Authority (URA). This strategic framework coordinates underground development up to 150 meters deep, establishing depth zoning guidelines that prevent conflicts between different underground systems and facilities.

The extensive Mass Rapid Transit (MRT) network forms the transportation backbone, with integrated underground pedestrian walkways connecting stations to commercial developments. The innovative Common Services Tunnel system houses utilities—power cables, telecommunications, and water pipes—in shared corridors, reducing surface disruption and simplifying maintenance. Industrial applications include the groundbreaking Jurong Rock Caverns, Southeast Asia's first underground liquid hydrocarbon storage facility, located 130 meters below ground. This facility frees valuable surface land while providing secure resource storage. Water management infrastructure, including the Deep Tunnel Sewerage System (DTSS), handles wastewater through extensive underground tunnel networks.

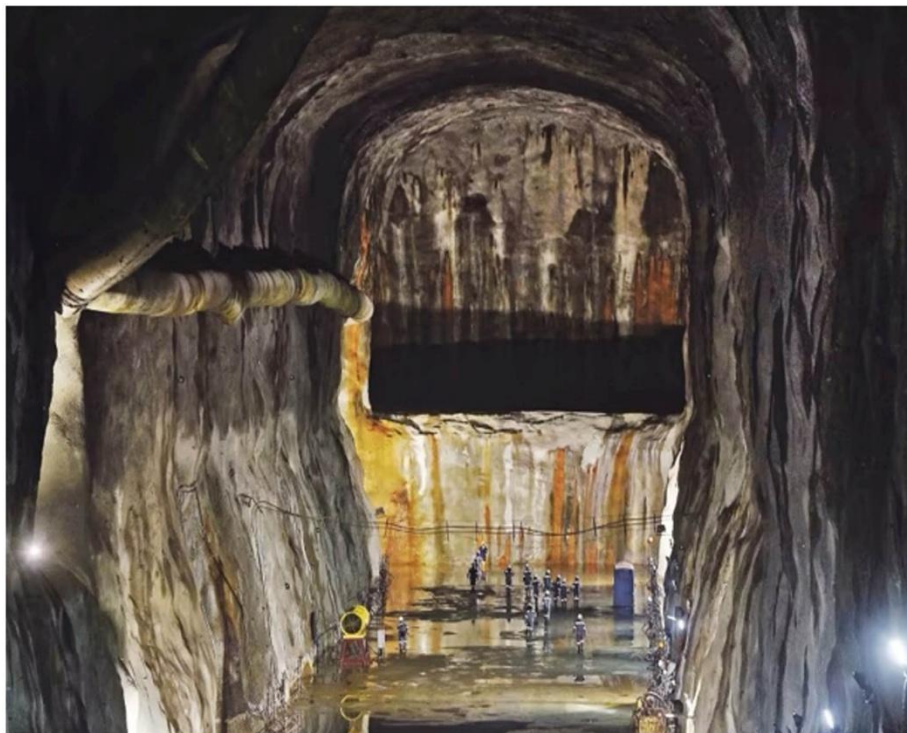


Figure 7 Singapore Jurong Cavern for deep oil storage

The planning principles guide development systematically. Depth zoning allocates shallow areas for utilities and pedestrian networks, medium depths for transportation, and deeper levels for storage and specialized facilities. Figure 7 shows Singapore Jurong Cavern, a 150 m deep Oil and chemical storage facility consisting of 5 caverns with a capacity of 1.47 million cubic meters. Geological assessments, particularly of the stable Bukit Timah Granite formation, inform construction decisions. Integration with surface development ensures underground spaces complement above-ground uses rather than competing with them.

The challenges include high construction costs, technical complexity in built-up areas, hydrogeological concerns, and the need for sophisticated stakeholder coordination. Singapore addresses these through careful planning, advanced engineering solutions, and comprehensive guidelines that streamline multi-agency collaboration.

Future directions emphasize expansion of pedestrian networks, additional utility corridors, underground industrial parks, and deeper specialized applications. Singapore's approach demonstrates how strategic underground development addresses urbanization pressures while preserving surface land for green spaces and community facilities. By systematically planning subterranean space as a valuable resource, Singapore has positioned itself as a global leader in sustainable urban development, offering valuable insights for cities worldwide facing similar land constraints.

#### **5.4 JAPAN UNDERGROUND SPACE PLANNING**

Japan has developed a comprehensive underground space planning policy to address land scarcity in dense urban areas while prioritizing safety and functionality. The cornerstone of this approach is the 2001 Deep Subterranean Utilization Law, which permits infrastructure development at depths exceeding 40 meters or 10 meters below existing building foundations without compensating surface landowners. This legislation has enabled extensive subway, utility, and commercial projects beneath major cities.

Disaster resilience forms a critical component of Japan's strategy, reflecting the nation's vulnerability to natural hazards and security threats. Tokyo's Metropolitan Area Outer Area Underground Discharge Channel exemplifies flood management infrastructure (Figure 8), while stringent seismic engineering standards ensure underground facilities withstand earthquakes. The 2024 directives further expanded protective capabilities by mandating reinforced underground shelters in remote regions like the Sakishima Islands for civil defence purposes, including missile attack protection.



Fig 8 Tokyo's Metropolitan Outer Area Underground Discharge Channel – one of the world largest flood controls

Urban planning policy encourages integrated, multi-level underground networks that combine transportation hubs, retail spaces, and parking facilities. Cities like Tokyo and Osaka have created interconnected subterranean environments that enhance convenience and maximize limited surface area. This approach transforms underground spaces into functional extensions of the urban landscape rather than mere infrastructure repositories. Overall, Japan's underground space policy represents a sophisticated response to geographic constraints, combining innovative engineering, comprehensive

disaster preparedness, and coordinated urban planning to create resilient, efficient metropolitan environments beneath the surface.

## **5.5 UNDERGROUND URBAN PLANNING GAP IN WESTERN CITIES**

Despite advantages, many Western cities lack comprehensive underground planning. In London, while several major underground infrastructure projects are recently completed or under construction—Crossrail, Thames Tideway Tunnel, Northern Line Extension, and London Power Tunnels—there is no holistic underground space planning. Only six of 32 London boroughs consider underground structures in their plans, all related to residential basement design standards rather than overall underground space planning.

New York City's planning system has evolved since 1811, establishing the Manhattan grid pattern and implementing the first zoning resolution in 1916, and the City Planning Commission established by 1936, but it never addressed the underground space. In general, the underground space in New York transformed itself into the shallow level for basements and utilities, followed by transportation, and deep level for water tunnels.

Although planning agencies in both London and New York share similar objectives for improving urban environments—addressing housing, neighbourhoods, parks, transportation, energy, water, waste management, air quality, climate change, and resilience—neither has underground spatial planning or design strategies. Very few cities worldwide have such underground spatial use policies or standards.

## **6. EMERGING TECHNOLOGIES AND DATA-DRIVEN PLANNING**

Planning technologies now utilize advanced analytical tools including spatial statistics, machine learning, and causal inference to uncover utilization patterns and optimization strategies. The review underscores increasing integration of planning and governance, merging resource evaluation, demand forecasting, layout planning optimization, and development benefits evaluation into cohesive frameworks. Enhancements in 3D cadastral systems, innovative management models, and digital twin technologies further bolster this integrated approach.

However, despite significant strides, challenges in data integration, model complexity, and practical application persist. Current underground planning knowledge faces limits, requiring interdisciplinary approaches and robust model development to fully harness transformative potential for sustainable, resilient, and human-centred urban environments. The subsurface represents a non-renewable resource in the sense that, unlike surface development, we cannot spatially perform a reset to the original state once volumetric incursion or material extraction occurs.

## **7. ECONOMIC IMPACTS OF UNDERGROUND TRANSIT SYSTEMS**

Metro systems demonstrate positive capitalization reflected in property values surrounding stations, though impacts vary spatially, temporally, and geographically. Transit systems impact natural and built environments by reducing air pollution and greenhouse gas emissions, encouraging new developments and urban renewal, shaping urban development and land use, facilitating commercial growth and residential development, and promoting underground space utilization.

### **7.1 TRANSIT-ORIENTED DEVELOPMENT AND JOB CREATION**

Case studies indicate successful transit-oriented development is founded on integration of transit stations with mixed-use development, encouraging public transit use while supporting financial sustainability through real estate development, as demonstrated in New York, Hong Kong, Singapore, and other major cities.

Government policy and strategic planning involvement, including zoning laws, funding mechanisms, and incentives for high-density development, prove crucial for success. In addition, case studies show wide variation in jobs attributable to transit projects, with most significant development and employment following transit line openings in areas where new service improved access to underdeveloped land close to urban cores that could not develop as densely relying solely on private vehicles such as the case in Grand Paris Express project. Local economic development impacts prove most evident where supportive business communities, zoning flexibility, growing regional economies, and good transportation network

connectivity exist. However, not everyone affected by the transit-oriented development benefits from it as discussed in the following section.

## **8. EQUITY AND SOCIAL CONSIDERATIONS**

### **8.1 ACCESS AND DISPLACEMENT CHALLENGES**

Underground transit system placement decisions face many challenges among competing interests. Political views, community interests, commercial benefits, and tax incentives affect route, alignment, configuration, station locations, and surface connections with potential future developments. Construction impacts on traffic, businesses, and daily community life can deter public acceptance.

Affluent area residents may express security concerns and integration fears, believing mass transit will bring unknown and undesirable people to their neighbourhoods—Georgetown area in Washington, DC lacks subway service despite that plans have existed since the mid-1970s. Conversely, when development succeeds around station locations, real estate prices rise, displacing lower-income residents and gentrifying neighbourhoods. This pattern appears in many large cities with underground transit systems including New York, Washington DC, and Los Angeles.

### **8.2 ADDRESSING TRANSPORTATION INEQUITY**

It is important to address the inequity when planning a mass transit system. For example, despite New York City subway system's widespread reach, the City's Fourth Regional Plan issued in 2017 identified that more than one-third of all New Yorkers don't live within walking distance of subway stations. Most are low-income neighbourhoods and communities of colour for whom transit access is disproportionately important and who have no other transportation means to workplaces. Similarly, the San Francisco Bay Area Planning and Urban Research Association identified equity as an essential strategy for successful transportation planning in their August 2020 report "The Future of Transportation," recommending setting prices to promote efficiency and equity.

New or extended underground transit lines must address these disparities by establishing policies regarding land use around stations to minimize resident displacement. Implementation of mixed-use development and affordable housing with public amenities meeting environmental and sustainability goals creates vibrant public places fostering strong economies benefiting everyone including local communities.

## **9. POLICY AND GOVERNANCE FRAMEWORKS**

### **9.1 REGULATORY APPROACHES AND ENABLING POLICIES**

Strong policies and administrative controls for implementation in China, as discussed above, would not necessarily be possible in the West. However, policies facilitating effective long-range planning of underground space use, as found in Singapore or Helsinki, help those locations move closer to sustainability goals and integrate underground space with urban planning. These approaches can be applicable to many American and European cities.

Policies enforcing preservation of surface environments while permitting facility expansion underground would provide reason for moving more infrastructure underground in deliberate planned approaches. For example, Japan's policies allowing public agencies rights to develop deep underground space under private properties avoid lengthy legal barriers and allow more versatile and expedient underground project development.

### **9.2 INTEGRATED PLANNING SYSTEMS**

It is important to establish underground space planning guidelines and be incorporated into urban regulatory planning systems to guide urban construction as a basis for urban management. Then underground space should be part of the urban development to meet the needs of the anticipated growth of urban centres. This requires awareness programs and continual dialogue among many stakeholders including policymakers, city planners, engineers, developers, and the public.

## **10. SUCCESS FACTORS AND FUTURE DIRECTIONS**

The foundation of successful underground development rests on three interconnected pillars. First, thorough geological assessment proves essential. Cities must comprehensively evaluate underground resources across shallow, middle, and deep layers, examining available space, development difficulty, potential value, and overall quality. This scientific understanding enables rational planning decisions about optimal uses for each subsurface level based on geological suitability.

Second, interdisciplinary collaboration transforms potential into reality. Underground development cannot exist in isolation—it must integrate seamlessly with existing urban planning frameworks. When properly coordinated across engineering, architecture, planning, and environmental disciplines, efficient underground space utilization promotes sustainable development, improves urban environments, conserves natural resources, and delivers long-term triple bottom line benefits spanning economic, social, and environmental dimensions.

Third, public engagement and awareness remain critically underutilized. Policymakers and urban planners frequently overlook underground opportunities, failing to recognize subsurface space as valuable urban assets. Building successful projects requires educating stakeholders, cultivating public support, and demonstrating how underground development enhances rather than diminishes quality of life.

### **10.1 STRATEGIC RECOMMENDATIONS**

Moving forward, cities should pursue four key strategies. Comprehensive master planning must treat underground space as integral to overall urban planning, mapping existing infrastructure, identifying future needs based on population projections, establishing layer-based allocation systems, creating legal frameworks for underground rights, and integrating with surface planning for holistic three-dimensional city development.

Technology integration offers transformative opportunities through digital twin systems for visualization and management, Building Information Modelling (BIM) and digital twinning for design coordination, artificial intelligence for system optimization, advanced geotechnical investigation with 3D geological modelling, and data-driven planning methodologies enabling evidence-based decision-making.

Policy development must establish legal frameworks clarifying underground ownership and development rights, zoning regulations encouraging subsurface construction, financial incentives for moving infrastructure underground, requirements for underground space consideration in new projects, and standards ensuring safety, accessibility, sustainability, and environmental protection.

Finally, equity-centred approaches must guide all planning processes, prioritizing equitable access to underground transit and facilities, implementing anti-displacement policies around transit stations, requiring affordable housing in transit-oriented developments, ensuring meaningful community engagement in development decisions, and distributing benefits so all neighborhoods gain from underground investments.

## **11. CONCLUDING REMARKS**

Underground space development has proven itself as a powerful catalyst for urban growth when properly planned and implemented. Historical examples from New York City to contemporary developments in Singapore, Helsinki, and China demonstrate how strategic subsurface utilization can transform cities, enhance economic vitality, improve environmental sustainability, and provide resilient infrastructure.

However, success is not automatic. It requires comprehensive planning frameworks integrating underground space into overall urban strategies, supportive policies enabling development, technological innovation facilitating design and construction, interdisciplinary collaboration among stakeholders, and commitment to equity ensuring benefits reach all community members.

With predicted population growth and megacity expansion, efficient underground space use becomes not merely advantageous but essential. Cities must recognize underground space as the invaluable asset it represents—the final frontier for urban development. Those cities developing comprehensive underground space strategies today will be best positioned to accommodate future growth while maintaining liveability, sustainability, and prosperity.

The question is no longer whether cities should develop underground space, but how quickly and effectively they can integrate subsurface planning into urban development frameworks. The underground represents our cities' future—it is time to bring that future to light through comprehensive planning, innovative technology, equitable policies, and collaborative implementation.

## **LITERATURE**

*List all references in alphabetical order under the LITERATURE heading at the end of the paper. Sources are listed alphabetically by author or institution; citation format is according to ISO 690. A period is added at the end of the listing. If several works by the same author are cited, they are listed in chronological order. Style Reference text.*

CRAIG-THOMPSON, A., & KUCHLER, M. (2025). Surfacing the urban underground: Knowledge production, modes of governance. *Geoforum*.

GEOENGINEER.ORG. (2025). Hidden Potential: The Role of Underground Spaces in Urban Growth.

ITA/ITACUS/ISOCARP (2015) "Think Deep: Planning, development and use of underground space in cities"

MUNFAH, N. (2020). Utilization of Underground Space Promotes Urban Development. *Tunnelling Online*.

PENG, F.-L., ET AL. (2023). The next frontier: data-driven urban underground space planning orienting multiple development concepts. *Smart Construction and Sustainable Cities*, 1, 3.

VÄHÄÄHO, I. (2014). Underground space planning in Helsinki. *Journal of Rock Mechanics and Geotechnical Engineering*.

WANG, J., ET AL. (2025). Role of Urban Underground-Space Development in Achieving Carbon Neutrality. *Engineering*.

WANG, W., ET AL. (2025). Urban Underground Space Planning Idea and Path Based on a "Dual-Use" Concept. *Strategic Study of CAE*.

ZHENG, S., ET AL. (2022). Impacts of Urban Rail Transit on City Growth: Evidence from China. *Urban Rail Transit*.

ZHOU, Y., ET AL. (2018). Singapore Underground Space Master Planning. *Urban Planning Review*.

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