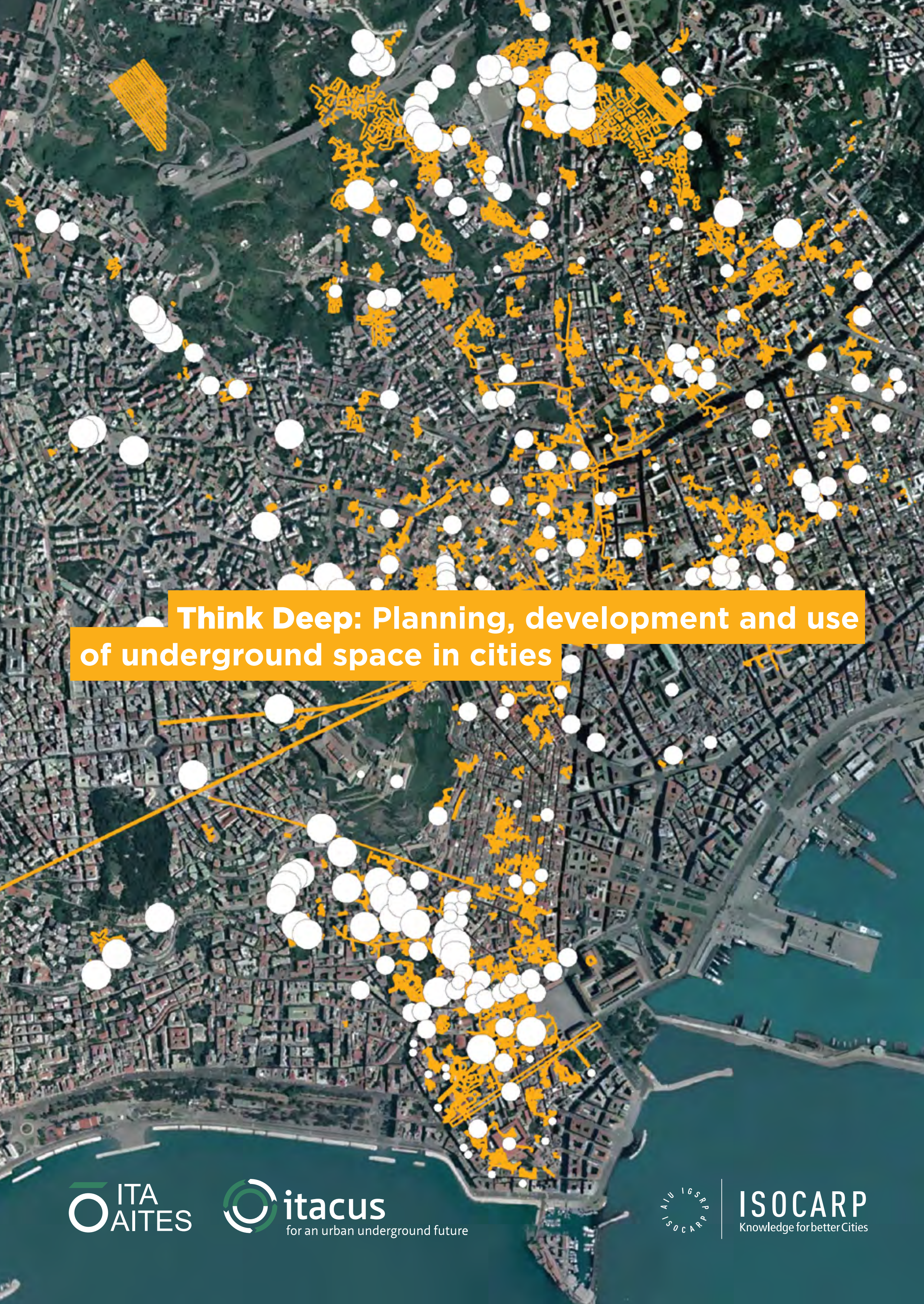
# Think Deep: Planning, development and use of underground space in cities



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# Think Deep: Planning, development and use of underground space in cities

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*This publication is part of the ongoing co-operation between ISOCARP and ITA/ITACUS. This project was managed by ISOCARP and financed by ITA. All contributors are members of ISOCARP.*



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## FOREWORD

Jan Rotmans, Professor of Transitions and Transition Management at the Erasmus University, Rotterdam, the Netherlands, is often quoted as saying: '*We do not live in a era of change, rather we live in a change of eras*'. The world is facing challenges on an epic scale: rapid urbanisation, natural hazards, and the effects of climate change, to name just a few. All these challenges are impacting our cities and they all need to be considered when looking at the cities of the future. But more than just looking for some quick fixes, we need to consider that the world is transitioning to a new era. This requires us to think in bold new ways based on new paradigms.

It was Eugène Hénard, French architect and planner, who in 1910 first used the phrase 'The Cities of the Future' in relation to underground space. During the Town Planning Conference in London that year he presented his now famous paper[1], in which he set out his vision how the use of the subsurface would enable cities of the future to exist, because, as he propositioned: '*Whatever form its future expansion may take, there will always remain, in every large urban community, a centre of intense activity wherein the buildings will always be placed close together, as they are in our cities of the present day.*' It was this density that intrigued Hénard and made him think of utilising new spaces, hitherto not considered. His most famous comment on considering the subsurface must be the following: '*All the evil arises from the old traditional idea that "the bottom of the road must be on a level with the ground in its original condition." But there is nothing to justify such an erroneous view. As a matter of fact, if we were to establish as a first principle the idea that "the pavement and carriage-way must be artificially constructed at a sufficient height to allow thereunder a space capable of containing all the installations needed for the service of the road," the difficulties I have just pointed out would disappear altogether*'.

Hénard wrote these words and presented them over 100 years ago. It is now more than ever that we can take heed of these words in our current search for new spaces for our cities. ISOCARP and ITACUS joined forces to commission five case studies on the use of underground space beneath our cities. This has led to five very different studies ranging from the identification of long lost spaces beneath the city of Naples to purpose-built caverns in Hong Kong. One case study looks at how it was possible to build a metro in Athens and not destroy the archaeological assets buried in the soil beneath the city. If you were to compare New York City and London, what can you say about the use of underground space and the key factors governing this development? One of the case studies does just that and comes up with interesting conclusions. The fifth case study looks into how underground space planning has been utilised in the Chinese city of Tianjin.

Five case studies undertaken by planners, urban designers and architects. Five case studies that intend to show the richness of underground space. Five case studies that start to give some insights into the possibilities but also the impediments of underground space use. If all the case studies illustrate one point, it is that the use of urban underground space is very much situational and often restricted not just by geology or underground ecology, but equally by legislation that never considered the possibility of large-scale subsurface development and use. One overriding consideration seems to surface from all case studies, and that is the need to plan. Without a vision on the use of urban underground space, without planning and without a strategy for managing the use of this vast spatial asset, all developments will be based on 'first come, first served'. This will lead to spatial congestion and competition between resources. Many cities are already developing large energy schemes by driving vertical pipes into the underground. Whether these are making future horizontal alignments of transport solutions impossible, just for example, is often not even being considered.

A contemporary of Hénard was George Webster, Chief Engineer and Surveyor of Philadelphia, USA who in 1914 wrote about the necessity to plan the layout of what he called "the subterranean street"[2]. Webster was concerned with the placement of utilities in the subsurface and chaos arising if not planned. But his vision went further, like Hénard he saw a future for underground space. Hénard and Webster were followed by French architect Édouard Utudjian who famously wrote[3]: '*It is necessary that the urban planner thinks deep and that underground development of cities is done not through random necessities, but according to a definite commitment, legislation and a predetermined plan.*'

This joint publication by ISOCARP and ITACUS hopes to stimulate some innovative thinking on the use of underground space. We urge planning practitioners not only to consider the possibilities, but also to think deep and to make underground space part of the planning of our future cities. In doing so, we reaffirm that the time has come for new planning paradigms as we are transitioning to a new era in which our cities will continue to play an evermore important role for people; cities of the future, which are resilient, inclusive and above all liveable.

Shipra Narang Suri, *ISOCARP Vice President*
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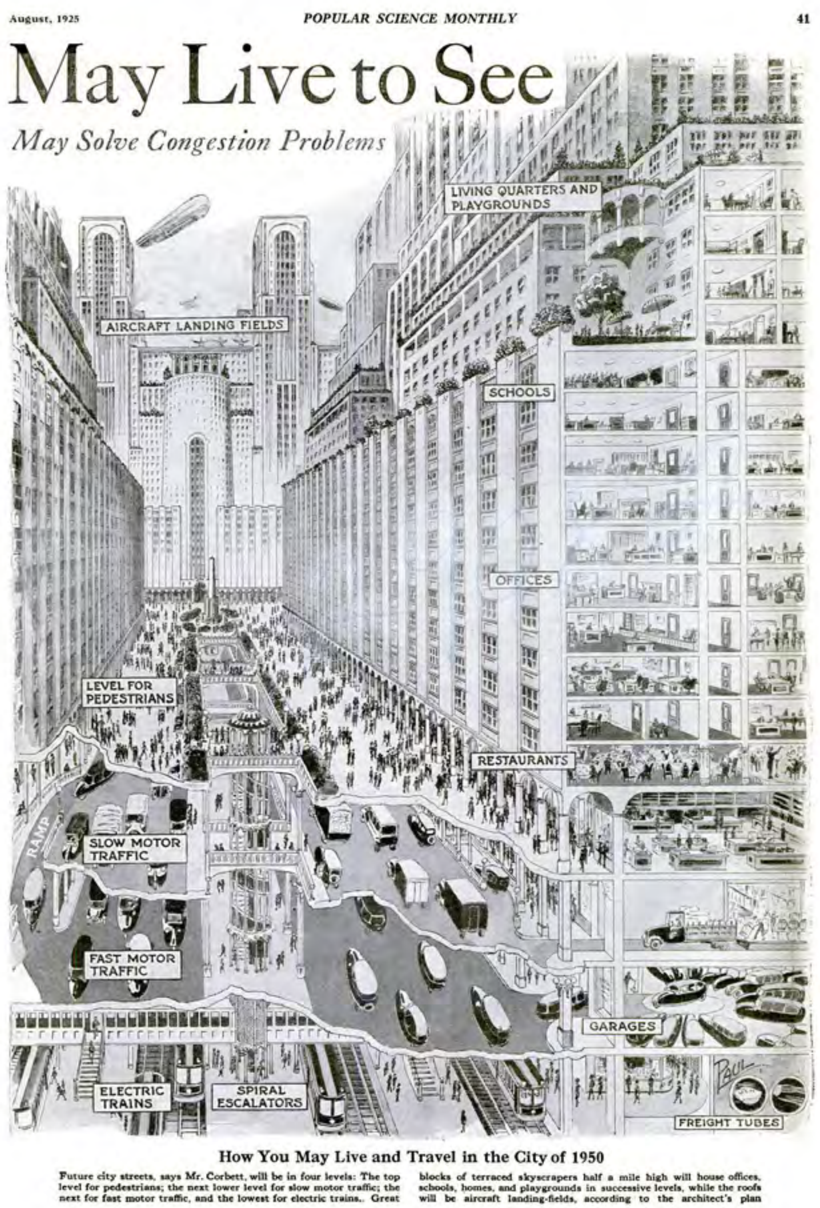
1 Royal Institute of British Architects, Town Planning Conference London, 10-15 October 1910, Transactions (London: The Royal Institute of British Architects, 1911): 345-367.

2 Annals of the American Academy of Political and Social Science, Volume 51 (1914): pp 200-207.

3 L'Urbanisme Souterrain. Édouard Utudjian. Presses Universitaires de France (1952).

# PLANNING FOR UNDERGROUND SPACES "NY-LON UNDERGROUND"

Elizabeth Reynolds · Paul Reynolds






## INTRODUCTION

London and New York have long enjoyed a friendly rivalry as global hubs of finance and culture, with correspondingly high land values yet very different approaches to planning and development. As both cities try to balance environmental sustainability with growth in population and consumption, it is an opportune time to consider underground spaces as potentially valuable urban assets.

It is clear that the reasons that the two cities diverged so greatly, with New York looking up while London went downwards, is a combination of nature and nurture, or more specifically geology and policy.

Geologically, London is largely bedded on gravels and clay – materials that are great for tunnelling into, but less helpful for founding tall buildings. New York on the other-hand is made of rock that is great for underpinning the tallest of buildings, but challenging to dig through.

From a political perspective, building controls in London have, since their earliest incarnations, set strict limitations on height. In contrast, New York has tended to focus on Floor Area Ratios (FAR) that have the effect of promoting building tall.

This research paper will look at the contrasting approaches to underground development, focusing in particular on some of the most recent ideas and projects being delivered and considered in the two cities. It aims to illustrate how underground space is being used in the two cities; the advantages of activating underground spaces; and challenges faced in planning and implementation.

## HISTORY AND CONTEXT

The settlement that has become known as London was founded by the Romans in approximately 43 AD. Situated on the tidal River Thames, it was a location chosen for reasons of security and trade – and London has been a continuous centre of commerce that draws in, processes then redistributes goods and knowledge from around the world ever since. The shape, density, typology and function of the city not only evolved in response to changing threats and opportunities, but in response to geological, climatic and cultural attributes. Although the broader London Basin is primarily filled with tertiary age clay and sands, as indicated in figure 1, a large area at the centre of the city comprises "London Clay". London Clay is considered an ideal medium for excavating and tunnelling - a key factor in the development of the docks, and also a driver for underground development of London.

London has long relied on tunnels for security, logistics, transport and utilities. The oldest building in the city, the Tower of London was first built for William, Duke of Normandy following his conquest and subsequent coronation in 1066. The Tower continued to expand and fortify under successive monarchs, many of whom relied on its network of secret tunnels to ferry goods, prisoners and even forbidden lovers.

However, it was 1843 before an underwater tunnel was first attempted. Designed and constructed by Sir Marc Brunel it opened initially as a pedestrian tunnel, but in 1869 was converted to a railway tunnel that is now part of the London Overground Network. Briefly described as the 8th Wonder of the World, the Thames Tunnel was a tourist attraction with visitors promenading through it's below ground arches (figure 2).

The technology used to construct the Thames Tunnel no doubt influenced the

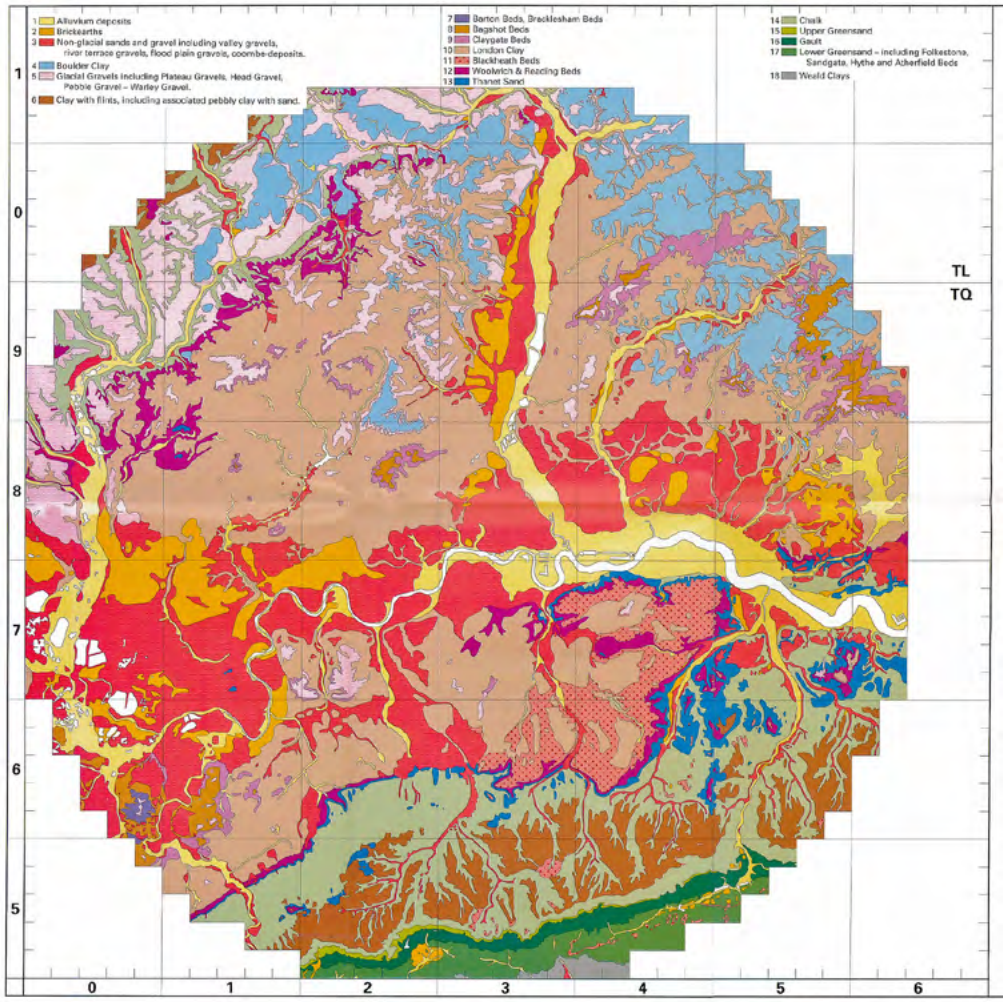



Figure 1: Geological map of London

Figure 2: Thames Tunnel 1843

design and construction of the London Sewer System. Designed by Engineer Sir Joseph Bazalgette, the combined sewer and storm water system was vital to address the public health and amenity crisis caused by sewerage in the River Thames. Constructed between 1859 and 1865, the sewer also incorporated several of London's "lost" underground rivers and still serves modern day London.

The 1860's were an exciting time for big thinking engineering projects, with London's first underground rail line opened in 1863; the Metropolitan line was constructed using cut and cover techniques and operated initially with steam trains. The London Underground train system quickly grew to become a critical part of London's infrastructure and identity, beginning with 40,000 passengers there are now more than 1,107 million passenger journeys per year (Bownes, Green and Mullins 2012).

The expanding underground rail network was used as a shelter for London residents in both the first and second world wars (figure 3). To protect citizens from air bombing raids, between 1940 and 1942 eight deep level shelters were constructed below existing underground rail station tunnels. Able to hold up to 8,000 people each, the shelters were adapted for accommodation and medical purposes. Key government and military figures including Prime Minister Winston Churchill were also protected in underground spaces, primarily the Cabinet War Rooms, a 1.5m thick concrete bunker which served as a command centre for the Allies in the Second World War. The history of Londoners using underground spaces for safety and security could be considered an important factor in their perceptions of underground space when compared to residents of other cities.

London's transport and utilities infrastructure has continued to expand below ground level, most notably the creation of the Channel Tunnel (1994); the Jubilee Line Extension (1999); Crossrail which is currently under construction (estimated opening late 2018); and the proposed Thames Tideway sewer tunnel (estimated operation 2023).

Although London's residential, recreation and retail land uses are still primarily at ground or above ground level, interest seems to be growing in utilising below ground spaces. The Canary Wharf Group recently added a further 44,000 sq ft of predominantly basement level retail space at Jubilee Place, connecting to an existing mall and train station beneath a cluster of office towers.

At a domestic scale, there is a trend for residential basement extensions, particularly in London's wealthier suburbs where "iceberg houses" that are even bigger below surface level than they appear above are digging out substantial new living spaces for home cinemas, cigar rooms and private beauty spas. The planning policy response to this basement gold rush will be explained further in section 3 of this paper.

The trend for lower level luxury also seems present in the retail and leisure sector. A cavernous basement in part of the former Regent Palace Hotel recently reopened as Brasserie Zedel and basement level nightclubs at the Edition and Ace Hotels have also recently opened, building on the popularity of similar bars No 41, Cumberland's Carbon Bar, Whisky Mist and Bodo Schloss (Hermann, 2013). Basement spaces are often preferred for these uses as they can successfully operate without natural light, and indeed are often designed around that central theme. In addition they provide spaces that are insulated for noise (minimizing disturbance to adjacent land uses).

In trying to identify further unique business opportunities for under-utilised (and potentially undervalued land), there are currently several quirky projects hop-


Figure 3: London Underground Station Air Raid Shelter

ing to adapt London's underground spaces, namely:

- The Old London Underground Company hopes to raise £200m capital to use 26 former train stations for shopping, tourism and events (Spillane, 2011);
- British Postal Museum & Archive are attempting to restore sections of the pneumatic mail rail system as part of a new postal museum; and
- Zero Carbon Food is trialling the hydroponic production of vegetables in former air raid shelters.

In comparison to London, across the Atlantic, New York has a very different origin. Native Americans are believed to have first settled in New York State in 10,000 BC, but the history of New York City began when the French visited the region in 1524. In 1609 it was colonised by the Dutch as New Amsterdam, and then the English, who proclaimed it New York, after the Duke of York, in 1664. In 1674 the remaining sections of the commercially and strategically significant trading port was purchased by England from the Dutch in exchange for Suriname. However, the English occupation of New York only lasted until 1783 when they were forced to evacuate after the American Revolutionary War. Following the American Civil War of 1861 – 1865, the City of New York was officially formed in 1898.

The island of Manhattan is part of a landscape sculpted from an ice sheet formed in the Pleistocene Era approximately 1.5 million years ago (New York City Parks, 2014). It is built on three strata known as Manhattan Schist, Inwood Marble, and Fordham Gneiss (figure 4). The Schist forms the island's spine, running from the Henry Hudson Bridge at its north end to the Battery on its southern tip; it dips abruptly several hundred feet below ground at Washington Square, and makes a gradual ascent beginning at Chambers Street. These dips and rises account for the gap between "midtown" and "downtown" in the Manhattan skyline - the tall buildings had to be anchored on solid bedrock, and not on the glacial till that fills the valleys. (Merguerian, C. and Sanders, J., 1990).

This tough bedrock, which allowed the city to build tall skyscrapers, didn't however deter those who saw the underground as a way to deliver the infrastructure needed to support the city. To ensure a fresh water supply for the growing population, construction commenced in 1837 on the Croton Aqueduct to divert water from the Croton River to the centre of New York City using a series of underground tunnels. Heating, cooling and energy for the city continues to be supplied through an underground network of pipes initiated by the New York Steam Company in 1882.

Experimental transport systems such as the Broadway pneumatic subway (1870) and Brooklyn Bridge cable railway (1883) predated the steam locomotive Atlantic Avenue Tunnel (1844), that made New York the first city in the world to have a formal underground passenger rail line (BHRA 2011). The next evolution in New York's underground transport was the introduction of the Interborough Rapid Transit system (figure 5) that opened in 1904 using electric powered trains (MTA 2013).

The iconic Brooklyn Bridge designed by John Roebling in 1867, and completed in 1883 by his son Washington and daughter in law Emily, utilized innovative underground construction techniques - with caissons (large inverted wooden boxes) framing the foundations of towers supporting the suspension bridge. The 16 ton caisson boxes were sunk (open at the bottom) using stone weights, before compressed air was pushed in, forcing the water out and allowing the workers access to dig out space for the foundations that would eventually be filled with concrete. Consequently, compression sickness or "The Bends" often affected the brave men toiling in the dark underground space. The mostly German, Italian and Irish immi-

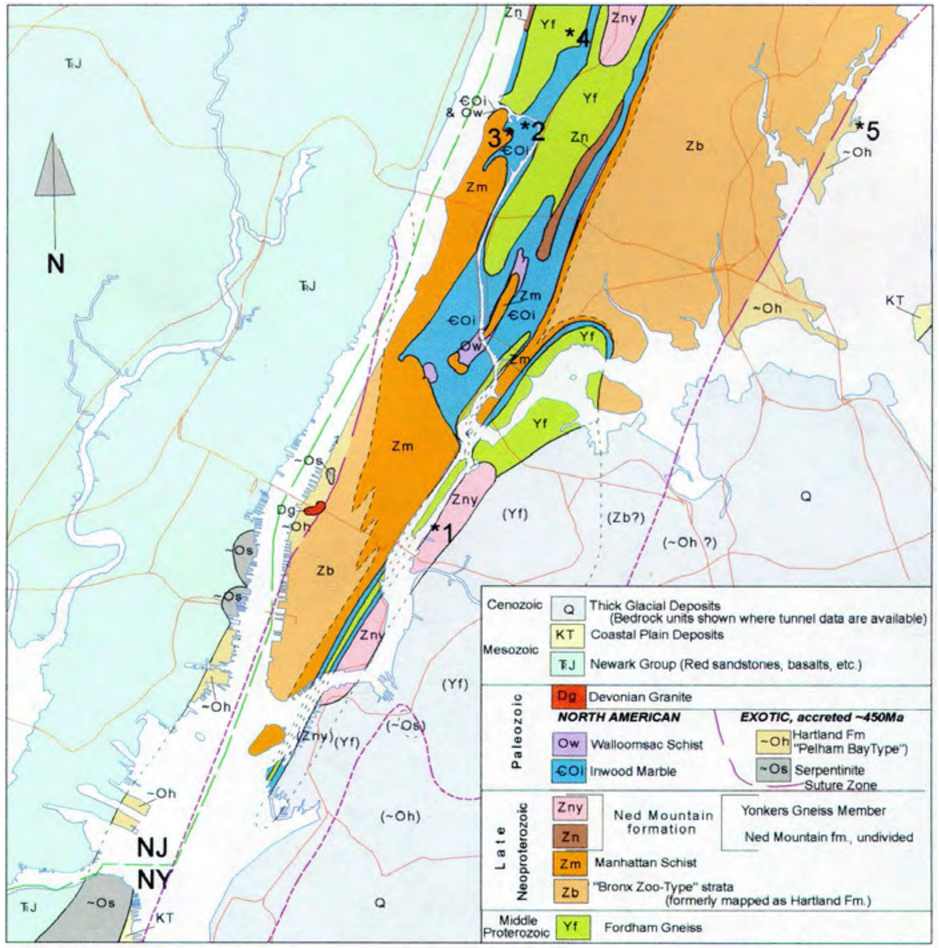



Figure 4: Geology of New York City

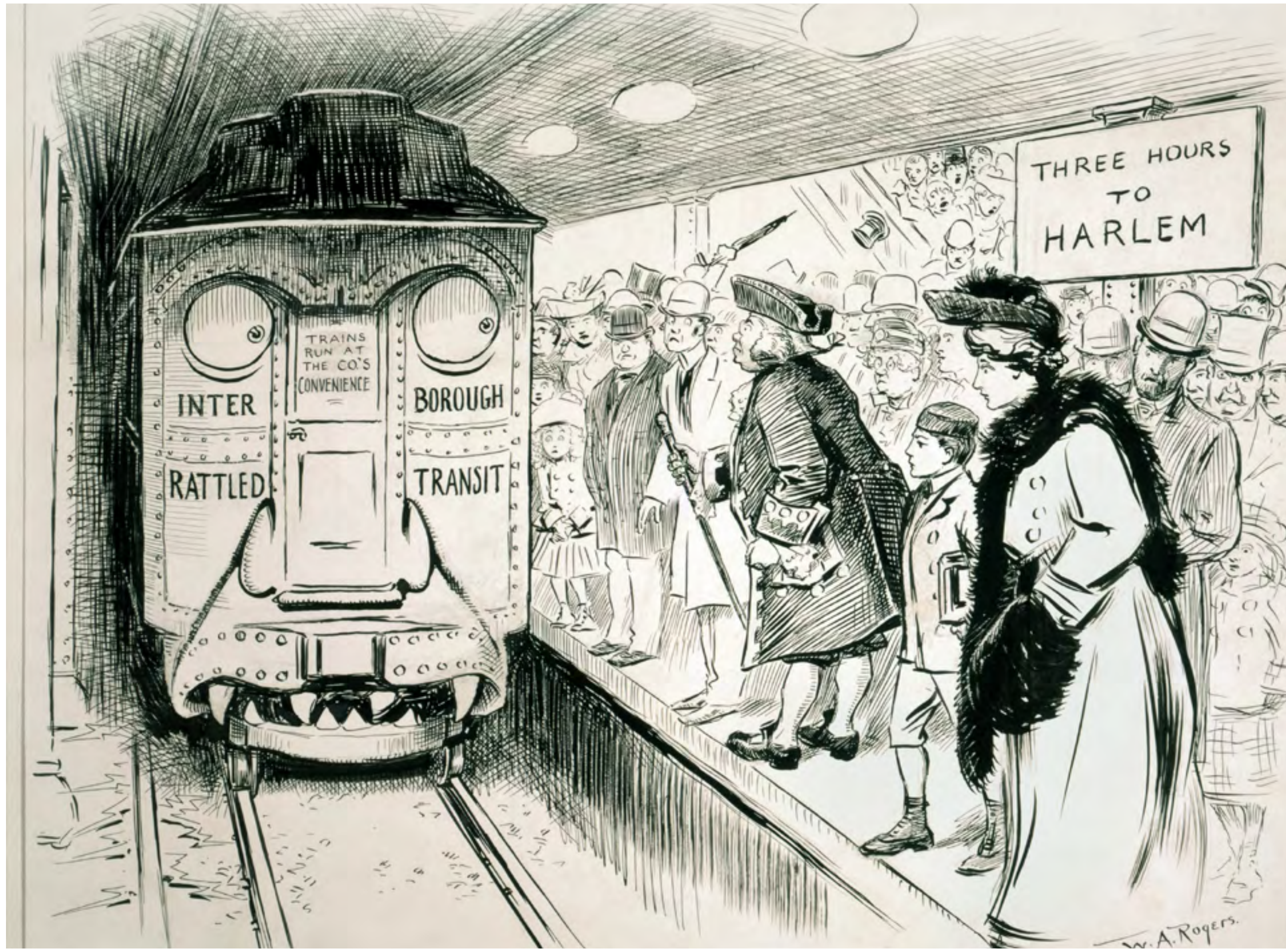



Figure 5: Interborough Rapid Transit system

grants that worked under these dreadful conditions became known as "Sandhogs" (Delaney 1983). This unique group of construction workers continue to specialise in urban mining and practice the difficult but vital work of delivering underground infrastructure to New York City (figure 6).

Though construction health and safety has improved considerably for the urban miners, it remains a difficult and dangerous job, particularly as explosives are often needed to break through the bedrock beneath the city. This combination of gruelling physical labour, explosives and high tech Tunnel Boring Machines (TBMs) are currently carving out the following projects below New York's streets:

- Water Tunnel 3 (also known as the Kensico – City Tunnel that was proposed in 1954, began construction in 1970 and is estimated to complete in 2021);
- Second Avenue Subway (initially proposed in 1929, commenced construction in 1972 and estimated to be operational in 2016); and
- East Side Access project to run the Long Island Rail Line deep below Grand Central Terminal by 2023.

## PLANNING REGIMES

While the physical characteristics of the two cities' geology have without doubt had a significant influence on their differing approaches to underground construction to-date, of equal importance is the differing planning policy regimes that have prevailed over time.

London has always had strict building controls that have had a constraining impact on the height of the city. In 1875, the Public Health Act was introduced at a national level. It required urban authorities to make byelaws for new streets, to ensure structural stability of houses and prevent fires, and to provide for the drainage of buildings and the provision of air space around them. However, when the London County Council was created in 1889, it wanted to amend the legislation to make it more London-specific, and it sponsored the London Building Act of 1894. As well as refining the rules around foundation construction and wall thicknesses, the Building Act of 1894 also prohibited buildings over 80ft high. Height restrictions were a consequence of Queen Anne's Mansions, an apartment building in Westminster over 100ft tall, which prompted many complaints – including from

Queen Victoria herself, who objected to the new building blocking her view of Parliament from Buckingham Palace. Although these restrictions have long since been relaxed, the culture of low rise had become embedded in 20th Century London construction and to this day individual planning authorities have the ability to set their own height limits. In London, regulations remain in place to preserve "protected views" – including to St Paul's Cathedral, which at 111m had been the tallest building in London for over 250 years until it was overtaken by the BT Tower in 1962 – then only allowed as it was part of an evolving communications infrastructure.

More broadly, across the UK, the post-war Town and Country Planning Act 1949 established the framework for modern planning policy and took the historical building controls such as the 1894 Act and established plan-led policy approaches instead. The system has evolved multiple times in the years since, but many of the central tenets have endured.

In March 2012, the National Planning Policy Framework (NPPF), the latest of these evolutions, was introduced. The framework is the highest tier in a plan-led system that informs the production of local plans by City and borough level organisations, with community groups also able to prepare Neighbourhood Plans. The NPPF contains 12 planning principles that should inform plan-making and decision-making, one of which is that "planning should always seek to secure high quality design and a good standard of amenity for all existing and future occupants of land and buildings". Importantly, the NPPF also contains a presumption in favour of sustainable development, meaning that applications for development consent should be approved unless they are contrary to sustainable development criteria set at a national and local level. The NPPF also states that Local Plans should "reflect and where appropriate promote relevant EU obligations and statutory requirements"; these include EU Directives on Strategic Environmental Assessment.

As the top-tier planning body for London, the Greater London Authority (GLA) produces and regularly revises a spatial development strategy known simply as the London Plan. The London Plan has six objectives. As of the 2011 revision, the objectives currently are to ensure that London is:

- A city that meets the challenges of economic and population growth
- An internationally competitive and successful city
- A city of diverse, strong, secure and accessible neighbourhoods
- A city that delights the senses
- A city that becomes a world leader in improving the environment
- A city where it is easy, safe and convenient for everyone to access jobs, opportunities and facilities.

Despite the increasing popularity and occurrence of underground development in London, the Plan does not include any reference to spatial or regulatory policy for basements or below ground spaces specifically. An example of the plan's content can be seen in figure 7.

While the GLA has strategic planning oversight, and can choose to determine individual projects as it wishes (particularly those seen as being of city-scale significance), the majority of planning is undertaken by the constituent Boroughs, each of whom produce their own spatial development plans.

At present, while six of the 32 London boroughs consider underground structures in their plans, all of these are residential basement design standards. However, two of the 32 boroughs - the Royal Borough of Kensington and Chelsea (RBKC) and



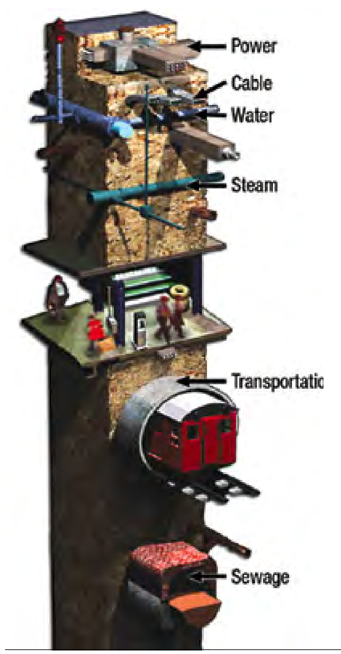



Figure 6: New York Underground

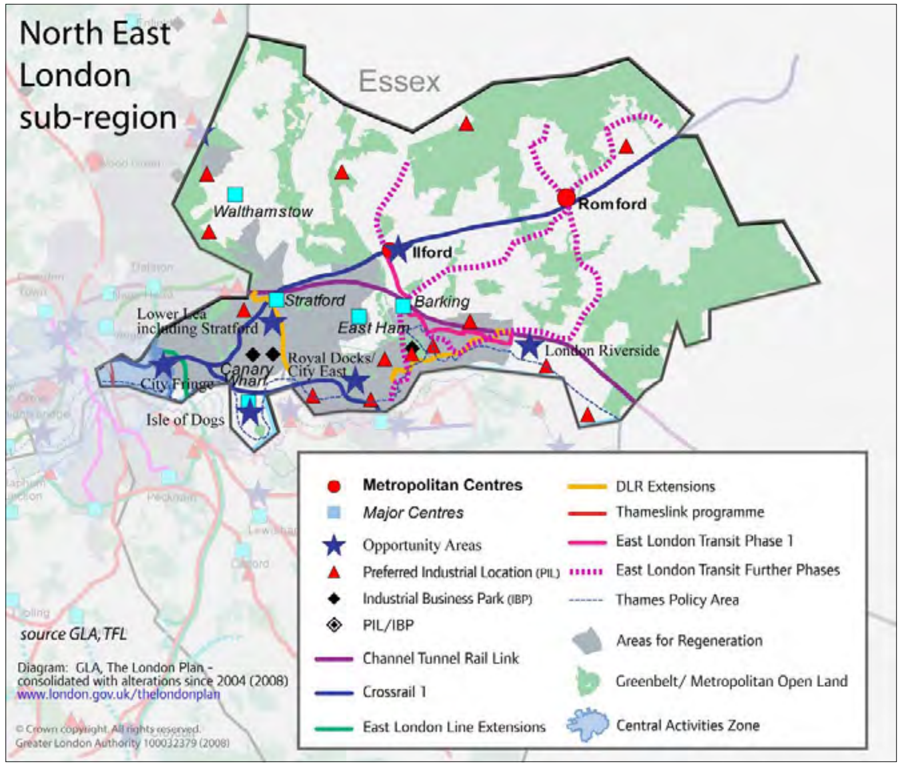



Figure 7: London Plan

Westminster City Council (WCC) - are developing specific planning policies on below ground development. These policies are being drafted as a reaction to the construction of mega basement extensions on high value properties close to the centre of the city, similar to the one proposed by a media tycoon in figure 8 (Hasler 2012).

The average price of residential property in Greater London was £475,940 in June 2013, this had risen 4.7% in the previous quarter, but is a considerably lower value than the average cost of residential property in RBKC (£1,586,426) and WCC (£1,383,459), the two highest residential land values across the London local authorities (Land Registry 2013). These two local authorities are also amongst the densest in Greater London with RBKC 4th at 128.4 people per hectare (pph) and WCC 7th at 105.5 pph (Greater London Authority, 2014).

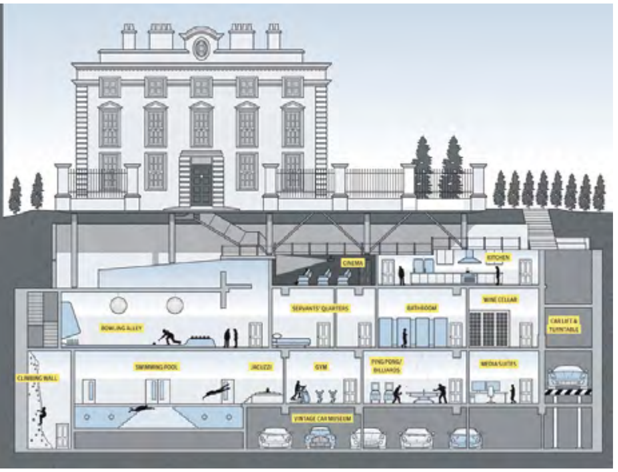


Figure 8: "Iceberg house"

In their Basements Publication Planning Policy Partial Review of the Core Strategy, July 2013 RBKC explain that "A basement development next door has an immediacy which can have a serious impact on the quality of life, whilst the effect of multiple excavations in many streets can be the equivalent of having a permanent inappropriate use in a residential area with long term harm to residents' living conditions. There are also concerns over the structural stability of adjacent property, character of rear gardens, sustainable drainage and the impact on carbon emissions. For all these reasons the Council considers that careful control is required over the scale, form and extent of basements" (paragraph 34.3.50, page 5).

Westminster City Council has also prepared an Interim Planning Guidance Note setting out the policy framework and approach for the development of basements, namely:

- Sustainable design;
- Trees, gardens and landscaping;
- Flood risk;
- Land stability;
- Ground conditions and structural issues;
- Heritage assets;
- Archaeology;
- Visual impact;
- Use of basements for living accommodation; managing the impacts of construction; and
- Developments under the highway.

As well as real estate uses, the growth in London's population places increasing pressure on its resources and infrastructure. Therefore, to cope with existing and anticipated demand, the following underground infrastructure projects are also planned or under construction (figure 9):

- Crossrail
- Thames Tideway Tunnel
- Northern Line Extension
- London Power Tunnels

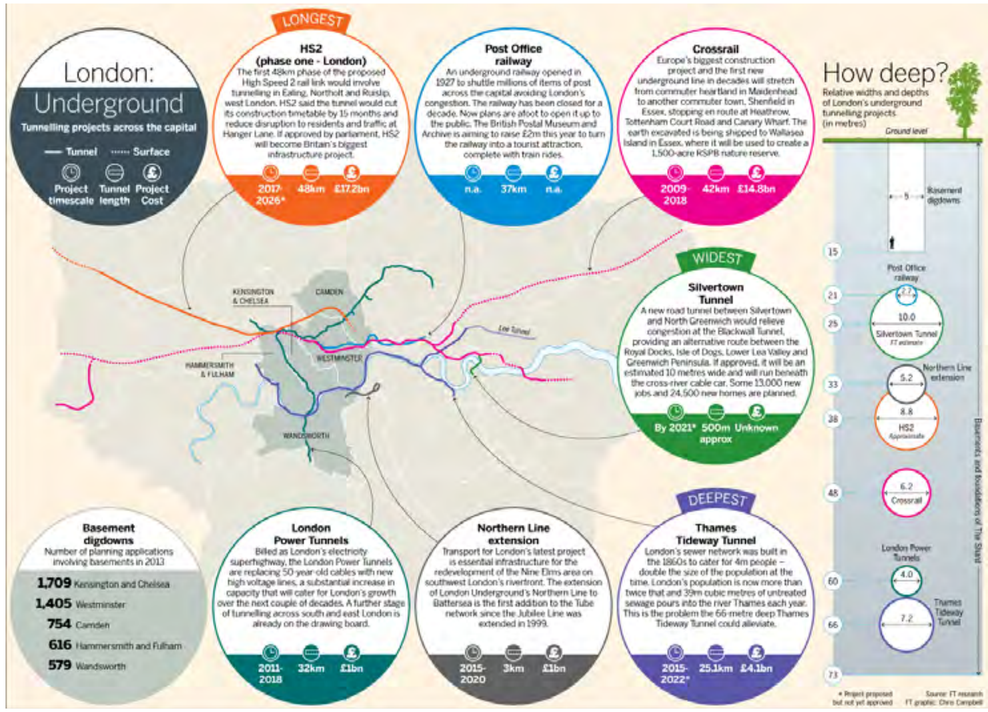



Figure 9: London's subterranean building boom

Unlike the development control system managed by local boroughs to assess applications for new development, major infrastructure projects are subjected to different processes that have also undergone changes to improve the efficiency of the decision making process. Currently, major projects are subjected to one of several different types of development consent process:

- Hybrid Bill
- Transport and Works Act
- Development Consent Order (for Nationally Significant Infrastructure Projects)
- Application for planning consent (major)

These processes are used as major infrastructure projects normally cross multiple boroughs and impact on many different landowners.

In contrast, the planning system in New York has evolved differently. In 1811 the grid pattern for Manhattan's urban development was set down in the "Commissioners' Map and Survey of Manhattan Island". The map laid out a 7-mile area of the city with 11 major new avenues and 155 cross town streets to create 20-foot long blocks predominantly containing 25 by 100 foot (metric) plots of land (Robert, 2011). Speculators snapped up the new plots, with the value of property in Manhattan more than doubling between 1842 and 1860.

In 1916, New York was the first city in the country to implement a zoning resolu-

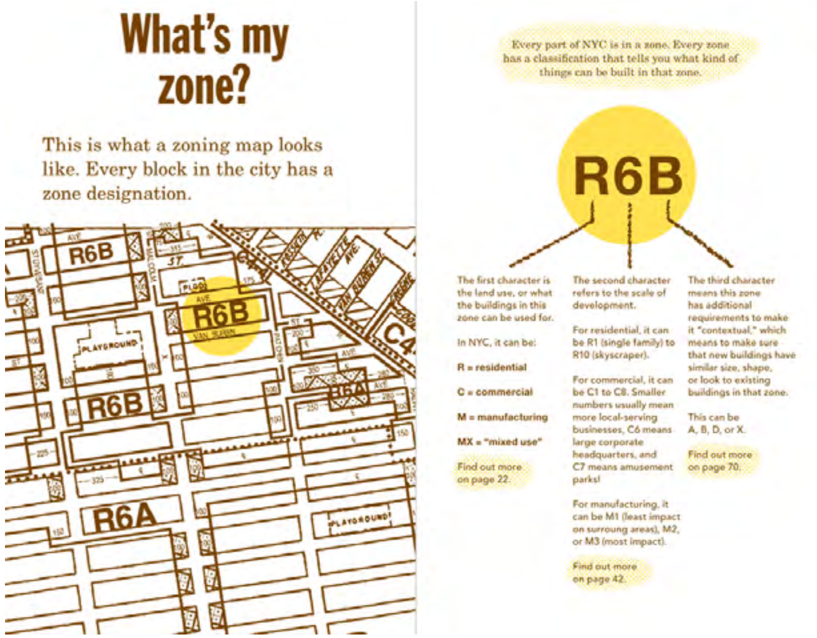



Figure 10: What's My Zone?

tion and twenty years later, established a City Planning Commission which was responsible for preparing spatial plans and approving amendments to the initial zoning resolution. Rather than a federal policy directive, the City Planning Commission and the Department of City Planning operate under rules in Title 62 of the Rules of the City of New York (City of New York 2014). Both organisations are responsible for the orderly growth and development of the city, in a manner that supports the multifaceted needs of its population.

Zoning is a key feature of the US urban planning system and it is used to direct land use, development density, building height and appearance. All land in New York City falls into one of four zones: residential, commercial, manufacturing, or mixed use; however a "special district" (of which there are currently 60) can also be declared. Zoning plans for each borough allocate land with a code comprising three characters. As indicated in figure 10, the first character is a letter explaining the type of land use, the second character is a number indicating the scale of allowable development; and the third character is a letter indicating any contextual requirements (Architectural League 2014).

Application of the Zoning Resolution of the City of New York is a topical subject at present, firstly on account of the large areas of the city that were rezoned under the previous Mayoral administration of Michael Bloomberg; and partly due to increased trading of so called air rights. If in London the current trend in property 'value-adding' is all about mega-basements, in New York City, the speculative property market has always had a greater focus on view. In other words, while apartment blocks with a view of the Thames do attract a premium in London, in New York the premium on a view is even greater. This has led to a surge in trading in air rights – a transferable (and saleable) commodity. As the New York Times set out in a recent article called "the Great Air Race", Transferable Development Rights (TDRs)

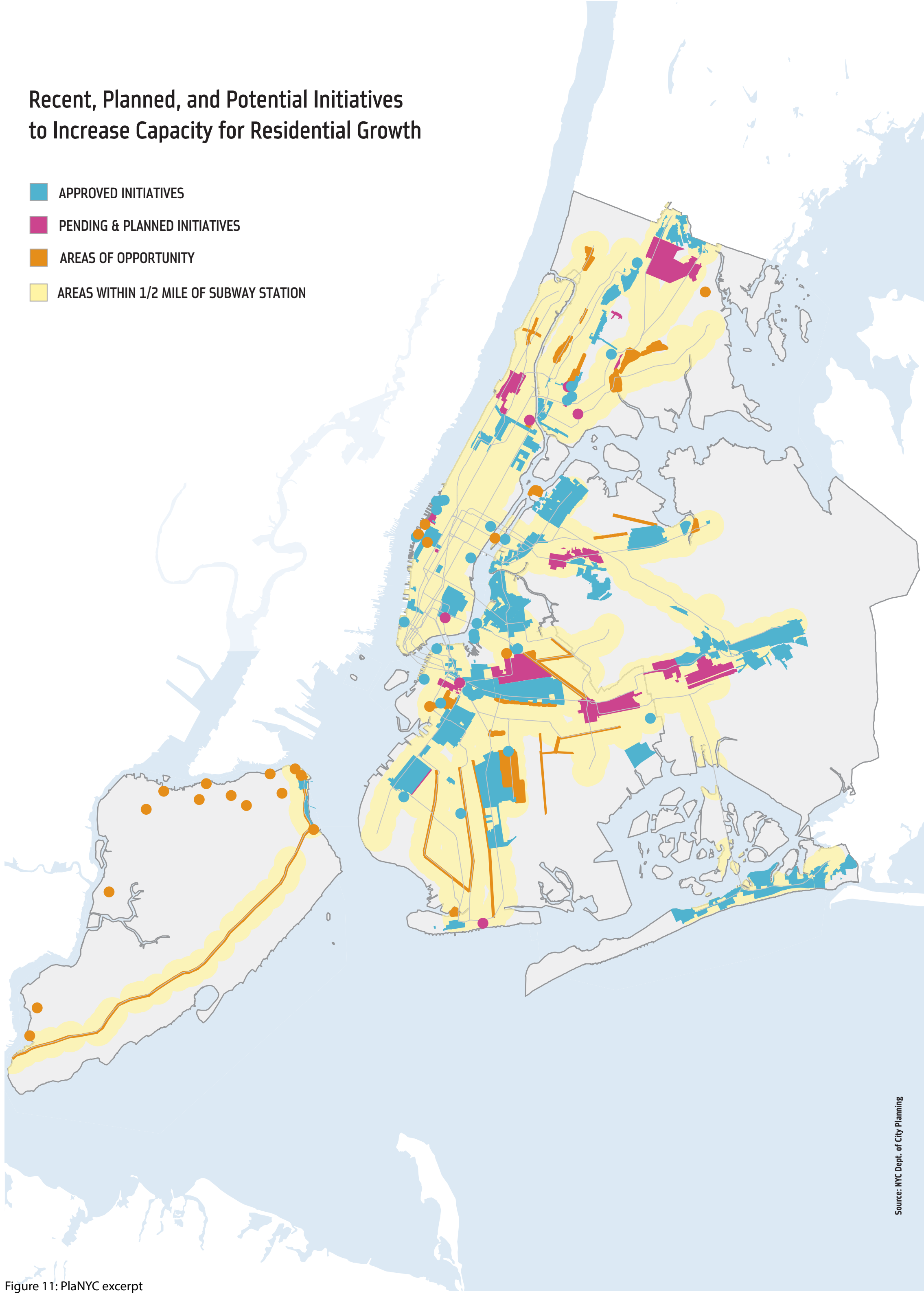



Figure 11: PlaNYC excerpt

are a saleable commodity produced as a result of the city zoning regulations that established density quotas for every block (Finn 2013). The restrictions are defined by a Floor-Area-Ratio (FAR) that determines a building's permissible bulk. Any unused or excess development rights can be quantified and sold from one buildable lot to another, becoming a key influencing factor in a vertical transformation of the city's skyline. As Finn explains, "With Manhattan's skyscraper-proof bedrock in finite supply and the city's fixation on housing and envelope-pushing office buildings on the upswing … the sky is not only the limit, it's the solution".

Overlaying the regulatory planning system, PlaNYC was released in 2007 and revised in 2011 with the objective of setting a 2030 vision for a "A greener, greater New York" (figure 11).

In order to improve New York City, the plan sets out the following objectives:

- Housing and Neighborhoods - Create homes for almost a million more New Yorkers while making housing and neighborhoods more affordable and sustainable;
- Brownfields - Clean up all contaminated land in New York City;
- Parks and Public Space - Ensure all New Yorkers live within a 10-minute walk of a park;
- Waterways - Improve the quality of our waterways to increase opportunities for recreation and restore coastal ecosystems;
- Water Supply - Ensure the high quality and reliability of our water supply system;
- Energy - Reduce energy consumption and make our energy systems cleaner and more reliable;
- Transportation - Expand sustainable transportation choices and ensure the reliability and high quality of our transportation network;
- Air Quality - Achieve the cleanest air quality of any big U.S. city;
- Solid Waste - Divert 75% of our solid waste from landfills;
- Climate Change - Reduce greenhouse gas emissions by more than 30% ; and
- Increase the resilience of our communities, natural systems, and infrastructure to climate risks.

Thus, despite their very different approaches to planning, both London and New York apparently share similar objectives for improving the quality of their urban environments. The two cities are also similar in not having prepared any underground spatial planning or design strategies. In this respect, they are not alone - very few cities across the world have such spatial land use policies or design standards for their underground spaces.

The notable exceptions to this are Helsinki, Montreal and the Municipality of Zwolle in the Netherlands. Additionally, Singapore is currently in the process of developing it's own guidelines that will attempt to identify opportunities for underground pedestrian network uses, infrastructure networks, housing utility plant and masterplanned spaces of varying land uses.

There are several factors that could be said to influence the limited attention underground planning receives from policy makers:

- A lower level of public interest than above ground buildings as underground spaces are considered "out of sight, out of mind";
- Limited interaction with underground spaces aside from transport;
- An emphasis on outward facing design in the planning process ranging from stakeholders critiquing contextual design response, through to acting as "taste police"; and
- Underground spaces being considered technical solutions on which stakeholders have a lower level of knowledge and correspondingly, lower expectation of amenity.



## CHALLENGES TO DELIVERY

### Perceptions of underground space

The 1926 film Metropolis by director Fritz Lang perhaps best encapsulates an exaggerated societal view of the contrast between above and below ground spaces. Though a narrative on society and industrialization, the film also clearly illustrates the contrast between a positive, light filled Metropolis of sky scrapers with its highest echelons playing in a heavenly "Club of the Sons", whilst below ground a dark, foreboding worker's city toils to support the beauty above it.

In their book Underground Infrastructures Planning, Design and Construction, Goel et al. provide an assertion that "For common people, the idea or working of living underground elicits a negative (emotional) reaction. Negative associations with underground space generally include darkness combined with humid, stale air, and no sunlight.

Among the most powerful associations (emotions) are those related to death and burial or fear of entrapment from structural collapse. Other negative associations (fears) arise in relation to feeling lost or disoriented, as normal reference points such as the ground, sky, sun, and adjacent objects and spaces cannot be seen. Also, with no direct view of the outdoors there may be a loss of connection with the natural world and no stimulation from the variety of changing weather conditions and sunlight. Physiological concerns with the underground focus pri-

Figure 12: metropolis (1926) Subterranean worker's city

marily on the lack of natural light and poor ventilation. People want to see sun and open sky. They do not want to feel like prisoners in underground facilities.

Continuing concern over placing people underground indicates that some of the historic images of dark, damp environments linger in our minds, even though modern technology has overcome many of these concerns. The generally negative reaction to underground space has forced designers and researchers to attempt to overcome these perceptions. "Adaptation to live in well-built underground openings takes some time" (Goel et al., pages 23 – 24, 2012).

Although Goel et al's description of common psychological and physiological considerations for underground spaces does not reference any specific user surveys, their assertion is considered reasonable for most populations. However, society evolves in response to its habitat and there are many positive examples of human interaction with underground spaces. The historic context of Londoners seeking shelter in underground spaces might for example, invoke a perception of refuge and comfort rather than confinement. Similarly in the harsh Canadian winters, Montreal's underground pedestrian walkways help people move more comfortably around the city and the network is seen as a desirable alternative to walking at street level, exposed to the elements. By contrast, the perception of crime on the New York subway system in the 1980s might be considered to influence people's attitudes towards the safety of underground, public spaces today.

In her book, New York Underground: The Anatomy of a City, Julia Solis writes of attitudes towards disused underground spaces, post the September 2011 attacks: "The attacks have had a profound effect on new York's underworld, an area that now seems rife with threats. Here, in an uninhabited realm, dark and unfamiliar to most New Yorkers, the city appears particularly vulnerable" (p.5 Solis, 2004). However, New York is turning part of this underworld into a positive public space, as illustrated by the case study on the Lowline.

### Skills and challenges

Another of the challenges to delivery of more high quality underground spaces is a depleted skills base capable of resolving the challenging logistics of working in densely developed cities. To deal with the first of these issues, the Crossrail project in London committed to building a 'Tunnelling and Underground Construction Academy' as one of its first objectives. This is a 'purpose-built training facility that supports the key skills required to work in tunnel excavation, underground construction and infrastructure' (http://www.crossrail.co.uk/careers/tuca) which has been established in recognition of the increasing demand for, in particular tunnelling, skills with a steady stream of apprentices passing through the academy and getting jobs with Crossrail and on other infrastructure projects. However, it is hard to tell how many graduates are moving into other types of underground construction such as basement excavation for mixed-use developments, as opposed to tunneling for utilities.

In New York, the special status and reputation of the 'Sand Hogs' within the wider construction industry has perhaps seen a more steady supply of labour, coupled with the fact that many families will pass the skills down through the generations. However, securing global skills and learning from geographies where tunnelling and underground construction is more prevalent, particularly in Europe, will be vital to securing the skills that will be needed to deliver an increased amount of subterranean construction.



There are also shared logistics challenges in the two cities. One issue is a combination of spoil (rubble) removal and access / ventilation shafts. The former creates significant vehicle movements and the large construction lorries typically engaged in this work are often cited as one of the biggest causes of cycling deaths on the roads of London (Walker, 2103). A recent study prepared for the Royal Borough of Kensington and Chelsea by Alan Baxter & Associates LLP estimates that a single storey domestic basement of 300sqm will generate in excess of 300 lorry movements alone. (Gardiner, 2014). The ability to remove this spoil from within the city limits is increasingly more difficult, although both London and New York have invested in the facilities necessary to make use of their rivers for this activity. In London, there is now a concern that the river itself will start to be congested by barge movements removing material from the largest tunneling projects. In New York, the "muck" from the various underground tunneling projects is put to good use landscaping public parks and golf courses or crushed for re-use in other construction projects, including land reclamation. Whilst difficult to remove, underground construction waste therefore has a recognised value that creates a symbiotic relationship between underground projects and above ground environments (http://newyork.thecityatlas.org/lifestyle/why-new-york-has-the-most-valuable-muck-in-the-world/).

### Integration with surface

The interface between the above and below ground realms appears to be a critical factor in the acceptability and success of underground spaces. In cases where there is a seamless route or movement network between spaces, there is a correlating level of patronage and footfall. It is no coincidence that the main spaces that do not fall into the category of simple building basements tend to be linked to major public transit nodes, such as Canary Wharf in London and the World Trade Centre Transit currently being completed in New York. These locations generate significant footfall, and are natural locations for the types of convenience retail that can be successful in underground spaces.

The issue in the use of any building is how you can move people vertically within the building, and any uses where people need to move around will try to limit the number of levels over which the building operates. Getting this circulation right is vital to success. The case studies explored in this paper combine many different approaches, from simple elevator or escalator cores, to the use of multilevel buildings to link the above and below ground levels.

Where there is the potential for the exploitation of underground space as a standalone destination, equivalent landmark entrances are required to highlight to people that this is the entrance to a below ground space worth visiting and exploring. This is a common feature in the many basement restaurants, clubs and bars that are increasingly popular in both London and New York.

However, there can also be concerns about the safety of underground spaces where links to the surface, particularly for evacuation, are limited or unclear. Clearly any scheme has to meet relevant building codes and evacuation standards, but in New York, plans to convert the disused but stunning City Hall Subway station (figure 13) into the New York transit museum were abandoned after the September 11, 2001 terrorist attacks in the city (http://jalopnik.com/5684329/how-to-see-new-yorks-secret-city-hall-subway-stop), presumably as a result of the perceived increased risk that such spaces bring.

Figure 13: City Hall Subway Station, New York

It is clear that the technical challenges and prevailing planning regimes are not the only constraints on below ground construction. The manner in which spaces interface with the ground level, is therefore also an important consideration in developing underground schemes.

### Costs and funding

One of the greatest challenges to overcome in looking to expand the use of underground spaces is the increased cost of construction in the subterranean environment.

Nearly all decisions in real estate are driven by land values. In London, basements were once a common feature of houses built before the First World War, but afterwards with the relatively cheap availability of land, their popularity diminished. Today they are seeing a resurgence as land values are being driven higher by a reduced availability of land. In other parts of Europe they have been more popular as development is more likely to be constrained by height, so a basement level is a good way of increasing area without risking planning infringements. However, in New York, the relative difficulty and cost of digging out basements coupled with the fact that adding a storey on top is likely to add more value than when it is underneath, have meant that basements have always been less popular.

Where basements are constructed, they have often been relegated to use as car parking, where a loss of daylight and view is unimportant. This typology is of particular relevance when contrasting London and New York. In London, a tipping point at which car parking is an economical land use within the central area has been passed, whereas in New York there is still a sound economic model for retaining above- ground parking garages and structures.



Alternatively, below ground spaces have been used for storage, both at a domestic scale and also on a commercial basis with many archive companies taking advantage of the ease of temperature and humidity control in subterranean spaces to store documents. This income-generating use of space is in contrast to a more typical model where uses that may generate less income are relegated to below ground floors, to maximise above ground floorspace for more valuable uses. This economic model for determining when underground construction is viable has further reinforced the popularity of this approach in London in contrast to New York, where re-zoning has had the opposite effect of encouraging and stimulating more above-ground development.

## CONCLUSIONS

So, in conclusion, what lessons can be drawn from New York and London? It is clear that the underlying geology of a city has a major impact on the approach that is taken to underground spaces. Those areas that have relatively easy to dig substrata, such as clay or chalk, will see an increase in the level of subterranean construction over those places where there is tough bedrock that prevents easy tunneling. Historically this has been particularly important in determining how a city has approached its subterranean development. However, it is not only about geology.

Planning policy also has a major impact on the development of the underground. Generally however, it is an unintended consequence rather than a pro-active policy decision. For example, constraints on height may encourage developers to look to basement levels as a way to accommodate more floorspace on a plot. Otherwise, despite the climactic advantages of below ground spaces, the increased construction complexity and cost coupled with the specialist skills required, means that most developers would choose to build up rather than down.

There are noticeable exceptions however. Major infrastructure is almost universally placed below the streets of the city, and where this involves moving people, there is a demonstrable opportunity to incorporate underground spaces into their onward connections and routes. Outside of this use however, aside from some specialist applications such as document storage, or destination attractions (disused stations etc), underground space tends to be directly related to an above ground use or occupier – the traditional building basement. In some cases these can be extensive, such as the five-storey basement at the new Edwardian Hotel in Leicester Square, London (see case studies), in others they may only be a single level.

What is clear though is that the subterranean environment, while bringing technical delivery challenges, does offer some advantages to certain categories of use. Yet the need for extensive subterranean masterplanning of London and New York in either city is not really made, although there is some provision for elements of such a device in, for example, the process of 'safeguarding' for new underground transit routes in London. In general it seems that the appetite for comprehensive guidance in relation to the design of underground space is absent, and the only concern from the public at large is the impact that construction and operation will have on surrounding neighbourhoods. The challenges in delivering more underground spaces in future will be around the skills, capacity and techniques necessary to build, rather than the policy context or economic imperatives to start developing downwards.

## CASE STUDIES

### Rockefeller Center, New York

The iconic Rockefeller Center in New York commenced construction in 1930 and is a complex of 19 commercial buildings covering 22 acres (89,000 m2) and is declared a National Historic Landmark.

In 1999 the basement level below the Rockefeller Center used by commuters for shortcutting across the block was refurbished to create a "concourse" with retail shops (Collins, 1999). As shown in figure 14, shops and restaurants line the pedestrian concourse that links six key buildings, a public ice-skating rink, and Concourse entrance is also accessible through a subway station below Sixth Avenue (B D F M trains). Interestingly, the Rockefeller Center management explain on their website that "Although the Concourse has been replicated in hundreds of arcades around the world, it was never commercially successful for the owners until a thorough renovation brightened its spreading network of corridors and passageways" (http://www.rockefellercenter.com/art-and-history/history/concourse/).

### Canary Wharf, London

When the original Canary Wharf complex opened, it was focused on a series of retail podiums linked to tall office and commercial towers that were designed and built in, what was at the time, a new 'North American' style, almost unknown in London, and certainly not seen on such a scale. However, it was always intended that the masterplan would develop over time, and with future phases would come the need to deliver new supporting infrastructure. The Canary Wharf Jubilee line underground station opened in 2000, and was constructed in a former dock by dewatering and then excavating down to the level of the railway lines. This provided an opportunity for some creative architecture, resulting in not only the dramatic cathedral like structure that supports the roof and public gardens that are located on top, but also creates an intermediate level which in turn provides below-ground routes into the basements of a number of the surrounding commercial towers. These routes were lined with retail units, and developed into a significant new shopping plaza for the district – Jubilee Place.

The use of basement level across the site in this way allowed for a quantum of retail that would have otherwise interfered with the commercial zoning and layout of the site, but which is vital to supporting such a dense employment centre, and especially one that is also growing its residential population. The integration with the above ground environment combines simple lift and stair cores, escalators into the building lobbies of commercial towers and also key multi-level buildings that penetrate the ground and provide multi-level occupiers such as department stores and sports clubs. As shown in figure 15, Jubilee Place has glazed roof lights that provide daylight to the mall and provide views to external buildings, thereby assisting pedestrians with orientation (https://www.bdp.com/en/Projects/By-Name/F-L/Jubilee-Place/).

The recent Jubilee Place extension added 25 new retail stores across 44,000 sq. ft. of retail space to Canary Wharf in the form of a primary, below ground mall supplemented by three mezzanine areas with onward connections to adjacent headquarter buildings and the new Jubilee Park. The new retail space links directly to the existing below ground retail concourse and Canary Wharf underground station.

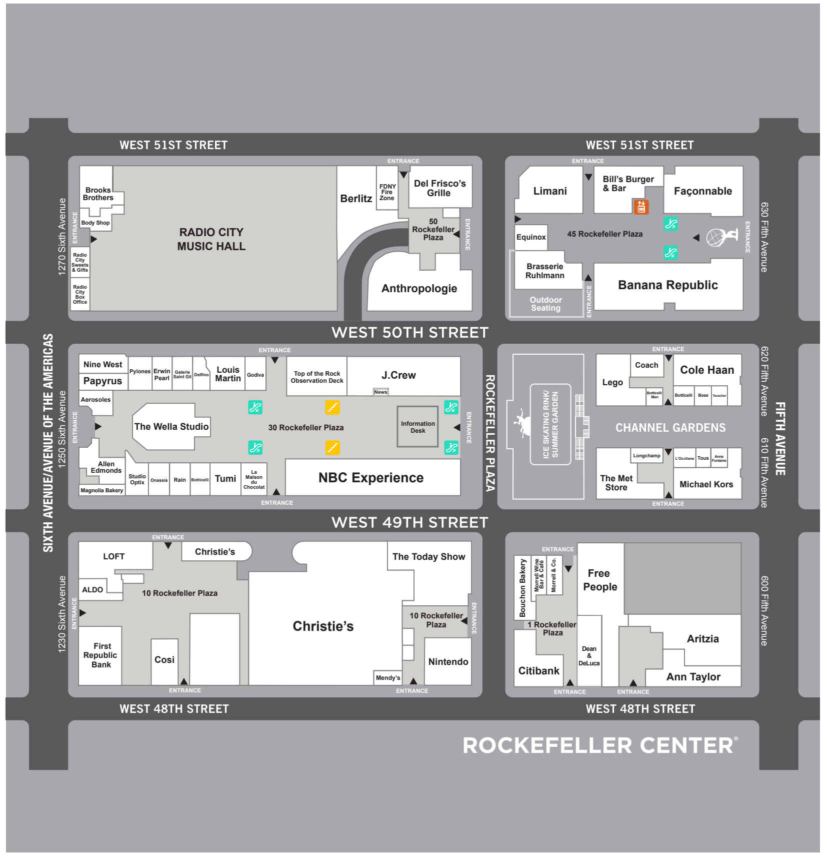



Figure 14: Rockefeller Center Plaza (basement)

### Second Avenue Subway, New York

The Second Avenue Subway project was first mooted in 1929 but has been delayed by recession and war, along with the usual challenges associated with financing and constructing major projects. In 2005, New York State passed the Transportation Bond Act to facilitate the project. Ground officially broke in April 2007, followed several months later by a $1.3 billion federal funding commitment for phase one of the project (http://web.mta.info/capital/sas_alt.html). The Second Avenue Subway is a monumental construction project involving underground explosive excavation as well as use of a TBM (figure 16).

Once complete, the subway will stretch 8.5 miles along the length of Manhattan's East Side, from 125th Street in Harlem to Hanover Square in Lower Manhattan. In addition, a track connection to the existing 63rd Street and Broadway Lines, will allow a second subway line to provide direct service from East Harlem and the Upper East Side to West Midtown via the Broadway express tracks. The project also involves the construction of 16 new stations with climate control and disabled access (features not often found at subway stations), which will also provide transfers to other subway and commuter rail lines.

The first phase is estimated to be completed by 2016 and serve approximately 200,000 daily riders, decrease crowding on the Lexington Avenue Line by up to 13%, and reduce travel time by 10 minutes or more for many passengers traveling from the Upper East Side.

However, in addition to the transit connectivity and capacity benefits, this underground infrastructure will provide a stimulus for Transit Oriented Development, and potentially create a modal shift from private cars to public transport.

Figure 15: Jubilee Place at ground level

### Crossrail, London

Crossrail is Europe's largest infrastructure project, the new railway will cover over 100km of track including 21km of new twin-bore rail tunnels and nine new stations (all references this section www.crossrail.co.uk). When complete in 2018 the new railway will increase London's rail-based transport network capacity by 10 per cent, reduce journey times, ease congestion and improve connections for approximately 200 million passenger journeys annually. The new rolling stock for the rail line will be around 200 metres long and able to accommodate up to 1,500 passengers. New Crossrail stations will be built at Paddington, Bond Street, Tottenham Court Road, Farringdon, Liverpool Street, Whitechapel, Canary Wharf, Custom House and Woolwich. The new stations are large scale, contemporary and technologically advanced facilities more akin to modern airports than train terminals.

The proposed Crossrail development was granted government planning consent using a special hybrid bill of parliament in 2005. Bills are policy proposals that with approval from the House of Lords, House of Commons then formal approval by the monarch ('Royal Assent') become law as an Act of Parliament. Hybrid bills are those that affect individuals directly as well as the broader public through their nationally significant status (www.parliament.uk). The Crossrail Bill contained a description of the proposed works, their location and any land needed temporarily or permanently to deliver the project. The process of obtaining a parliamentary bill for Crossrail has been used periodically for very large rail and other major projects such as the Channel Tunnel, the Channel Tunnel Rail Link and the Dartford Tunnel. Individuals and organisations can oppose the bill or to seek its amendment before a Select Committee in either or both the House of Commons and House of Lords. Although the project has received planning consent, in parallel to construction there is an ongoing process of submitting application to local planning authorities for the approval of design details and minor amendments.

Crossrail is being constructed with eight TBMs that weave their way between existing underground lines, sewers, utilities and building foundations at depths of up to 40 metres. The custom made 1,000 ton and 150 metre long machines are giant underground factories that are not just tunneling, but removing the muck

Figure 16: Construction works on Second Avenue Subway

and creating a sealed concrete tunnel as they go. Each machine has a rotating cutter head at the front, and a series of trailers behind, housing all the mechanical and electrical equipment required for the excavation of material. Almost all of the excavated material will be reused, with three quarters being delivered by rail and ship to Wallasea Island in Essex to create a new nature park. At Canary Wharf alone, more than 300,000 tons of material has been excavated, with 100 million litres of water pumped out of North Dock to create a station box extending nearly 30 metres below the dock floor.

Similar to the Second Avenue subway, the benefits of this underground infrastructure extend to broader urban regeneration across the city.

### Lowline, New York

The Lowline (http://www.thelowline.org) proposes to use solar technology to illuminate an historic trolley terminal on the Lower East Side of New York City, in order to create an underground park (figure 18). The site was opened in 1908 for trolley car passengers, but has been unused since 1948 when the service was discontinued. Despite such a long period of neglect, the space is said to still retain beautiful original features such as cobblestones and vaulted ceilings. It is also adjacent to an existing subway station to encourage people from all across the city to visit and enjoy the park, even in winter. Although funding and planning approval are yet to be finalized, the project appears to have strong public backing in principle. If opened in 2017 as scheduled, the Lowline could act as a game changer in people's perceptions of underground public spaces.

### Edwardian Hotel, Leicester Square, London

Planning consent was recently granted for a new hotel on the perimeter of London's famous Leicester Square. The development site is tightly bound by Leicester Square and four narrow streets with vehicular service only access, supplemented by large volumes of pedestrian traffic. The project controversially proposes the demolition of existing buildings including a cinema and the construction in their place of a new 10-storey building with five basement levels occupying an entire city block to provide a 360 bedroom hotel (with ancillary facilities including function rooms, spa, three ground-floor restaurants and bars) and a two-screen cinema with 407 seat and 139 seat auditoriums (a slight variation to the description of the originally consented scheme).

What makes the project interesting is that one third of its height is located below ground (figure 19), maximising the floor area ratio and property value without creating an overly tall building that could otherwise impede protected views. The site is designated in local planning policy as being located in a Landmark Viewing corridor; plus the Wider Setting Consultation Area of Protected Vistas at the Palace of Westminster; and in two aspects from Parliament Hill.

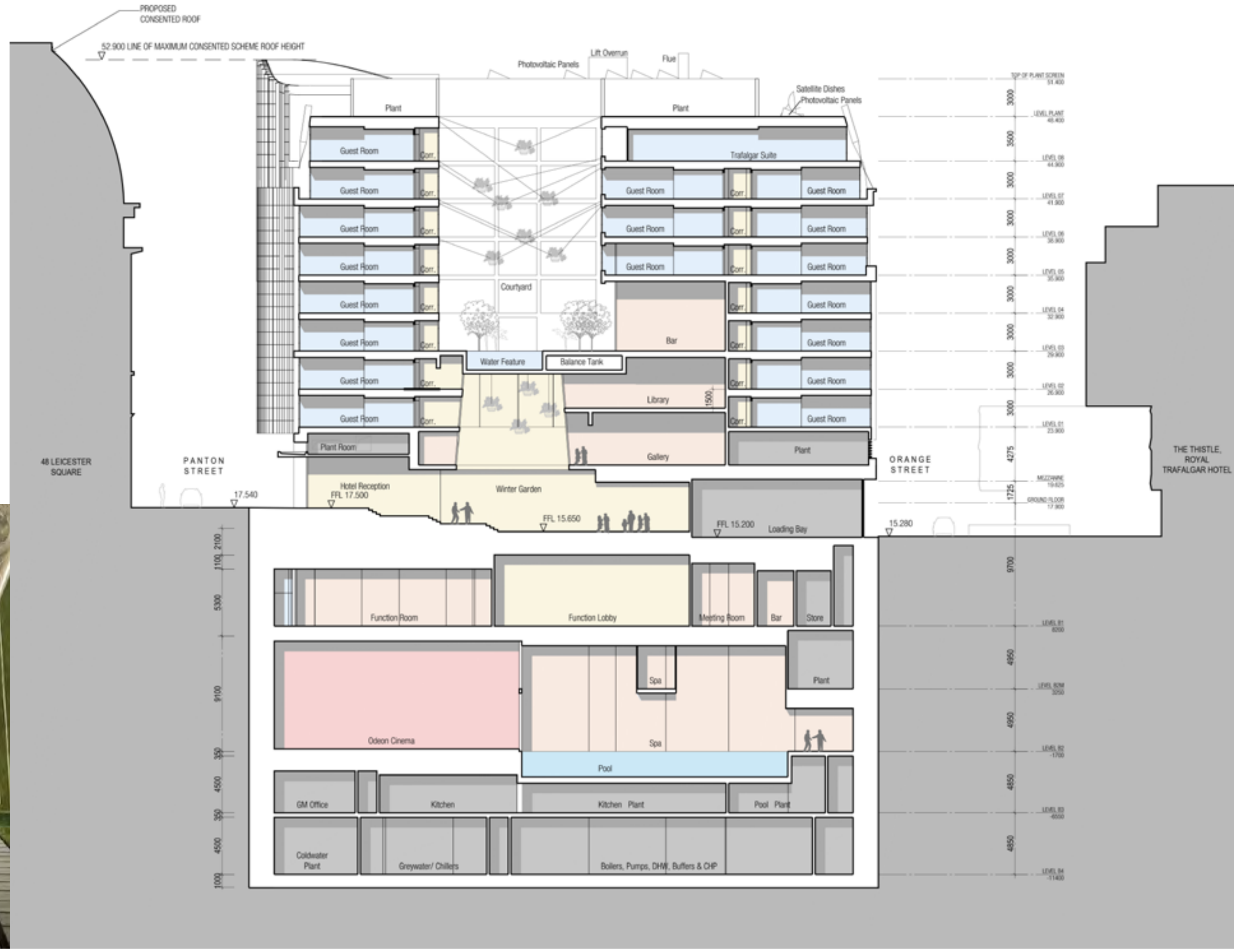



Figure 17: Proposed Crossrail station, Canary Wharf (left)

Figure 18: Lowline underground park (right)

Figure 19: Proposed hotel section showing extent of basement level use.

## AUTHORS

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Elizabeth Reynolds is an urban planner with international experience in large scale regeneration and infrastructure projects. In 2011 Elizabeth established Urben, a London based planning and design practice focused on making cities better places. Since co-authoring 'NY-Lon Underground', Urben has been granted a Design Innovation Award by the Royal College of Arts to investigate how disused construction grout shafts could be converted into commercial and community uses and in November 2014 Elizabeth also spoke at the Commonwealth Association of Planners conference in Singapore, where she presented a paper on 'Living underground - is it science or fiction.

**Paul Reynolds**

Paul is an Urban Designer and Chartered Landscape Architect specialized in regeneration, masterplanning and public realm work, primarily in London. Paul's experience includes working with local authorities, central government and private developers on major projects such as Oxford Circus and Euston Station Masterplan. In 2012 Paul was elected as Chair of the Urban Design Group. He is also a member of the Urban Land Institute (ULI) and a Fellow of the Royal Society of Arts (FRSA). Paul is also an Expert Advisor to the Northern Ireland Ministerial Advisory Group on Architecture and the Built Environment, Chair of the London Borough of Hackney design review panel, and a member of the Islington Panel. He regularly contributes to professional journals and publications, and speaks around the world at industry conferences.

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Figure 16
Construction works on Second Avenue Subway http://assets.nydailynews.com/polopoly_fs/1.1273262.1361833458!/img/httpImage/image.jpg_gen/derivatives/gallery_1200/east-side-subway-construction.jpg

Figure 17
Proposed Crossrail Station, Canary Wharf http://www.building4change.com/filelibrary/news/Canary_wharf_crossrail_design_229.jpg

Figure 18
Proposed Lowline underground park http://www.thelowline.org

Figure 19
Leicester Square Hotel Project City of Westminster (2013) http://idoxpa.westminster.gov.uk/online-applications/applicationDetails.do?activeTab=summary&keyVal=MQQYHARPZ5000

# NAPLES AND ITS PARALLEL CITY

Vincenzo De Stefano · Valerio Di Pinto · Carlo Gerundo

## BRIEF HISTORY OF UNDERGROUND SPACES IN NAPLES

Naples is the capital of the Italian region of Campania and the third-largest municipality in Italy. Its metropolitan area is one of the most populated in Europe. The city rises up in the middle of an extremely elaborate and characteristic volcanic region that includes the *Somma-Vesuvius* crater complex to the east, and dozens of craters in the *Campi Flegrei* volcanic district, to the west. Almost the whole area where the most densely built conurbation lies was created by the volcanic activity of the *Campi Flegrei*, while the eruptions of *Somma-Vesuvius* gave origin to the eastern outlying areas.

For these reasons, Naples and its historical centre sits on a bank madeup of the volcanic rock known as *yellow tuff*, never less than 10 meters thick. The geological subsoil structure has undoubtedly been a critical factor in the city's development, determining, since its establishment, the main building technology (Figure 1).

Moreover, Naples can be proud of a very long urban history. The city was founded in the VII century BC as a Rhodian colony named *Palaepolis*, and was built in the traditional archaic settlement shape: a dock downstream of a hill village. *Palepolis* maintained its independence for over four centuries, despite the Etruscan pressure, till 474 BC, when a new colony, named *Neapolis*, was established. The new town was settled in a plain by the sea, enclosed by a hill system and two rivers (no longer visible), large enough to allow the development of a well-structured urban texture. During the III century BC, a defending wall system started to be built. This process gave birth to the methodical extraction of yellow *tuff* from Naples subsoil as a building material, which engendered the former and oldest artificial hypogean cavities[1]. The persisting *tuff* mining over the centuries gave birth to a complex system of underground spaces, nowadays consisting of more than 800 elements for an overall volume of 6.000.000 $m^3$, and, at the same time, allowed the development of a building technology based on the *tuff* bricks that had been regularly used and improved till the first half of the XX century. In this way, the transformation of the visible city has gone hand in hand with the enlargement of the invisible one.

In the *Pax Augusti* era (29 BC - AD 180) *Neapolis* suffered from urban decay. In this period the existing hypogean cavities were often re-used as early Christian Basilicas. After the Western Roman Empire downfall (AD 476) the city experienced a new period of development and prosperity. From the year 1000 to the late Renaissance, Naples was conquered and governed by many foreign powers (Angevins, Normans, Aragons), which gradually expanded the city boundary and increased the existing settlements. During the reign of Charles V of Habsburg (1516-1558) the city doubled in size, compared with the pre-imperial one, and, simultaneously, the underground spaces system was hugely enlarged. Naples and its population kept on growing during the next two centuries and new suburbs were built outside the walls, in the external belt of the old city. This massive building construction led to very intense mining activity to extract the yellow *tuff* from the subsoil. During the Spanish Bourbons domination (1734-1861) Naples became one of the most important European capitals, experiencing the best period of its history, in terms of expansion, magnificence and wealth. Great urban infrastructure was built to improve the hygienic conditions of a large part of the urban area, giving it the modern im-

1 It refers to the underground network made of passages, tunnel, wells, tanks, and variable-size cavities.

age we know today. In the same way, underground networks and cavities were improved and visionary building works were designed, like the underground tunnel between the Royal Palace and the seaside, already known as the *Tunnel Borbonico*.

In 1861 Naples and  and the area it ruled was handed over to the new Kingdom of Italy and in 1884 the Italian Government enacted a law in order to solve critical hygiene problems that had caused a Cholera epidemic. Huge dismemberment and reconstruction works were planned and realized, and many historical neighbourhoods definitively changed into modern urban settlements (Figure 2).

The XX century was the age of planning for Naples but the city plans adopted were generally chaotic and ineffective.

In the period between the end of the XIX and the beginning of the XX century, population increase produced an urban growth to the east and west of the old core and new underground infrastructure was built in order to link the city centre with its peripheries. Two tunnels were dug under *Posillipo* hill to join the western suburbs to the historic city (1884 - 1925) and one other tunnel was realized piercing *Pizzofalcone* hill (1929) so as to get a faster access to the eastern periphery. In addition, from 1909 to 1925, important underground tunnels were made to complete the Rome-Naples railway and the Funicular railway system.

After the Second World War, during which the hypogean cavities were used as air-raid shelters, uncontrolled development emerged as the key urban issue. The city was overwhelmed by real estate speculation. From the 1950s, concrete became the most-used building technology: the cavities were no more exploited to extract *yellow tuff* and began to be used as urban garbage dumps. A renewed attention to the underground spaces came in the late 1960s, when a new underground mobility system was drawn up. It is still under construction and, during the last 40 years, has allowed the identification of many hypogean cavities. However, none of them has been integrated into the underground mobility system.

In the '90s, several alarming ground collapses occurred in different neighborhoods of the city and called attention to the poor condition of the Naples subsoil. These experiences have shown how an underground spaces planning process is absolutely necessary to ensure a careful and, at the same time, profitable use of subsoil resources in order to reduce ground collapse risk and to ensure permitted uses compatible with the overground city life.

To sum up, the history of Naples proves that the close link between the over- and underground spaces during the millennia is the extraordinary condition that distinguishes Naples from all the other metropolitan areas in Europe. It is unusual, in fact, to find a city, as Naples is, where the relationship between overground activities and underground spaces has always been highly symbiotic. Nowadays Naples is still influenced by its "underground twin" not only for hydrogeological risk connected to underground spaces instability, but also because in the last decades some positive attempts, analyzed in-depth in the following paragraphs, were made to regenerate and requalify its underground cavities.



## USE, RE-USE, AND ABUSE OF THE UNDERGROUND CITY

Naples urban area, as mentioned above, has a huge heritage of underground spaces both artificial and natural, made up of *tuff* hypogean cavities, quarried sandstone caverns, tunnels, Greek and Roman tombs, and aqueducts, which constitute a "parallel city" laid down beneath the bustling streets of the ancient city.

Minimal attention had been paid to the Naples subsoil by local government and scientific community in the past till the end of the 1960s when the condition of underground spaces started to be investigated following many road surface collapses and damage to buildings in the old city centre.

A research study developed in 1967 revealed the existence of cavities of 220.000 square meters in Naples subsoil. They "became" more than three times as wide (700.000 square meters) thirty years later, according to a study carried out in 1997. These two studies were published by Naples Municipality after two committees had been created in order to study the city subsoil through the cavity census. In the first study, 366 caves were recorded whilst in the second one 472 were detected, across 13 districts. The existing census of underground cavities reported that in the *Stella* district there are 62 man-made cavities occupying a volume of 160.000 cubic metres. Another 86 caverns are beneath *San Carlo all'Arena*, 85 in the *Avvocata* district, 34 in *San Fernando* and others in the *Chiaia* district, 32 beneath *San Lorenzo* and 28 under *Posillipo*. In 2007 the association "Naples Underground" presented an underground spaces report arguing that there are approximately 1600 existing cavities but only 800 are presently identified.

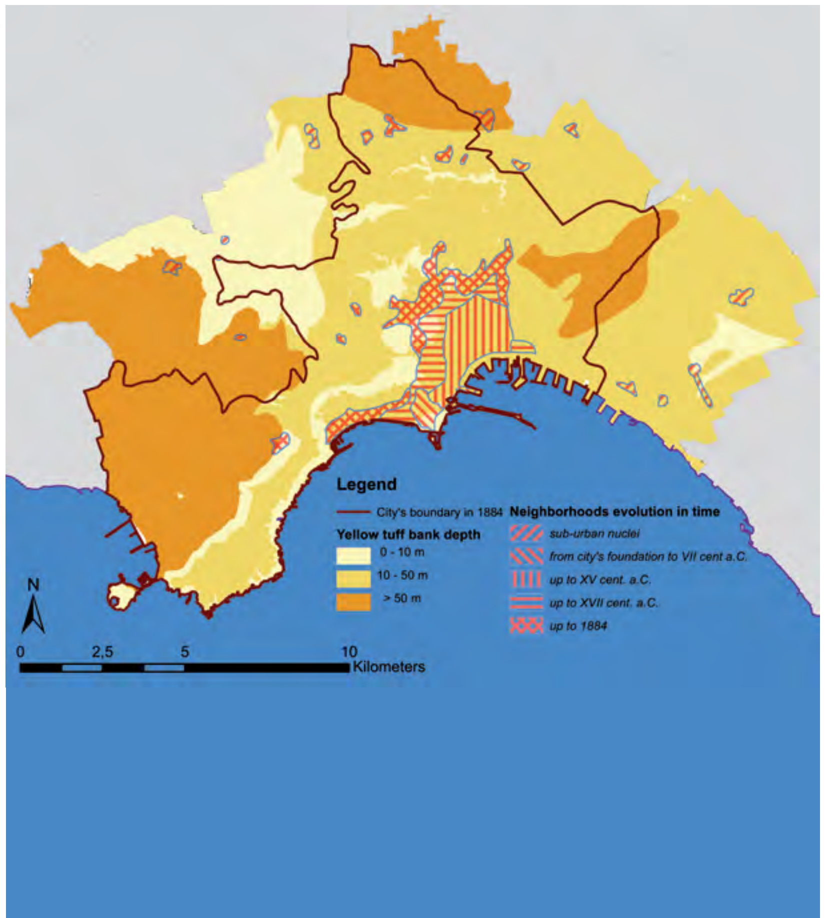


Figure 1: Time scale and *tuff* bank depth in Naples.

The multitude and variety of hypogean cavities make it difficult to present an overall view of these underground spaces. It is possible to categorize the artificial caves in Naples subsoil into the following sections:

- Tombs and places of worship;
- Rain tanks;
- Aqueducts;
- Tuff caves;
- *Lapillus* and *Pozzolana* caves;
- Tunnels and walking caves.

This paper does not take into account excavation works to realize modern water supply, sewer and technological systems because they go beyond the purpose of the study and do not illustrate anything particularly special about Naples.

Most ancient artificial caves were dug to build burial places. In 1950, two rock-cut tombs were discovered in *Stella* district. They are estimated to be 4500 years old and were originally located just outside the city walls. As time went by and the city grew, they were included in the urban perimeter.

The spread of Christianity played an important role in increasing the use of underground caves as burial places. The burial of the mortal remains of the Christian dead has always been regarded as a solemn religious act and it brought about the building of catacombs in the II century AD. The major catacombs in Naples subsoil are, in chronological order:

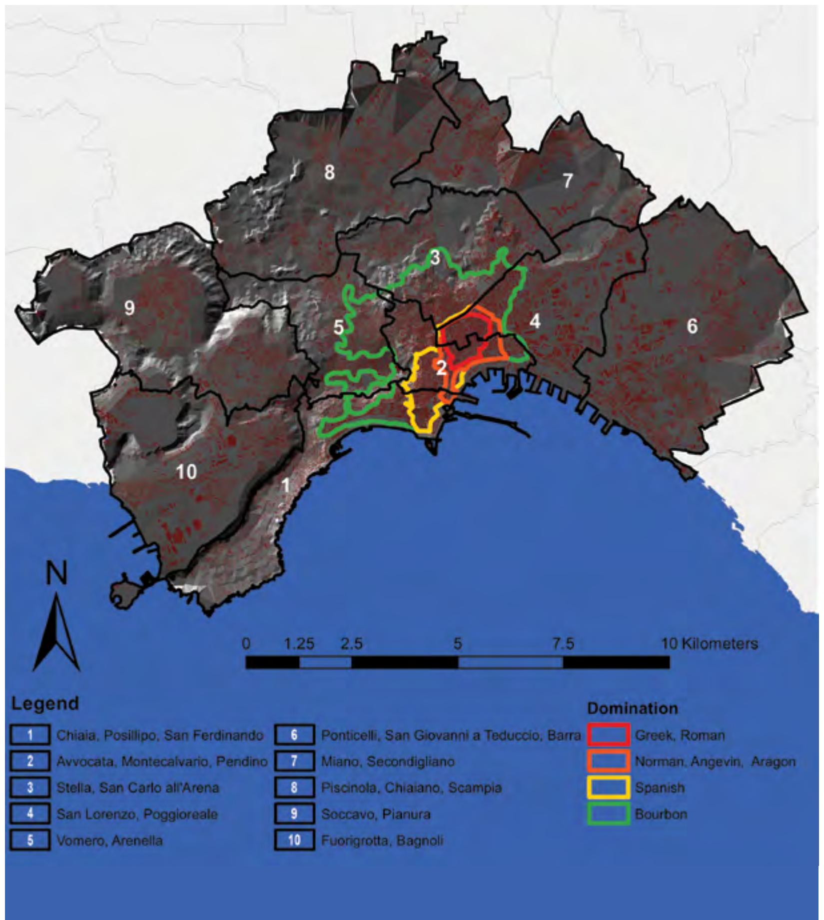


Figure 2: Naples districts and its stages of expansion.

1. Catacomb of *Sant'Arpino*, (II cent.) renamed Catacomb of *San Gennaro* after he was buried there at the beginning of V century (Figure 3);
2. Catacomb of *Sant'Eufebio*, (end of III cent.);
3. Catacomb of *San Severo* (end of IV cent.);
4. Catacomb of *San Gaudioso* (V cent.);
5. Catacomb of *Santa Maria del Pianto* (uncertain date);
6. Catacomb of *San Martino* or *Sant'Eramo* (historical hints as its location cannot be precisely traced).

As also previously discussed, Naples has created links to its cavities and underground spaces from the start. Long hypogean cavities were dug since the Ancient Greek period not only for service infrastructure as holding tanks and Roman aqueducts, but also for leisure and recreation as thermal tanks or theatres. Under the Spanish domination (1588-1615 AD) some royal edicts forbade the introduction of building materials within the city walls to avoid the uncontrolled expansion of its core. In order to avoid penalties and, at the same time, to satisfy the necessity of new building construction, people used to extract *tuff* in the subsoil through already existing wells, extending the existent cisterns for drinking water and building new ones. This type of extraction created a sort of parallel underground city consisting of miles and miles of tunnels, tanks, cavities and narrow channels used as links between other cavities known as *cunicoli*.

In addition to catacombs, a great number of water tanks of various size was dug in Naples subsoil since water supply was one of the first issues that Neapolitan area colonizers had to face. With the increase in demand for water, it was necessary to overcome the dependence on rain water and to build the network of channels and cisterns that now constitute the bulk of underground *cunicoli*.

The first aqueduct that was built was the "Bolla", running about five miles from a hinterland hilly area to *Stadera* district, distributing the water drawn from the river *Sebeto* to the districts of *Dogana, Mercato, Annunziata, Cappella Vecchia and Loreto*.

During the I century AD, under roman Emperor Claudio Nerone, a second aqueduct started to be built; it carried water from the headwaters of the river *Serino* to the *Piscina Mirabilis* in *Baia*, running 92 km, and crossing the whole city. At *Piedigrotta* it forked: one branch crossed lengthwise *Posillipo* Hill to serve the *Gajola*; the other one followed a perpendicular path and ran inside the city to come out in the plain of *Fuorigrotta*.

Moreover, in the XVIII century, a new aqueduct was built to support the existing ones.

*Tuff* was not the only volcanic rock extracted from the underground since ancient times. Lapillus and Pozzolana were also intensely exploited in building works to improve the mechanical qualities of cement mixture.

It is possible to classify the underground cavities on the basis of their entrance type:

- at-grade access;
- access from wells or tunnels.

The last category of underground cavities includes pathways and galleries. The old city core was surrounded by a hilly range, and the creation of connecting routes that could allow a faster transit of people and goods was necessary. The first galleries excavations, carried out by Romans, were the *Crypta Neapolitana* and the *Seiano Grotto*. The first one starts from *Piedigrotta*, crosses the Hill of *Posillipo*, and arrives in the plain of *Fuorigrotta* (Figure 4). The second one goes from *Gajola* to *Coroglio*, traversing the Cape of *Posillipo* (Figure 5). No other underground roads

Figure 3: Catacomb of San Gennaro



were built for a very long time thereafter. In 1855, under the Bourbon Reign, an underground tunnel was planned to link the Royal Palace to the beach of *Chiaia*, passing underneath the Hill of *Pizzofalcone*.

As previously mentioned, in the first half of the XX century, important road and railway galleries were built to connect the city centre and the suburbs which had come up beyond the hill range. The latest excavation of buildings carried out, with modern building techniques, are the tunnels of the Naples Bypass, High Speed Tramway and Underground Metro.

It is possible to say that the most recent and widespread uses of underground spaces in Naples, and more generally in Italy, apart from sporadic tourist initiatives, were directed at improving the quality of both urban and suburban mobility, and then aimed at improving the living conditions of these places. Most of the investment was directed mainly at the implementation of urban and national underground railway routes. Underground parking lots with different design solutions are also gaining popularity.

## PLANNING, PLANNERS, AND THE UNDERGROUND CITY: AN EXAMPLE OF WORST PRACTICE

Underground city planning and the planners' role has never sparked a keen interest in Italy: until 1999, the basic regulation about underground space utilization was limited to a few rules included in the Italian Highway Code (1992) and in its Fulfilment Regulations (1992), mainly focused on preserving road safety. Similarly, other sector-based rules had been introduced in 1993 (related to taxes) and in 1997 (related to the installation of telecommunication networks).

The first general and consistent regulation was the Guideline of Italian Prime Minister dated 1999, also known as *Direttiva Micheli*. It approached the underground space administration as a planning issue, introducing a specific instrument of planning: the General urban plan of underlying utilities, also known by its Italian acronym P.U.G.G.S., required for cities with more than 30.000 inhabitants. Unfortunately, very poorly detailed indications concerning the P.U.G.G.S. subjects and contents are given by the *Direttiva* and consequently only a few cities have drawn up and approved it.

Although Naples is supposed to adopt a P.U.G.G.S., not only has the local administration never fulfilled this obligation, but also scarce attention is paid to the hypogean cavities in the Town Plan, ratified in 1999. Underground spaces are seen simply as potential sources of archaeological discoveries. The Town Plan identifies the undercity as a means to show the relationship between the ancient town and the contemporary one. Anyway, no practical recommendations are given to regulate how historical underground spaces should be linked to urban strategies.

As far as the Town Plan is concerned, functional use of hypogean cavities is only contemplated for underground car parking. Building works inside cavities are permitted and an increase in floor area is allowed, providing that new excavations are prevented and building works do not interfere with vertical walls and ceilings.

The Town Plan commits the historic city centre regulation to specific legislation wherein building typologies are described item by item, but it provides no hint about the hypogean cavities existence and how these spaces have to be used.

Collapses in the undercity periodically wreak havoc overground, and there is no doubt that these events, in the historic city centre, are not due to the instability of the structure of the cavities but to the meager and badly-maintained underground infrastructural system. Recurring water leakages in the aqueduct network and their consequent interaction with pre-existing underground spaces are the main cause of instability, collapses and damage to buildings and, sometimes, to people.

In this context of risk, a deeper knowledge of the location of underground spaces is needed, but it is definitely not enough. An underground spaces use plan is equally necessary to facilitate cavities and wells maintenance work, both to preserve their efficiency and to plan their functional use. On the contrary, poorly planned interventions, without taking into account all the problems of the subsoil system, prevent local administration from both solving subsoil instability problems and ensuring sustainable uses to underground spaces from which Naples and its population could benefit.

Underground spaces, therefore, have to be assessed, monitored, evaluated, planned and managed as other natural resources are. To do that, first of all, new legislation is needed to regulate their development and use.

Figure 4: *Crypta Neapolitana*.

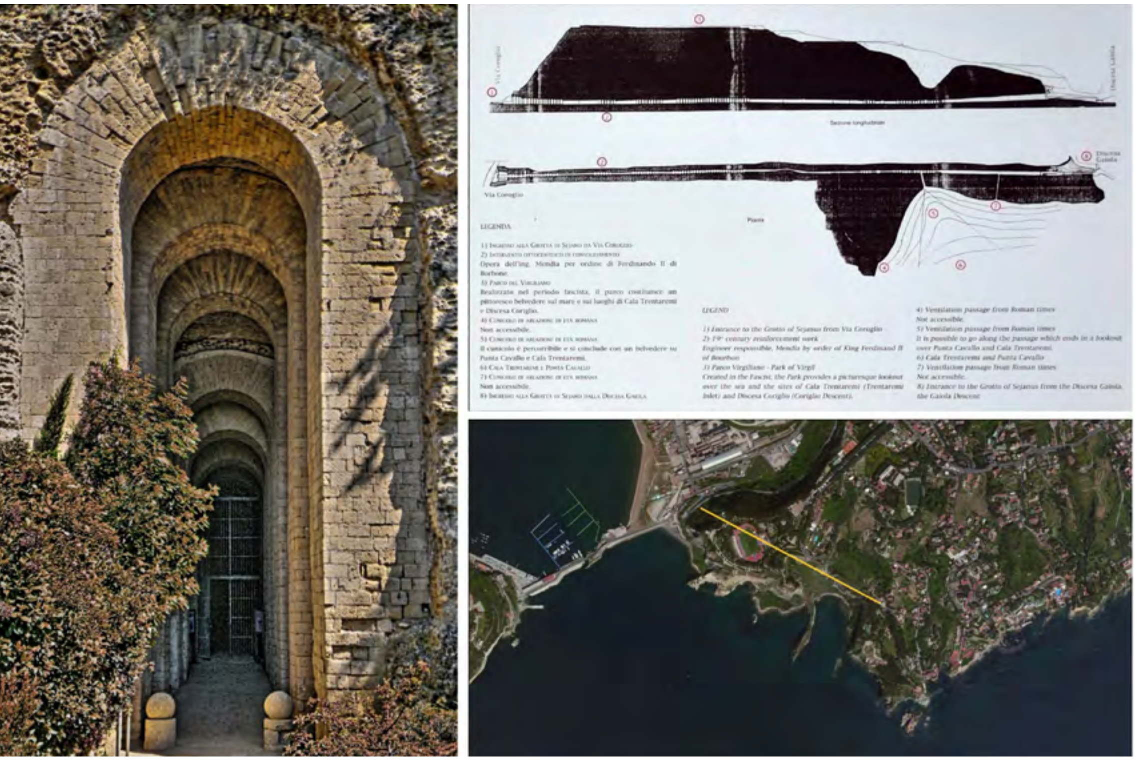

Figure 5: *Seiano* Grotto.

## UNDERGROUND SPACES OWNERSHIP STRUCTURE: ODD CAUSES AND CATASTROPHIC EFFECTS

As seen before, Neapolitan underground spaces could be described as a complex network in a widely integrated system, due to their generative dynamic. Nevertheless, an extraordinary historical fragmentation in property, paired with a tangled jurisdiction, has caused such a diversification in use and confusion in stakeholders that *the network system* is actually more similar to a sizeable set of patchwork tiles (Figure 6).

Jurisdiction and property of Neapolitan underground space had been all-in-one until the Second World War. Before this, in fact, the cavities had been managed by the correspondent foreground land owner, as a natural functional adjacency. It had allowed the linking together of the best part of the cavities in a functional network, operating at least until the first decade of XX century. By the mid-1940s, the need for an efficient set of air-raid shelters led to the requisition of an undefined number of hypogean cavities, especially those that were dug in the yellow tuff bank. The result was not only the impossibility of restoring the property distribution, but also a novel problem of management jurisdiction, which is still an issue today.

Presently we could recognize, in terms of property, five main types of cavity:

1. Cavities of definite municipal property: the space for underlying utilities – basically the layout of the ancient aqueduct, no longer in use;
2. Cavities of definite State ownership, known as *Demanio*: they are the set of cavities certainly used during the Second World War as air-raid shelters, of which there is testimonial evidence;
3. Cavities of definite private property: they are the cavities certainly used by private users during the Second World War, of which there is testimonial evidence – a very limited number;
4. Cavities unused or inaccessible for a long time, generally still in this state before the conflict, without any clear ownership: the precise number is unknown, but they are estimated to be more than those that are used or simply accessible;
5. Cavities in use by private users in recent times without any clear ownership – the majority of the cavities in use.

This fragmentation and ambiguity in property recognition have obviously created a murky management jurisdiction.

Furthermore, at the end of the War, the Italian Government passed a law bringing all the air-raid shelters built in the wartime, under State ownership. According to this law, Municipalities had to maintain these assets and gained the right to use them also for non-military purposes, including by granting private stakeholders the right over them after paying an administrative fee.

In addition to the state of uncertainty regarding underground spaces property, frightening hydrogeological instability phenomena, like street pavement collapses, occurred at the end of the 1990s, which drove the Italian Home Office to institute a special Commission for Naples' subsoil emergency. Established in March 1997 and presided over by the Mayor of Naples, the Commission had to pinpoint all the causes of the instability problems and determine suitable solutions to guarantee city safety. A technical committee, appointed by the Commission, pointed out 42 priority actions, solely regarding sewers. Nevertheless, during the Commission activity period, from 1997 to 2012, huge amounts of public resources were spent to finance survey campaigns and build a geographic information system, as well

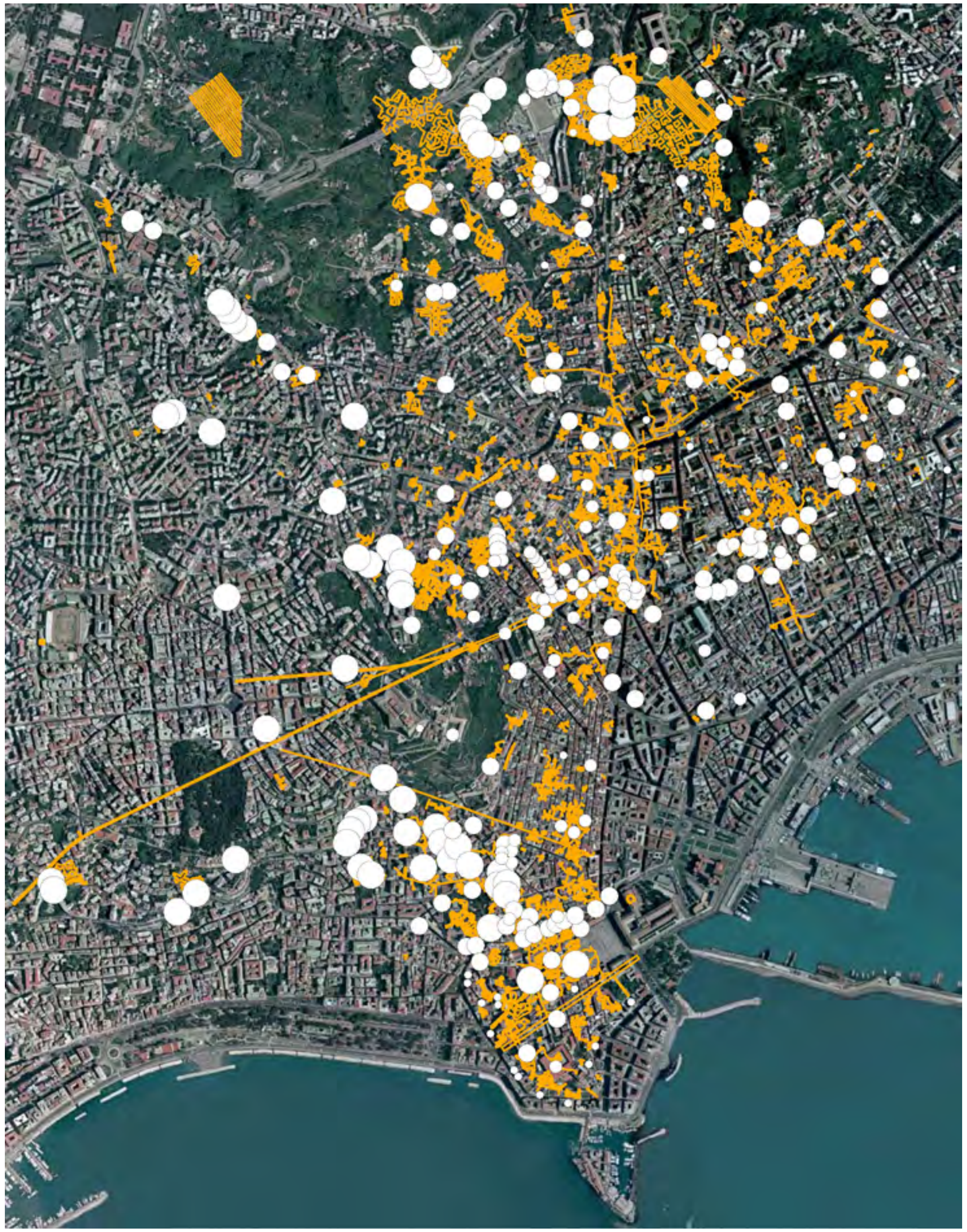

Figure 6 - City center of Naples with cavities (points size grows with age of cavities).

as to assure the maintenance of hypogean cavities. Moreover, to coordinate this prolific fact-finding survey, a pre-existing municipal soil conservation department was strengthened. It continues to manage the upgrade of the underground spaces register, even if new hypogean cavities are identified only when collapses or soil instability happen. Unfortunately, the Naples subsoil has always been considered as a problem for the city safety and not as a resource, implying that no in-depth analysis on property and usage rights was carried out. In other words, the Commission acted without knowing who the main beneficiaries of their efforts were. Moreover, it established the common practice to consider the Municipality as the only actor in charge for cavities maintenance, and so relieving private users of their responsibility. In other words, the commissarial regime has not contributed to solving this long-standing issue.

In this same frame, from the late 1980s, sporadic business initiatives have contemplated the opportunity to take advantage of the underground city through the granting of concessions to hypogean cavities. It generates a new controversial issue, founded on the unclear property distribution and the very confused Italian legislation about public concessions. Moreover, the Municipality of Naples, years before the Commission, autonomously decided to sign a set of *memoranda of understanding* with private stakeholders to grant them the right over some cavities, even though those spaces didn't belong to the municipality . Today it can be argued that this was not the best choice.

In 2005, a new Italian law allowed a public concession to be obtained directly from the State, excluding the intermediation of local institutions, which was previously required. Before 2005, in fact, Government public concessions were submitted to the signature of an institutional agreement between the State and a local institution, such as a Municipality. As a consequence, the stakeholders became more interested in Naples underground spaces, and the Italian State was inevitably re-involved in that issue. Unexpectedly, it claimed possession of the hypogean cavities requisitioned during the Second World War. Anyway, for the cavities previously categorized as *definite State ownership*, the old agreements were replaced by new Government concessions, costly and at a renewable fixed-term.

In 2010, the Italian Government reformed the military organization and decreed that the hypogean cavities used as air-raid shelters were not assets of the State (referred to as *Demanio*), but the special assets of Military property (*Demanio Militare)*. It obviously generated a new wave of confusion. In particular, the Government concessions have been frozen, and at present no one is able to foresee when and in which way this litigation will finish.

Finally, in May 2010, a federal reform act was approved by the Italian Government in order to make over to the local authorities' ownership some state-owned assets, among which properties belonging to *Demanio Militare,* not used for military purposes like Naples underground cavities are, were included.

This complex framework has obviously prevented the development of an institutional *culture of the underground* in Naples, clashing with the common sentiments of the inhabitants associated with these mysterious locations. *De facto*, the underground has been completely marginalized from any planning and regulatory process. Due to the lack of an underground spaces plan, regulations and planning strategies developed and established for overground development are roughly applied to the underlying cavities. Proposals openly developed are caught in red tape: this leads people not to take entrepreneurial initiatives, or worse, to sidestep the system.

Despite this situation, notable success has been achieved by some initiatives. If progess has been made in recent times, in fact, it is only due to the commitment of a small group of businessmen that have carried on their proposals struggling against institutional opposition. Two of the most interesting cases from this viewpoint are *Napoli Sotterranea* and *Tunnel Borbonico*. The former initiative led to a renewed attention to the Neapolitan hypogean cavity system in the late 1980s, after being in limbo for over forty years. It was the first, and for many years the only, activity that had ever been formalized by relationship with the Municipality, inciting the latter to the development of a kind of agreement, achieved in the memorandum of understandings previously discussed. The second one, the *Tunnel Borbonico*, obtained in 2005 the first direct State concession in Naples, and probably in Italy.

In the next two paragraphs the two cases are analyzed in-depth in order to highlight the complexity of the Neapolitan hypogean grid as well as the need of a master-plan able to define ideas and a strategy for the future of such an important resource of the city.

**Napoli Sotterranea**

The complex of tunnels which is commonly called *Napoli Sotterranea* is located in the heart of the historical centre of Naples (Figure 7). There are several access points to this maze that is about 30 metres below the street level, running under downtown streets, but not all of them have been discovered yet (Figure 8). The main body of such a tourist complex is formed essentially by aqueducts, water storage tanks and their connecting pipes. They are mainly characterized by classical architecture: Greek and Roman.

The non-profit association which takes care of these was founded in the 1960s in order to begin an exploratory, geological, speleological, archaeological and anthropological program for every artifact of artificial extraction and of the subsoil of the city of Naples. In addition, these activities were aimed also at building a better understanding of these cavities to assess the safety of the city of Naples, which is historically known to rest on an empty space for nearly a third of its surface area.

In the mid-1980s, this association fostered the establishment of a committee to value and revive Naples' underground. The organization of "walking tours" in some historically and archaeologically interesting hypogean cavities was one of its key efforts. These excursions were repeated weekly and aroused the interest of hundreds of people who booked these underground trips.

Thus, born as a movement involving just experts and technicians keen on Naples' under-city, at the end of the 1980s it turned into a touristic phenomenon with the Association signing a *memorandum of understanding* with the Naples Municipality. This agreement allowed the Association to manage more than 4000 square meters of hypogean cavities underneath Naples historic city centre, in return for maintenance and clean-up activities.

Although the ownership of these cavities didn't belong to the Municipality, but to *Demanio*, the Association managed it from 1989 to 2005, pursuant to the *memorandum of understanding* mentioned before and never institutionally opposed by *Demanio* itself.

The lack of any underground space planning activities and public funding has not prevented the Association from independently managing these hypogean cavities, giving life to an international tourist phenomenon which, thanks to the interest and


Figure 7: Layout of Napoli Sotterranea.

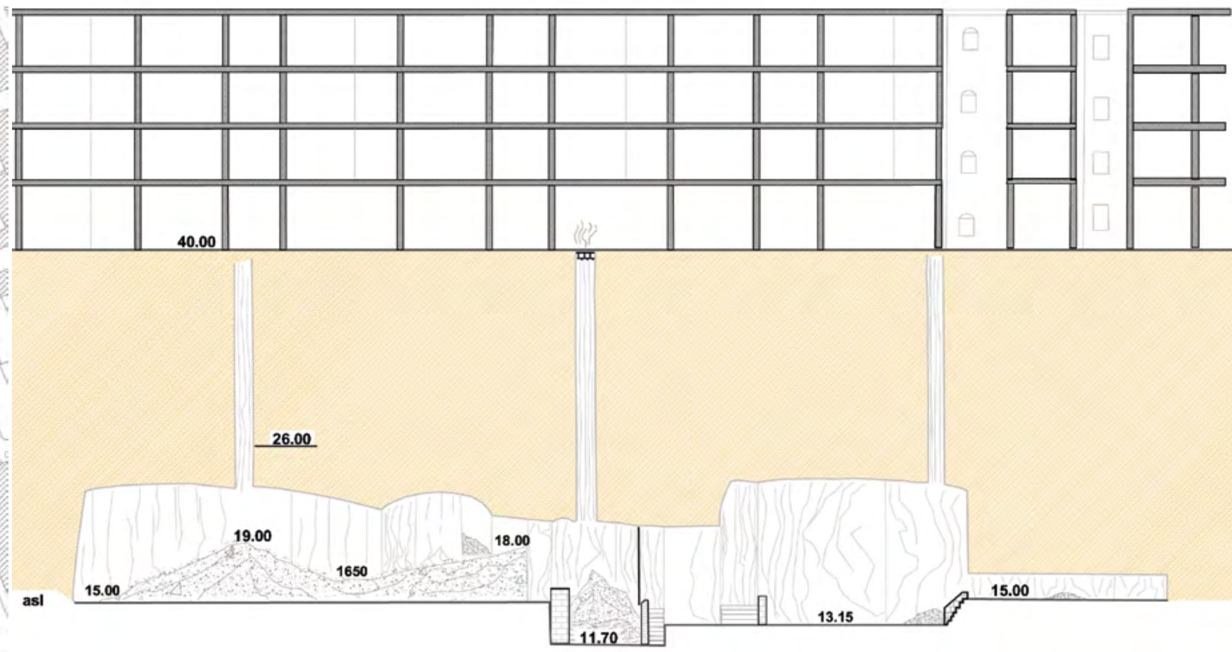


Figure 8: Cross-section type of Napoli Sotterranea.

dissemination of the mass media, has been attracting tourists from all around the world for 25 years.

In 2005 a new law concerning criteria and procedures to follow for Government real estate grants, threw light on the controversial agreement signed by the Municipality. The Association had to adapt to this regulation and got a 12-year Government real estate grant.

In the absence of a clear planning framework for underground spaces, with the ability to unravel and solve the thorny problem of the cavities propriety, one of the most appreciated hubs of the tourist industry in Naples could have been seriously jeopardized.

Today this Association continues to be motivated by its primary exploration mission, bringing to light hidden sides of the Neapolitan underworld and, at the same time, preserving underground spaces from degradation and neglect. It still organizes excursions starting from Piazza San Gaetano, a square that, at first in the Greek age, and then in the Roman one, was occupied by the *agora* and the *forum*, respectively. The path followed during these underground "walks" is long and twisting and leads visitors to 17 hypogean cavities and tanks linked by 9 main *cunicoli*.

Napoli Sotterranea's success has obviously been produced by private enterprise, which was the first to grasp the potential charm and appeal of urban cavities touristic exploration in a town where there is a profusion of historic and cultural attractions. The lack of underground space planning has, however, slowed down the processes activated by the Association.

## Tunnel Borbonico

The *Tunnel Borbonico* is a long underground passage, built in the XIX century beneath *Pizzofalcone* hill. In February 1853, Ferdinand II of Bourbon commissioned the famous Neapolitan architect Errico Alvino to design an underground passage under *Pizzofalcone* hill that would link the Royal Palace with a barrack near the seaside, for a total length of 530 meters (Figure 9). The aim of the project, originally envisaging two underground parallel paths, was to create a rapidly accessible military passage to defend the Royal Palace, and a safe exit route for the royal family.

The works started by digging into the hill from a little square by the seaside and creating two parallel tunnels. After 84 m, the double path stops and runs into a huge empty space, 3180 square meters wide and 35 meters high, used as a yellow *tuff* cave since 1512 and named "Cave Carafa"; thereafter, only a single tunnel was built (Figure 10).

The project did not fare well, however, and the building works were interrupted in 1855, before the second exit was ever realized, due to the numerous setbacks encountered and the political upheaval which led to the end of the Kingdom of the Two Sicilies and the Bourbon rule.

During the Second World War, this cavernous structure served as an air raid shelter and military hospital, providing aid and protection to almost 10,000 Neapolitans. After the war, the tunnel was used as an impound lot until the 1970s.

In March 2005 a group of geologists and speleologists[2], members of a cultural association, accessed the *Tunnel Borbonico* to do some surveys and found it had

2 Scientist and/or researcher in the field of speleology, the scientific study of caves, their make-up, structure, physical properties, history, life forms, and the processes by which they form (speleogenesis) and change over time (speleomorphology).


Figure 9: Layout of Tunnel Borbonico.

been left in a state of abandon, totally degraded, filled with debris and residue coming from the new subway digging works. These surveys enabled them to discover hypogean cavities that were never surveyed before and enhance the awareness of underground spaces in that area.

The Association began to clear the tunnel of the debris with the sole support of its members and other volunteers who also contributed during a five-year period to organizing and studying the archaeological material discovered. They then managed to secure a Real Estate Grant from *Demanio,* and *Tunnel Borbonico* was opened to the public in October 2010, after five years of cleaning and restoration work. Today, a section of the path is reserved for the exhibition of cars and motorcycles, abandoned for years in the tunnel, freed from piles of rubbish, restored, arranged and illuminated ad hoc for the route (Figure 11).

At present, the *Tunnel Borbonico* has regular state authorization to carry out guided tours and cultural events are also periodically organized right inside.

The important contribution made by the Association could be seriously compromised due to the lack of underground space planning, which prevents the Association itself from improving the touristic package of *Tunnel Borbonico*. The prospect of creating a permanent museum inside, for instance, has not materialized because the developed project can't be authorized, in accordance with the building code, commonly used to regulate building work procedures above the ground.

The *Tunnel Borbonico*, since December 2010, has benefited from a restored and scenic entrance thanks to the opening of a multi-storey car park, built up in a huge hypogean cavity (it can reach 40 meters in height) used since the 16th century as a water tank. Seven parking floors (overall, about 20,000 square meters wide), connected by a circular ramp, offer long and short-term parking. In the hall, located in

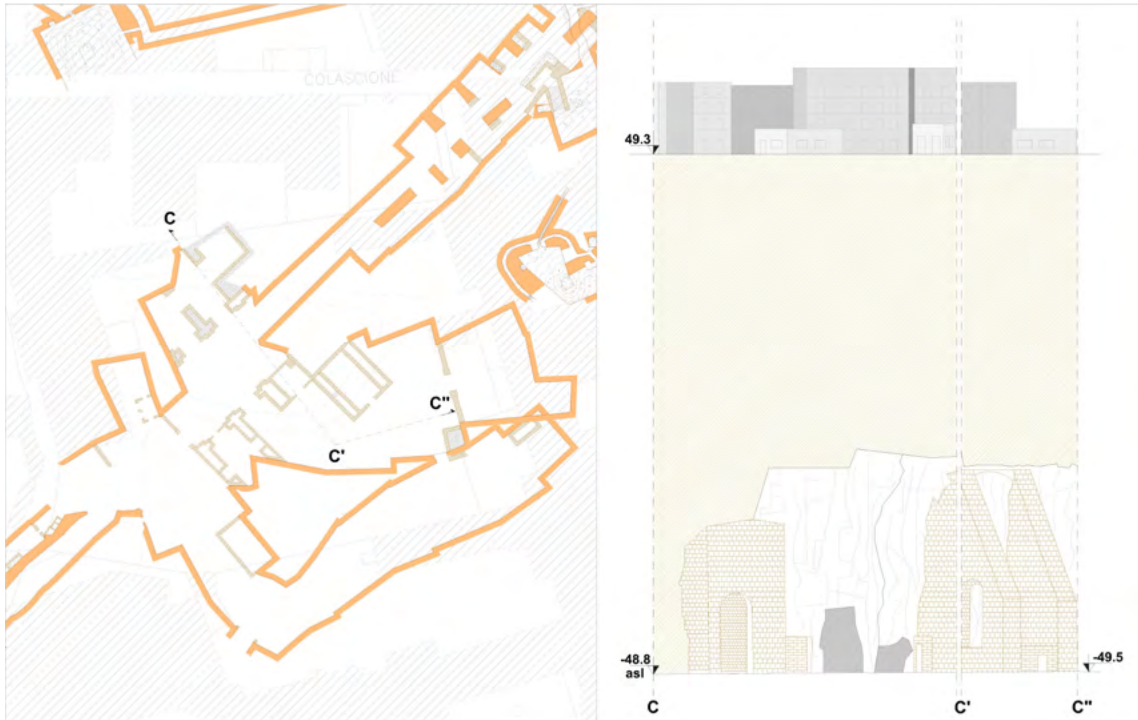


Figure 10: Cross-section type of Tunnel Borbonico.

the heart of the building called *Agorà*, cultural events, expositions, concerts, etc are usually organized.

Although this majestic building project has a strategic role in the reduction of traffic congestion, it too suffered from a lack of underground space planning and from red tape during its construction. A public company initially achieved a municipal concession in 1990 to build and manage the multi-storey car park, but building works, which lasted 3 years in all, ended in 2010, about 20 years later.

## CONCLUSIONS

The authors have attempted to demonstrate how Naples is unique from a morphological point of view, its historic city center area almost entirely settled on a bank of yellow *tuff*, whose easy workability and recurring use in the building industry had fostered, over the centuries, a constant underground mining activity. Therefore, Naples has inherited a large and complex system of underground spaces. Lacking an organic vision of their use, this system has always been perceived as a threat rather than an opportunity for the city to solve the problems it has always been beset with.

Naples is presently afflicted by soil instability, very high-density housing and a considerable lack of public services (e.g. parking lots) in the inner city. In this context, the planning of existing underground spaces is more urgent than other common urban planning activities. Therefore, a plan for underground spaces use (masterplan) needs to be drawn up. It should be based on a sound knowledge of the existing underground spaces, deeper and more accurate than the current one and it should plan:

- the hypogean cavities' permitted uses, considering not only the conservation status and the use-related risk, but also their location, accessibility, relationships with the upper-city, the potential use (e.g. touristic activities, new paths, etc.);
- permitted building works in each cavity in order to preserve the soil stability and allow a safe and easy conversion of abandoned cavities;
- -how to make a network of best practices in underground space utilization, born in the absence of planning activity.

Only through a planning process focusing on these aspects can a sustainable and responsible use of underground spaces be promoted in Naples. A stable and long-lasting use of underground spaces is essential to continuously monitor hypogean cavities, broaden Naples' subsoil knowledge, and subsequently implement a strategy to mitigate hydrogeological risk. Moreover, a clear framework of the ownership pattern of known cavities needs to be established. Only in this way will it be possible to successfully regulate the relations between the public and private sectors, overcome conflicts and encourage synergies between local owners, entrepreneurs, planners and associations. ■

Figure 11: Interior view of Tunnel Borbonico.

## AUTHORS

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# NETWORKING UNDERGROUND ARCHAEOLOGICAL AND CULTURAL SITES: THE CASE OF THE ATHENS METRO

Marilena Papageorgiou

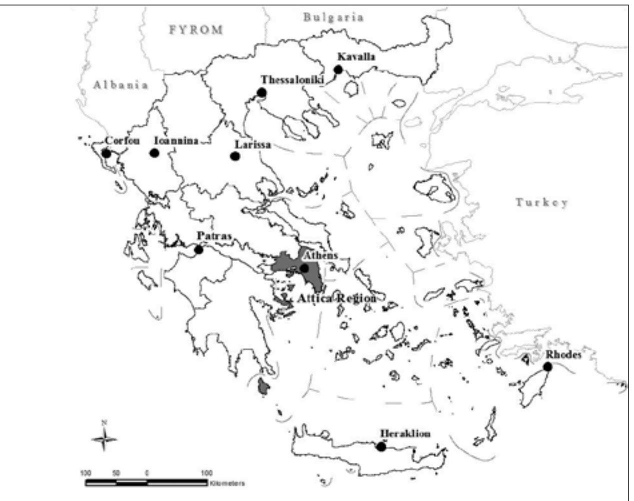
## INTRODUCTION: THE USE OF UNDERGROUND SPACE IN GREECE

Greece is a country that doesn't have a very long tradition either in building high or in using its underground space for city development – and/or other – purposes. In fact, in Greece, every construction activity that requires digging, boring or tunneling (public works, private building construction etc) is likely to encounter antiquities even at a shallow depth. Usually, when that occurs, the archaeological authorities of the Ministry of Culture – in accordance with the Greek Archaeological Law 3028 - immediately stop the work and start to survey the area of interest.

In general, due to the high density of archaeological items in the Greek subsoil, the surveys of the Hellenic Ministry of Culture might last for a long time, several months or even years. The whole procedure must be supervised by the Ministry, which is responsible for the preservation, conservation and the final decision about the destiny of the antiquities. This is the reason why antiquities and ancient built heritage is very often considered a 'curse' in people's eyes, rather than a blessing.

Apart from encountering antiquities, another reason that Greece has not "exploited" its underground space is the seismic activity of the wider area. Greece's location - in the east Mediterranean Basin - has the highest seismic activity in Europe. This means that construction aiming at either going high up or deep underground must follow extremely high construction standards to ensure safety against earthquakes.

Map 1: The Region of Attica in Greece




Due to the aforementioned reasons, for a long time in Greece, underground space was usually used only for the mundane and necessary, such as transportation infrastructure, parking spaces and in some cases for shelter in emergencies resulting from natural disasters or threats of war.

Recently though, Greece entered a new era regarding the use of its underground space. With the construction of the Athens Metro, the antiquities encountered - which were once considered to be a "curse" – turned into a "blessing". Indeed, since that time, the archaeological treasures found in other underground spaces are very often displayed *in situ* and in continuity with the cultural and archaeological spaces of the surface (e.g. in the building of the Central Bank of Greece).



In this context, the present paper presents the case of the Athens Metro and the way that this common use of the underground space can have an alternative, more sophisticated use, which can also serve to enhance the city's identity. Furthermore, the case aims to discuss the challenges for Greek urban planners regarding the way that the underground space of Greece, so rich in archaeological artifacts, can become part of an integrated and holistic spatial planning process.


Map 2: Administrative Units of Attica Region

Source: processed by the authors

## ATHENS IN LAYERS

### Key issues for the Athens Metropolitan Area

Since 1833, Athens has been the capital city of Greece. It is located in the Attica Region and is one of the oldest cities in the world, with a history spanning more than 3000 years.

Athens sprawls across the central plain of Attica, often referred to as the Athens Basin. Four mountains surround the basin: Mount Egaleo to the west, Mount Parnitha and Mount Penteli to the North and Mount Hymettus to the east.

The Athens Metropolitan Area extends over more than 400 km², covering approximately 20% of the Attica Region (ITA, 2005). According to the latest administrative reorganization (Law 3852 in 2010), the Attica Region is divided into 8 Regional Units, 5 of which together form the urban agglomeration of Athens (including the city of Piraeus). The 8 Regional Units are the following:

| | |
|---|---|
| North Athens | Metropolitan Area of Athens |
| West Athens | Metropolitan Area of Athens |
| Central Athens | Metropolitan Area of Athens |
| South Athens | Metropolitan Area of Athens |
| Piraeus | Metropolitan Area of Athens |
| East Attica | |
| West Attica | |
| Islands | |

Further, these 8 Regional Units are divided into 66 Municipalities. The Central Athens Sector/Unit consists of 8 Municipalities; the North Unit of Athens consists of 13; the West Unit 7; the South Unit 7; Piraeus 5; East Attica 14; West Attica 5; and finally the islands, 7 Municipalities (See Table 2).

As the capital of Greece, Athens is the economic, commercial and administrative center of the country. Moreover, it is the most populated urban center, home to almost 30% of the population of Greece. Despite the fact that it represents less than 3% of the total area of Greece, Athens and the Region of Attica produce almost 40% of the domestic product (statistical data of 2011: ELSTAT).

According to the data of the Regional Economic Plan of Attica (2007-2013), the structure of the regional economy of Attica is as follows: tertiary sector, 79.86%; secondary sector, 19.57%; and primary sector, 0.57%. Furthermore, according to the same Plan, amongst all metropolitan areas in the European Union, the Athens-Attica Metropolitan Area is ranked 8th according to its population size, and 14th as per its level/percentage of tertiary productivity.

Finally, it is worth mentioning that due to its long history, Athens is a vibrant capital, with many qualified universities and research centers. Moreover, its immense cultural heritage is reflected by its hundreds of museums, archaeological sites, theatres, galleries and other cultural institutions.

| | **Municipality of Athens** | | **Metropolitan Area of Athens** | | **Attica Region** | |
|---|---|---|---|---|---|---|
| | 2001 | 2011 | 2001 | 2011 | 2001 | 2011 |
| **Population** | 745,514 | 664,046 | 3,130,841 | 3,089,698 | 3,761,810 | 3,827,624 |
| **Area** | 38.964 km² | | 412.19 km² | | 3,808 km² | |
| **Density (res/km²)** | 19.133 | 17.042 | 7,595.62 | 7,495.81 | 987.87 | 1,005.15 |

Table 1: Key data for Athens and Attica Region
Source: ELSTAT (Hellenic Statistical Authority), Census 2001 and 2011

| **Regional Units** | **Population** | **Area size** | **Municipalities** |
|---|---|---|---|
| **Central Athens** | 1,029,520 | 87.3 km² | Athens, Vyronas, Galatsi, Dafni-Hemyttos, Zografou, Ilioupoli, Kesariani, Philadelfia-Chalkidona, |
| **South Athens** | 529,826 | 68.9 km² | Ag.Dimitrios, Alimos, Glifada, Elliniko-Argiroupoli, Moscha-to-Tavros, N.Smirni, P.Faliro |
| **North Athens** | 591,680 | 138.79 km² | Ag.Paraskevi, Maroussi, Vrilissia, Heraklion, Kifisia, N.Erithrea, Lykovrisi-Pefki, Metamorfosi, N.Ionia, Papagou-Cholargou, Penteli, Filothei-Psichico, Chalandri |
| **West Athens** | 489,675 | 66.8 km² | Ag.Varvara, Ag.Anargiri-Kamatero, Egaleo, Ilion, Peristeri, Petroupoli, Chaidari |
| **Piraeus** | 448,997 | 50.4 km². | Keratsini-Drapetsona, Koridalos, Nikaia-Ag.Ioannins Rentis, Piraeus, Perama, |
| **Islands** | 74,651 | 878.965 km² | Agkistri, Egina, Kithira, Poros, Salamina, Spetses, Trizina, Hydra |
| **West Attica** | 160,927 | 1,004.0 km² | Aspropyrgos, Elefsina, Mandra-Idilia, Megara, Fyli, |
| **East Attica** | 502,348 | 1,512.993 km² | Acharnon, Varis-Voulas-Vouliagmenis, Dionysos, Kropias, Lavreotikis, Marathonas, Markopoulo-Mesogaia, Peania, Palini, Rafina-Pikermi, Saronikos, Spata-Artemida, Oropos. |
| **TOTAL** | 3,827,624 | 3,808 km² | |

Table 2: Key data for the spatial/administrative Units of Attica Region
Source: ELSTAT (Hellenic Statistical Authority), Census 2011



### The historical phases of settlement in the Athens (Attica) area

It is estimated that Athens has been settled since the Neolithic era, which means 7000 years ago (4th millennium B.C.). Athens was also an important economic center during the Mycenaean civilization, a fact that was proved by the existence of Cyclopean Walls in the Acropolis site (Travlos, 1993).

At the beginning of the first millennium B.C., Athens was a very small settlement. According to researchers of ancient writings, the ancient walled city covered a small area (of about 2 km²) and it was situated at a distance from the sea (Saronic Gulf).

By the period of the Peloponnesian War (5th century B.C.), Thucydides states/reports that the Athenians and their families numbered a total of 140,000 people, while the slaves numbered between 150,000 – 400,000, and the population without citizens' rights was about 70,000.

In the 4th century B.C. - after the conquests of Alexander the Great - the population of Athens began to decrease as the Athenians migrated to the East.

During the period of the Roman conquest, Athens was initially destroyed (by the Roman General Sulla) and then reconstructed. Indeed, during the times of the Roman emperor Adrian (2nd century A.D.), Athens acquired part of its historic glory with the construction of important buildings such as a library, a gymnasium, an aqueduct, several temples and sanctuaries, a bridge and the completion of the Temple of Olympian Zeus (Museum of the City of Athens, 1997).

During the Byzantine era, Athens was converted to a provincial town, with varying fortunes. In the 6th century A.D. the city shrank considerably, due to the barbarian invasions. It flourished again the 11th and 12th centuries A.D., due to which today the city possesses many well-conserved buildings, mostly churches, of the Byzantine era (Museum of the City of Athens, 1997).

However, this prosperity did not last for long. In the 13th century Athens was conquered by the Latins, and two centuries later by the Ottoman Empire. During these times, the Parthenon was converted into a mosque, the city faced a significant decline, and was finally burned in 1688. Moreover, at the beginning of the 19th century, Lord Elgin (the British Ambassador to the Ottoman Empire) arranged for the removal of many sculptures from the Parthenon (known as the Elgin marbles, which Greece still claims should be returned from the U.K.).

After the liberation of the country from Ottoman rule, Athens was chosen to become the capital of Greece in 1833. At that time, the population of Athens was nearly 6,000. It was then that the State appointed the Architects Kleanthis (a Greek native) and Schaubert (a Bavarian) to produce the first Master Plan for the Greek capital. Since the main reason for choosing Athens to become Greece's capital was its archaeological treasures, the primary goal set by the architects was to restore and protect the archaeological sites and monuments in the historic center and to expand the city towards other areas. This plan, though, was very soon modified (in 1834, by Klenze) and finally implemented in 1860 (by the Stavridis Commission) with many changes regarding public spaces (i.e. elimination of public squares, increase of the built up areas, etc). (Unification of Archaeological Sites of Athens S.A. · Travlos, 1993).

In the middle of the 19th century, the Master Plan of Athens designed the city for approximately 50,000 inhabitants. By the 1920's, Athens had grown to more than 450,000 inhabitants. Due to the immigration waves from Asia Minor during the following years, by the eve of the Second World War, the capital of Greece numbered more than 1,000,000 inhabitants, which means that it was already a metropolis (Ministry of Culture, 2005).

## ATHENS METRO CONSTRUCTION: CHALLENGES AND CONSTRAINTS

### Key elements of the construction of the Athens Metro

Until the construction of the Athens Metro, the only rapid transit line in the capital of Greece was the railway of ISAP S.A., which now represents Line 1 of the Metro network. Line 1 was initially opened in 1869 as a steam railway – serving the transit from the port of Piraeus to the center of Athens (Thissio). It was eventually electrified in 1904 and reached its current length (terminating at Kifisia, the northern suburb of the Athens conurbation) in 1957 (Androulidakis, 1995).

By the time Line 1 was completed, new aspirations for the evolution of the transportation system in Athens had emerged. As a result, in the early 1960's, the government started the preparation of several plans for the underground transportation in the capital of Greece, which in some cases included a fourteen-line subway network (Nathenas, 2007).

Despite the early conception, the Plans for the Athens Metro were only finalized more than two decades later, in the late 1980's. The reason for the delay was the multi-disciplinary dimension of the project, which set as a prerequisite the conduct of several ancillary, but totally necessary, surveys/plans for the realization of the project (see next section).

Finally, construction of lines 2 and 3 started in November 1992, with the hope that the new Athens Metro would contribute to the decrease of traffic congestion and would improve the air quality by reducing the smog in the atmosphere. Two decades later, the works are still proceeding at an intensive pace, using the most up-to-date technologies. The initial plan was to construct approximately 20 km of metro lines with 21 stations. Today, after several re-adjustments and extensions, the actual network extends to almost 80 km, includes 65 stations, and serves almost two million passengers on a daily basis. Moreover, according to a new contract signed in March 2013, the network is expected to extend its capacity in the near future through 6 additional stations and 7.6 km of new tunnels (Attiko Metro S.A., 2013).

| Lines | Route | First Section Opened | Last Section Opened | No of stations | Length of lines (km) |
|---|---|---|---|---|---|
| L1: Green | Pireaus – Kifisia | February 1869 | August 1957 | 24 | 25.6 km |
| L2: Red | Anthoupoli – Elliniko | January 2000 | July 2013 | 20 | 16.4 km |
| L3: Light Blue | Agia Marina – D.Plakentias/Airport | January 2000 | December 2013 | 21 | 37.6 km |
| L4: Orange | Petroupoli / Ethniki Odos | - | - | 29 | 33.0 km |
| L5: Dark Blue | Fyli – Nea Elvetia | - | - | Not defined | Not defined |
| L6: Pink | Amalia Fleming – Vryoni / Perama | - | - | Not defined | Not defined |
| L7: Yellow | Chaidari – Poseidonos | - | - | Not defined | Not defined |
| L8: Brown | Circular | - | - | Not defined | Not defined |

Table 3: Key characteristics of the metro lines
Source: www.ametro.gr (processed by the authors)

### Managerial, funding and property issues

Until June 2011, the operational management of the subway network of Athens was not unified. Line 1 was owned and operated by the management of the Athens & Piraeus Railway Company (ISAP S.A.), while Attiko Metro S.A owned and operated Lines 2 and 3.

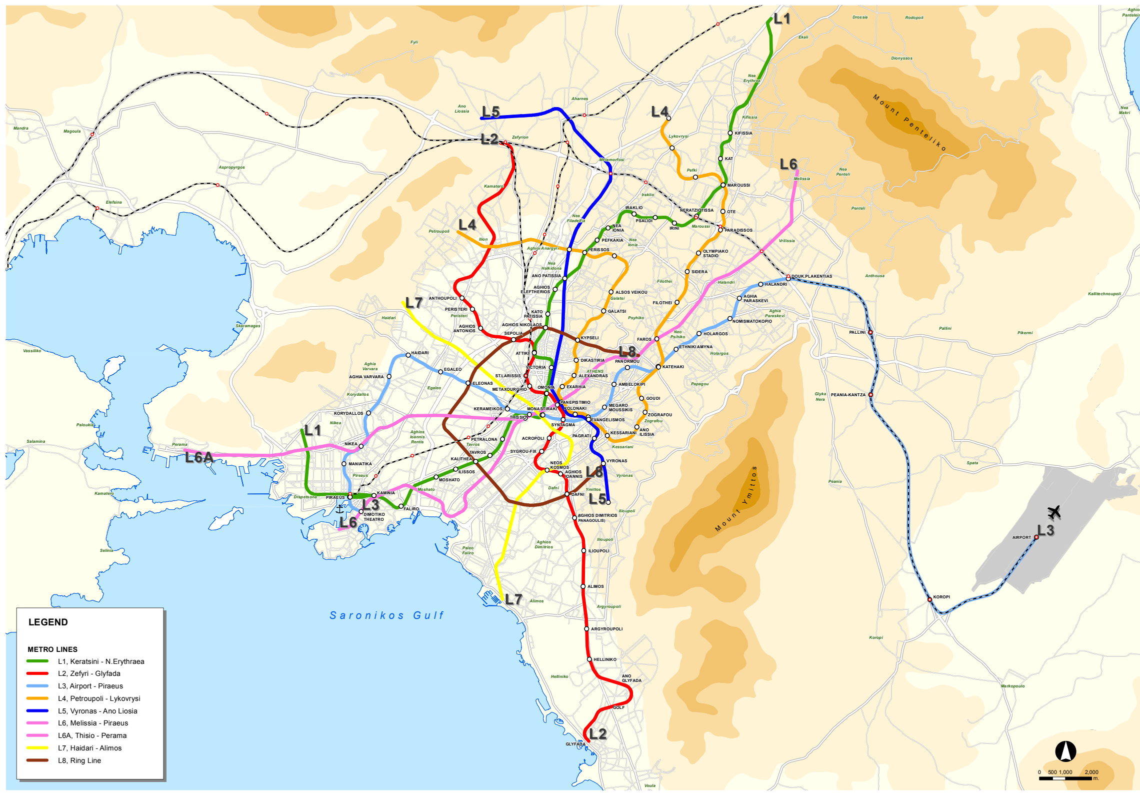
The consolidation of operations of the Athens Metro finally arrived with the enactment of Law 3920/2011, by which the Greek government unified all urban railway management (AMEL S.A., ISAP S.A. and Tram S.A.) into one Company: the Urban Rail Transport[1] (STASY) S.A., a subsidiary of OASA S.A. (Company of the Urban Transportation of Athens).

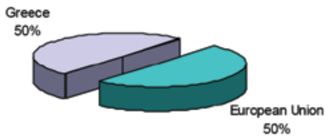
At the moment, the three-line Athens Metro network serves in total 65 stations, 60 of which belong to the Urban Rail Transport S.A. and the rest (in the vicinity of the Athens International Airport) to TRAINOSE, the main Railway Company of Greece.

According to the law and the contracts of the construction company, all the equipment is the property of Urban Rail Transport S.A. including the rails, while the underground space is 100% public. Moreover, according to Greek legislation,

1 It should be mentioned that the consolidation of operations was attempted for the first time in 1998 by the Greek Government (Law 2669/1998), but it never came to fruition.

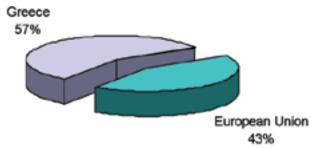
Map 3: Athens Metro Lines Development Plan
Source: Attiko Metro S.A.






**METRO BASE PROJECT**

**2.100 million EUROS**
50% - European Union – Subsidies
39% - European Investment Bank – Loans
11% - Greek State




**EXTENSIONS OF LINES 2 & 3**

**2.200 million EUROS**
43% - European Union – Subsidies
38% - European Investment Bank – Loans
19% - Greek State

Figure 1: Cost of the Athens Metro project and proportions of subsidies

depths lower than those that the Building Code allows to build basements belong fully to the State, as do all minerals and ores of the subsoil[2]. Consequently, in the case of the Metro construction, there are no serious problems relating to private property since any kind of construction usually occurs at a depth from 18 to 30 meters (far below the normal basement level for buildings) or under public spaces at ground level.

## Provisional studies undertaken

As mentioned above, the Athens Metro is the most extensive project ever envisaged in Greece and, therefore, for its realization multiple provisional - but totally necessary – surveys/ plans were needed. Indeed, the studies and plans, which began in the late 1980's, were of three broad categories and were conducted in sequential steps as described below.

### *Transportation Master Plan for the Athens Metro*

The Transportation Master Plan for the Athens Metro was of paramount importance before the construction of the subway, in order to develop the best scenario regarding the optimum route/alignment of the Metro to daily serve the maximum number of passengers. For the realization of the Plan, beyond Attiko Metro S.A., other authorities which were also involved in the project were: a) the Company of the Urban Transportation of Athens (OASA S.A.) and b) the Organization for the implementation of the Master Plan of Athens (ORSA).

2 In Greece there is no specific law or any other statute dealing with the use and the related property matters of underground space. However, these kinds of issues are indirectly addressed by the Greek Building Code. More specifically, the Building Code, as a rule, permits the construction of only two underground floors (basements) which means 6 to 8 meters below surface level. However, there are some exceptions for buildings with a special purpose (garages, hospitals, etc.) which receive the necessary building permission for the construction of more underground floors. Therefore, the ground below the depth of two floors is owned by the public authorities (state or local governments) and is used to meet the needs for infrastructure works (sewage system or water supply, subway metro lines, etc.). Very often, these infrastructures lie below open public spaces in order to be easily reached in case of repairs and maintenance work.



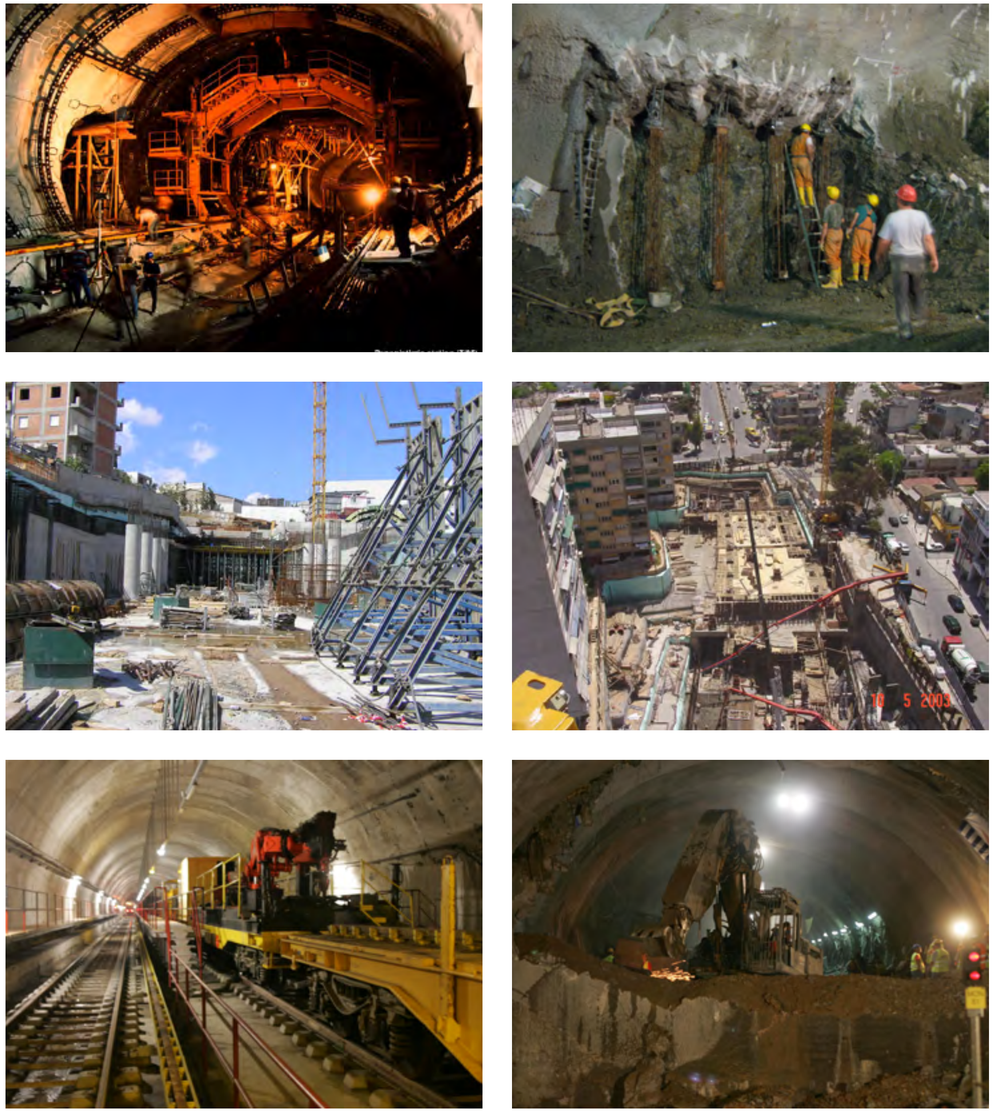
Finally, it is worth noting that for the elaboration of the Transportation Master Plan, the following surveys were also necessary:

- General Land-Use Plan of the Attica Region;
- Questionnaire survey regarding the daily mobility of the Attica Region citizens;
- Record of the existing road network of Athens;
- Record of the existing transportation means and itineraries of the Attica Region;
- Simulation studies regarding the land-use and real-estate changes expected in areas with metro stations.

### *Geological and Hydraulic Surveys*

The construction of the Athens Metro had to overcome two kinds of geological obstacles: the seismic activity of the area and the composition of the subsoil. Specifically, the soil of Athens

**PHOTO GALLERY FROM THE PERIOD OF THE CONSTRUCTION OF THE TUNNELS**



consists of a series of geological formations known as the system of the Athenian Schist, which in turn consists of rocks with little permeability (Andronopoulos and Koukis, 1976).

For the construction of the Metro, the engineers took into consideration the seismic activity of the area and adjusted the construction accordingly. Furthermore, geotechnical investigations were carried out prior to the construction - including more than 350 boreholes, which were dug at a depth of approximately 20-30m. Investigations were also carried out during the execution of the project, with the most important being the following (Attiko Metro S.A., 2013):

- Survey of the geological and geotechnical conditions with 1,100 boreholes;
- Geophysical surveys, using various techniques, in order to detect underground river channels, major objects, etc;
- Measurement of the underground water level along the metro lines;
- Tests of soil, rock samples and other data collected onsite;
- Geotechnical monitoring program (always in operation) for the safety of the buildings and structures in the tunnel alignments.

*Topographical Studies*

The topographical studies began right after the above-mentioned surveys and served to finalize the alignment of the tunnels and the location of the metro stations.

Ultimately, with the completion of all the above studies and plans, the construction of the metro was ready to begin.

## The uncovered archaeological treasures of Athens: Blessing or curse?

Given the long history of settlement in Athens, and therefore the massive expectation of archaeological finds in its subsoil, the beginning of the subway construction (in November 1992) was also the beginning of the most extensive archaeological excavation in the Greek capital. For more than 6 years, teams of archaeologists carried out excavations, which revealed more than 50,000 ancient objects in a total area of 80,000m² (Attiko Metro S.A.).

More specifically, the excavation program – which was totally funded by the Attiko Metro S.A. – revealed archaeological finds, such as: aqueducts, cemeteries, sanctuaries, ancient streets, houses, public workshops, foundry pits, sewage tunnels, drains, wells and kilns, allowing new insight into Athens' ancient topography. Indeed, in order to avoid encountering or destroying antiquities during the construction, the operations/excavations for the opening of the tunnels took place at a depth of 15 meters and deeper, which is considered to be a much lower level than the one where antiquities are usually encountered.

The average depth at which the objects were found varied between 0.5m to 7.0m, although in some cases archaeological 'layers' (regarding mostly "hydraulic" structures) were found at greater depths, i.e. from 15m to 45m (Hellenic Ministry of Culture).

In general, it is worth noting that more than twenty excavations were carried out in stations and ventilation shafts. The antiquities revealed were recorded in detail and preserved using modern techniques under the guidance of the relevant services of the Hellenic Ministry of Culture (MoC).

Undoubtedly, the most significant antiquities were found during the excavations in the historical center of Athens and specifically during the construction of

| Location | Archaeological Finds |
|---|---|
| Syntagma Station | - a sculpture foundry dating from the Classical Era<br>- a cemetery dating back to the sub-Mycenaean and Byzantine times<br>- a baths complex dating back to Roman times<br>- a section of the Peisistranian Aqueduct<br>- the bed of the Iridanos River<br>- the ancient road leading from the gates of the wall to the municipalities of Messogaia region. |
| Keramikos Station | - part of a cemetery of the ancient city of Athens, with 1200 graves dating back to the beginning of the 7th century B.C. up to Roman times<br>- the western surrounding wall of the cemetery<br>- burial grounds, dating back to the beginning of the Peloponnesian War<br>- the remains of a ceramic art workshop<br>- the bed of the Iridanos River |
| Monastiraki Station | - the vaulted bed of the Iridanos River<br>- buildings, workshops, graves and a variety of water supply and sewage systems<br>- residential remains dating from the 8th century B.C. (Geometric Era) up to the 19th century A.D. |
| Acropolis Station | - a few graves of the Middle-Helladic and Post-Helladic Eras, houses, workshops, roads and baths. |
| Historical center ventilation shafts | - a Roman house, a cemetery and hydraulic systems, in "Irodou Attikou" Shaft<br>- a Roman bath of significant importance, in "Amalias" Shaft<br>- building remains, in "Mitropoleos" Shaft<br>- a cemetery dating from the Classical up to the Byzantine period, as well as a room supported on columns, in "Petmeza" Shaft<br>- a building dating back to the Roman era and Byzantine storage facilities, in "Fokionos" Shaft<br>- a building dating back to the Post Classical times and workshops, in "Thissio" Shaft<br>- workshop areas and hydraulic systems, in "Ermou – Arionos" Shaft<br>- an ancient cemetery, in "Iachou" Shaft<br>- a building of significant importance, in "Assomaton" Shaft |
| Evangelismos Station | - an ancient cemetery with its surrounding wall, a Peisistranian duct and a road |
| Panepistimio Station | - an ancient cemetery |
| Egaleo Station | - parts of Iera Odos dating from the 7th century B.C. up to the Roman era. |
| Eleonas Station | - the part of the bridge belonging to the ancient Kifissos river, dated between the 5th and the 6th centuries BC.<br>- a handicraft workshop facility<br>- a cemetery |
| Between Monastiraki and Egaleo Stations | - parts of cemeteries<br>- residential complexes and workshops dating from the early Archaic to the Byzantine years<br>- parts of ancient walls with particularly solid masonry, possibly belonging to ancient temples<br>- ancient disposal areas with numerous finds dating from all ancient eras |
| Between Eth.Amyna and D.Plakentias Stations | - archaeological investigations were executed in an overall area of 12,000m² and revealed remains of buildings and an ancient road leading to inland Attica |
| Between Anthoupoli and Ag.Antonios Stations | - an ancient well<br>- ceramic items<br>- bones and the head of a young woman, probably dating back to the Roman era |
| Ag. Antonios Station | - a cemetery of vacant Kalyvites-type tombs, dating back to the early Christian years |

Table 4: Archaeological finds by area of excavation
Source: data obtained from the Ministry of Culture
and the Attiko Metro S.A. (processed by authors)

**PHOTO GALLERY FROM THE TIME OF THE EXCAVATION PROJECT**

SYNTAGMA STATION

ACROPOLIS STATION

KERAMIKOS STATION

ELLINIKO STATION

the Metro Stations of Syntagma, Keramikos, Monastiraki and Akropolis. Amongst the most important finds during the boring of the tunnels were the following:

- the Adrianion Aqueduct;
- the Iridanos River which was the basic axis of the town planning of Athens in all eras;
- the ancient Iera Odos axis which connected Athens with Eleusis and was the route that followed the procession of the Eleusinian Mysteries, during the celebrations for Demeter and Persephone;
- part of the ancient bridge belonging to the Kifissos River in the Eleonas area, the most ancient bridge excavated in Greece dating back between the $5^{th}$ and $6^{th}$ centuries B.C.

The excavation program that took place in Athens for the Metro construction compounded both the cost and the time of the construction. Nevertheless, due to the massive presence not only of archaeological items, but also of ancient constructions (i.e. non-removable findings), the case of the Athens Metro was the impetus for the Ministry of Culture to change its perception regarding the best practice for the preservation of the antiquities.

For this reason, ancient constructions found during the Metro excavations are left and exposed *in situ* (at specific Metro stations), as are quite a few removable items (authentic or replicas). Of the remaining hundreds of thousands of antiquities, some of them are displayed in the Zografou University Campus (in an open-air exhibition of approximately 2,000m² and a small museum), while the majority are kept in the storehouses of the Ministry of Culture for future display.

## Turning the Metro stations into free museums and cultural spaces

As described in previous sections, the Athens Metro construction was the impetus for the emergence of a new concept on how to deal with the archaeological finds. Therefore, instead of removing all items found, the Ministry of Culture decided on the *in situ* display of several finds in quite a few cases.

At present, six (6) of the Metro stations include exhibitions of ancient artifacts and/or their replicas which were found during the construction of the Metro lines. These exhibitions are open to the public free and constitute part of the greater monumental and archaeological treasures that are located in the historical center of Athens. More specifically, the stations with cultural and archaeological exhibitions are:

- Monastiraki Station: Although the majority of items found at the station were transferred to areas of the Ministry of Culture, part of the vaulted bed of the Iridanos River was preserved onsite and is now presented in a special part of the underground corridors.
- Syntagma Station: The most central and the busiest interchange station of the subway, it is right in the heart of Athens. Its underground space covers quite a large area compared to other Stations. Due to its centricity and size, the Syntagma Station was chosen to host the most important (in quality and in quantity) exhibition of artifacts and findings from the excavations for the Metro. In addition, the Syntagma Station also includes a spacious hall designed to host special cultural events (art galleries, exhibitions, bazaars etc).
- Acropolis Station: It is the main stop for visits to the UNESCO world heritage site of the Acropolis and the Parthenon. The excavations extended to more than 2,500m². The main underground area incorporates some of the articles found onsite, which were detached and placed in an exhibition open to the public.

| Metro Station | Exhibitions and uses |
|---|---|
| Syntagma | *Surface Area (Syntagma Square)*<br>- archaeological site with a section of the Peisistranian Aqueduct<br>- expanded shaft presenting the actual depth that tunnels reach in the Station<br>*Main underground area of Metro Station*<br>- cross-section presenting the underground layers of the city<br>- exhibition with artifacts and finds of the area<br>- exhibition hall<br>- modern sculptures |
| Monastiraki | *Platform Area (of Line 1)*<br>- archaeological site with part of the vaulted bed of the Iridanos River |
| Acropolis | *Main underground area of the Metro Station*<br>- exhibition with artifacts and finds of the area<br>- replicas of sculptures and statues found in the Acropolis area<br>- cross-section presenting the underground layers of the city<br>*Platform Area*<br>- Sculptures representing the authentic frieze of the Parthenon |
| Evangelismos | *Main underground area of the Metro Station*<br>- cross-section presenting the underground layers of the city<br>- exhibition with artifacts and finds of the area<br>- modern sculptures |
| Panepistimio | *Main underground area of the Metro Station*<br>- exhibition with artifacts and finds of the area<br>- modern sculptures |
| Eleonas | *Surface Area*<br>- archaeological site including part of the bridge belonging to the ancient Kifissos River, dated between the 5th and the 6th centuries B.C.<br>*Main underground area of the Metro Station*<br>- information presented with the help of modern artistic techniques |
| Egaleo | *Surface Area*<br>- archaeological site of Iera Odos Axis<br>*Main underground area of the Metro Station*<br>- exhibition with artifacts and finds of the area |

Table 5: Exhibitions in each Metro station
Source: processed by authors (data acquired by on site investigation)

- <u>Panepistimio Station:</u> Ancient artifacts and replicas are exhibited in the main underground area, while an exposed cross-section of the subsoil of Athens provides an unobstructed view of the underground layers of the city. The same rationale is also used in the exhibitions in <u>Evangelismos Station and Egaleo Station.</u>

During the works in the area of <u>Eleonas Station</u>, a part of a bridge belonging to the ancient Kifissos River was revealed. Since the bridge is the most ancient one found in Greece, the Central Archaeological Council of Greece decided to display the antiquity onsite. At Attiko Metro's expense, the abutments of this bridge were detached and preserved offsite and later placed in their original location.

Beyond the exhibitions of artifacts or the original archaeological structures, in the Metro areas, visitors and passengers can also find special information (accompanied by photo galleries) regarding the time and the findings of the excavation of each station. In addition, in the majority of these stations, orchestral music is used to make the journey of citizens and visitors using the Metro even more pleasant.


Map 3: Interaction of underground and surface sites of cultural interest in the historical center of Athens.
Source: processed by the authors on National Land Registry Cadastre and Mapping Agency S.A.

Another unique feature of the Athens Metro is the art program that was implemented from the beginning of the Metro's operation. The program's primary aim is to demonstrate a co-existence between the significant archaeological finds and the works of contemporary Greek artists. For the realization of the program, distinguished Greek artists were invited to create works of art to decorate the Athens Metro stations. These included sculptures, statues, photo galleries and other creative or interactive pieces of art.

The art program is still in progress, since it involves all new and under-construction stations of the Athens Metro extension. Undoubtedly, the combined incorporation of archaeological finds with modern works of art is expected to contribute further to the enrichment of the cultural heritage displayed in the underground space of the Metro.

All the above stations - located right in the heart of Athens, where the dense archaeological layers and the most important cultural institutions are found - undoubtedly contribute both to increasing the cultural spaces on offer in the city and to enhancing its cultural identity.

## THE ROLE OF URBAN PLANNERS IN THE ALTERNATIVE / CULTURAL USE OF THE ATHENS METRO

### The contribution of planners during the construction period

In general, the project of incorporating the antiquities in the subways of Athens was mainly a task handled by the engineers of the construction company and the archaeologists of the Hellenic Ministry of Culture. This means that urban planners were not that actively involved in the realization of the project and they did not play a significant role, either during the construction period, or after the opening of the Metro lines.

More precisely, during the construction period, the role of urban planners was mostly restricted to the approval of the plans regarding the alignments of the Metro tunnels. Specifically, the Urban Control Offices were responsible for certifying that the existing buildings in a buffer zone of 30 meters from both sides of the metro tunnels (50 meters from all sides of the stations) had no basements reaching close to the depth of the tunnels. The same Offices were also responsible for taking all necessary measures in case some of the existing buildings lying on the route of the tunnels were not in a condition to withstand the constant vibrations caused by the giant metro drills.

Furthermore, the Urban Control Offices were also responsible for the urban regeneration of the city above the metro stations and consequently for the re-adjustments to the land-use planning in the surrounding area.

### The provisions for the Athens Metro in the Master Plan for Athens and Attica

The existing Master Plan for the Metropolitan Area of Athens (Attica Region) was ratified in 1985 (by Law 1515), at a time when only Line 1 of the subway network existed and the plans for the new lines were still under discussion. Given this fact, the Master Plan of Athens (which was prepared for a period of 20 years) included ambiguous references to the Athens Metro. In fact, all guidelines were too broad, referring to the transportation system of Athens in general and not to each means of transportation separately.

To be more specific, although the Master Plan had set as a primary goal the development of an integrated transportation system in the Metropolitan Area of Athens (in which all means would connect and interact), no further details or guidelines were proposed, whether for the Athens Metro or for the other means of transportation. According to the Master Plan, the development of the transportation system in the Athens agglomeration was seen as a prerequisite for the reduction of the atmospheric pollution and thus, the improvement of the natural environment of Greece's capital.

Almost 30 years after the ratification of the Master Plan, the Hellenic Ministry of Environment, decided to open the Plan for revision. The elaboration of the revised Plan (including the periods of public consultation) lasted for at least 8 years and the plan was ratified by the Hallenic Parliament in 2014. As for the guidelines and regulations concerning the transportation system of the Metropolitan Area of Athens, the Athens Metro is expected to cover 85% of the wider area of the Attica basin and to expand to a total of eight lines, of approximately 220 km in length, serving 200 stations. At the same time, it is planned to interconnect with a dense Ring-Road network, the Tram network and the suburban railway. Ultimately, the basic priority of the new Strategic Plan of Athens is the reinforcement of sustainable mobility, through the increase in accessibility for all areas of the Attica Region mainly by Urban Rail Systems.

Unfortunately, the revision of the Master Plan for Athens-Attica failed to adopt an integrated planning approach for the alternate (cultural) use of the underground Metro spaces. Indeed, the new Master Plan for Athens: a) focuses on and promotes only the network of the surface cultural sites, and b) isolates the subway transportation and infrastructure from its cultural dimension.

More precisely, the Plan aims at organizing the historical center of the city in the form of a major open-air Archaeological Park, and sets the promotion and the upgrade of the cultural heritage of Athens as one of its guiding principles. In this framework, the Plan sets spatial guidelines, in which only the surface cultural sites are taken into account. Specifically, the spatial guidelines for the upgrade of the cultural heritage of Athens are:

- the enhancement of the historical features of the city;
- the design of large-scale interventions of high quality, with a priority to spaces with cultural importance (museums, archeological sites etc.);
- the promotion and the connection of cultural monuments and sites in the historical center of the city;
- the creation of new cultural uses and spaces, with a priority to places that are connected to railway systems (Metro stations etc.) for ease of accessibility;
- the creation and promotion of cultural routes and promenades, connecting important cultural sites;
- the completion of the projects for the unification (pedestrianisation) of the archaeological sites in the area of the historical center of Athens.

Undoubtedly, the exclusion of the underground cultural spaces from the archaeological and cultural network of Athens is an omission in the Master Plan for Athens that urban planners need to address at the earliest opportunity.

### The program for the unification of the archaeological sites of Athens

Another important chance for urban planners to incorporate the underground archaeological and cultural spaces into the city's cultural network was the program called "Unification of the Archaeological Sites of Athens", which was launched in 1997 by the Ministry of Culture and the Ministry of Environment and Planning, in the run-up to the Olympic Games in 2004.

The program focused on the promotion of the cultural identity of Athens and, therefore, aimed at creating urban areas for the harmonious co-existence of various elements associated with the city's cultural history and modern growth. More precisely, the program aimed at creating a continuous fabric of public spaces, parks and facilities for culture and recreation, embracing all cultural spaces, monuments and sites in the historical center of Athens. To this end, one of the most important interventions of the program was the pedestrianisation of several streets (Dionysiou Areopagitou St, Apostolou Pavlou St. and Ermou St.) creating the so-called "Grand Promenade" of Athens.

Despite the fact that the "Grand Promenade" was planned to connect all major archaeological sites of the city (the Acropolis Hill, the Olympieion, the Hill of Filopappou, the Ancient and Roman Agoras and the Keramikos area), these plans did not include the underground archaeological sites and exhibitions of the Metro Stations.

## CONCLUSIONS: IMPACT AND LESSONS LEARNT

Undoubtedly, underground space in Greek cities has not been sufficiently used and is not part of any integrated and holistic city planning, mainly due to the antiquities frequently found in the subsoil. Recently though - since the construction of the Athens Metro - Greece has entered a new era regarding the use of its underground space.

Indeed, the construction of the Athens Metro has triggered a new thinking in dealing with the treasures found in underground spaces. Specifically, instead of spending years excavating in order to remove all archaeological items from the site - which until then had been considered the only acceptable practice for their protection and conservation - the Hellenic Ministry of Culture experimented with another option: the display of antiquities *in situ* and in open view at public spaces.

As a result, Athens now has one of the most interesting and admirable subway systems in the world, which not only serves the everyday transportation needs of the public but also promotes the distinctive cultural history and identity of the city.

Despite this extraordinary accomplishment, this unique aspect of the Athens Metro has not been exploited enough. Of all the items and treasures discovered during the construction of the Athens Metro, very few are on display at Metro stations and very few Metro stations have exhibitions with the antiquities discovered in their surrounding area. Moreover, the majority of exhibitions take place in the main underground level of the Metro Stations (tickets level), while at the platform areas (the next lower level), only a handful of Metro Stations display ancient or modern artifacts (e.g. the Acropolis Station).

For the best promotion of the cultural and archaeological heritage of Greece, all Metro stations in areas where antiquities have been uncovered should become free underground museums, integrated into the network of museums and archaeological sites, which exist above ground. As is already the case in some stations, these sub-surface museums could: a) host exhibitions of ancient artifacts and modern art, and b) provide further information on the excavations and finds, including those not on display, using modern interactive technologies.

In a striking example of a missed opportunity, both urban planners and archaeologists have neglected to integrate the underground with the surface cultural sites to promote Athens' immense cultural heritage.

Nevertheless, it is never too late, and if planners think strategically, they can turn the historical center of Athens into a continuous cultural park, using multiple layers of the city, thus creating another, unique dimension to the cultural tourism offered. Furthermore, planners can also use the case of the Athens Metro as the first step towards greater knowledge and insight into how underground spaces, in combination with surface planning, can make Greek cities more functional and sustainable. It is an approach worth taking, since – contrary to international practice – Greek legislation has relatively few restrictions concerning underground construction either for public or for private use. ■



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# UNDERGROUND AND CAVERN SPACE DEVELOPMENT IN HONG KONG

Liang Huew WANG

## HONG KONG THE SPECIAL ADMINISTRATIVE REGION

Hong Kong, located at the eastern side of the Pearl River entrance in southern China, was under British rule for 154 years until it was returned to China as a Special Administrative Region (SAR) in 1997 (Wang and TSE (2014)). The territory is now administrated under the Basic Law of "One Country Two Systems", the mini constitution of the SAR which guarantees that the prevailing capitalistic system and social life will continue for at least 50 years after the reunification. This indirectly ensures that the planning system based on British practice will also remain unchanged. The modern cosmopolitan city is now a major transport and logistics centre in Asia and a global financial centre, after New York and London.

The SAR Government is headed by the Chief Executive supported by an appointed Executive Council. The administration is led by the Chief Secretary, Financial Secretary and the Justice Secretary under which together there are 13 other functional secretaries or ministries covering a wide range of administrative functions. The Secretary of Development is responsible for the operation of nine departments: the Architectural Services Department, the Buildings Department, the Civic Engineering and Development Department, the Drainage Services Department, the Electrical and Mechanical Services Department and the Lands Department, the Planning Department, the Land Registry, and the Water Supplies Department. Underground and cavern planning and development are under the jurisdiction of the Secretary of Development. Notwithstanding, planning issues in Hong Kong also involve the Secretary of Transport and Housing, Secretary for Environmental Protection and the Food and Health Bureau, which manages the parks and special areas, among others. It is also to be noted that the Secretary of Development is under the supervision of the Financial Secretary, while the other three departments report directly to the Chief Secretary. Coordination is needed to ensure balanced decision-making among various government departments in the SAR. The existing administrative system, which is based on the British practice, allows for effective coordination among different departmental bodies in planning and the day-to-day operation procedures. In addition, the powerful Independent Commission Against Corruption (ICAC) ensures all decision-making procedures follow the prevailing laws and regulations.



### The urban environment

Hong Kong is one of the most densely populated cities in the world, with over 7.23 million inhabitants crowding into an area of slightly over 1104 km², of which 40% is reserved as protected green areas  known as "country parks". To date, the built up area is only about 280 km², which yields a density of 25,357 persons per built up km². The most densely populated Kun Tong District has a figure several times that average.

The city core is located on both sides of Victoria Harbour (Figure 1). The crowded environment is a result of the intensive land use planning strategies adopted since the colonial era. Intensive land use design produced a sense of crowdedness  and ostensibly a lack of land supply. This in turn created a false illusion of potential housing shortage. Indeed, as a corollary of the intensive land use policy, a rigid land supply strategy has been upheld in order to beef up mechanically land price and land premiums for the comfort of the city coffers since the colonial era (Wang, L.H. 2014). Revenue from land sales (or land leasing, to be exact) has remained an important source of income for the government. The strategy of controlling land market curtails urban sprawl. The intensive land use practice also reduces the cost of public facilities provision and subsequent maintenance expenses. To provide the needed high value land to accommodate the expanding urban habitat, Hong Kong has reclaimed, at various coastal areas, in total over 67 hectares of land space from the sea. This successfully highlighted further the illusion of land shortage. In addition, a private car traffic management policy was mooted and has prevailed since the1920s. The convergence of the two parallel administrative strategies has resulted in the creation of a favourable public transport environment. The successful implementation of a Transit Oriented Development (TOD) in Hong Kong is in fact a consequence of environmental restriction and constraint of an artificially created dense habitat. TOD demands the full support of a well linked pedestrian walkway system, underground or otherwise.

Land use control, together with narrow streets and a strict policy on vehicle control, discourages private car use. More than 91% of the 11 million daily non-walking commuting trips rely on a wide range and extensive network of public transport options. Hong Kong claims to have the best mass transit system and once had the largest bus fleet in the world. Pedestrian areas are well developed to support public transport usage, with more than 70% of the mass transit passengers walking to and from the stations. Mass transit is the  backbone  of the public transport system, which


Figure 1: Location of Hong Kong SAR in South China. Source: Wang and Tsz (2014 pending).

is supported with a range of public transport services - bus, minibus, light rails, trams, ferries, taxis and speedwalks or passenger conveyors. The advanced underground space development in the city is partly a result of this well-developed public transport system, and partly a response to the lack of urban space.
The purpose of this article is to first explain the background of Hong Kong's development of underground usage and then to illustrate the ways underground space is planned and utilized to meet the increasing demand in transit, commercial and pedestrian activities on the one hand and the accommodation of environmentally-unfriendly public utilities on the other. Its impact on the overall land use arrangement, and the future design of the city, will also be discussed.

The paper will also highlight the planning issues and challenges faced in such a crowded and compact urban environment, including, for example, legal and policy challenges and constraints; land ownership issues; financing of underground development; incorporating existing development, both above and below the ground, and the challenges of urban design, among others. It is hoped that the paper may provide some input to the formulation of a planning paradigm for future underground land use planning, not only in Hong Kong, but also elsewhere.

## URBAN PLANNING AND UNDERGROUND AND CAVERN SPACE USAGE

### The need to explore underground usage

Increase in urban population in many cities has led to a high demand for more urban space to accommodate the ever-increasing activities associated with it. Extending the city boundary, either through land reclamation from the sea as has been done in Hong Kong and some other countries such as the Netherlands, or through permitting urban sprawl into the surrounding area of the city, as is happening in most cities in China and elsewhere, is the conventional option deployed by planners worldwide. Underground space, however, provides a new frontier mostly untapped in many cities. If properly designed and managed, underground space could become an essential resource for future urban development. Hong Kong started the large scale underground development process since the construction of the mass transit railway in the 1960s, although tunnels connecting with entrenchment did prevail during the Second World War. Similar to other cities, most of the existing underground space in Hong Kong is reserved for the development of transport facilities, including pedestrian underpasses and parking areas, and shopping malls. Cavern development, however is a more recent emphasis in Hong Kong. Consultancy studies are being commissioned to explore the potential expansion of cavern usage. Currently, urban refuse transfer plant and underground explosive depots are the two prevailing types of cavern utilization in Hong Kong.

Underground caverns in fact could provide a wide range of potential uses, such as shelter, recreational centres, water collection storage and treatment, sewage treatment, oil and gas storage, cold and dry storage, power stations, underground pumped hydroelectric storage, military installation, and industrial waste repository (Zhao, Choa and Broms, 1996). In addition, caverns can also be utilized to accommodate vehicle parking facilities, traffic tunnels, shopping malls and the like. At present, there are a number of purpose-built government facilities in rock caverns in Hong Kong, including, for example, a refuse transfer station, a sewage treatment plant, explosive depots and salt-water service reservoirs. According to Chan (2011), the Hong Kong SAR Government has included several additional potential land uses in the Hong Kong Planning Standard Guidelines (HKPSG) (see Table 1).

Further, an automated regional underground freight transport system may prove viable in the future as the highway transport facilities become increasingly congested (Liu 2004, Rijsenbrij et al. 2006). The underground trunk road in the city centre of Singapore as well as the one under construction in Hong Kong to link the high-speed railway terminal with the urban road system, or the proposal for a large scale underground freight distribution tunnel route for Tokyo, are interesting examples of future transport development in the modern urban landscape (Duffaut and Labbe 2002; Yokotsuka et al. 2007) .

### Cavern development as a planning option

In view of the need to explore land development options away from the usual practice, the Hong Kong Government has adopted a policy of encouraging use of rock caverns, where such development is appropriate, since the early 1990s (Malone 1996). As mentioned earlier, until now, the underground options in Hong Kong have been chosen mainly for certain uses that are considered environmentally not suitable for surface placement.

One of the considerations for Hong Kong to explore cavern development is also related to sparing urban land for property development. The government argues that relocation of the never-in-my –backyard (NIMBY) facilities away from inhabited areas releases valuable land (Development Bureau et al. 2012). In a city starved of land, to remove unfriendly public facilities away from inhabited areas enhances the land value in the vicinity. Further, the excavated materials from cavern engineering are useful construction aggregates, especially for land reclamation purposes.

With properly designed underground facilities, the land above it may provide the impetus for new development and improve the general quality of life of the vicinity (Durmisevic, 1999). This is especially valid when environmentally unfriendly facilities are removed from a crowded area. Due to the increasing emphasis on environmental protection and the upholding of the public interest in Hong Kong, it has been a challenge for the government to find suitable sites for certain "vital but unfriendly" public facilities within the densely populated area. The long process of public consultation and negotiation in search of a consensus or compromise often delays the completion of these projects. Odour from sewage treatment plants and landfill sites, for example, are common complaints of nearby residents. A proposal to relocate the Sha Tin Sewage Treatment Plant in Shatin New Town in the New Territories, to a nearby cavern 650m away, may result in improving the quality of the urban environment around the existing site. A suitable replacement site is usually hard to find in Hong Kong. This example will be further elaborated later in this article. However, the problems related to solid waste landfill sites, which is not underground in nature, may be more difficult to handle.

In view of the above-mentioned challenges, the Hong Kong SAR Government has re-focused its attention in searching for alternative solutions, with cavern development featuring prominently among these. Government departments are being advised that when planning for public facilities, cavern location should be considered as a priority option (Chan 2011). To this end, a holistic approach in planning and execution is needed. Private participation should be encouraged as there would be many non-governmental facilities, in addition to underground property

| Land Use Category | Potential Land Uses in the Current HKPSG | Potential Land Uses to be added to HKPSG |
|---|---|---|
| Commercial | Retail | Food / Wing storage<br>Warehousing |
| Industrial | Industry<br>LPG bulk storage<br>Oil bulk storage<br>Storage / Warehousing | Dangerous goods<br>Data centres<br>Research laboratories<br>Science Park |
| Government, Institution and Community | Civic centre<br>Columbarium /mausoleum /mortuary<br>Incinerator<br>Indoor games / sport halls<br>Refuse transfer facility<br>Sewage, / water treatment plant<br>Service Reservoir<br>Slaughterhouse<br>Transport Connections and networks<br>Wholesale market | |
| Public Utility | Power station | Substation |

Table 1: Potential Land Uses in Rock Cavern Development.

development, which could be located in caverns. The recent proposal of building data centres in caverns is one such example. How to engage private participation in cavern development remains an important issue. It is to be noted that even in Hong Kong, no concrete regulations and concession procedures are available for meaningful private sector engagement.

## TYPES OF UNDERGROUND DEVELOPMENT IN HONG KONG

### Tunnels

Tunnels normally refer to underground passages constructed for the purpose of transportation connection between two points, although tunnels for other purposes do exist. A variety of tunnels exist in Hong Kong, ranging from tunnels for the railway and metro system, for highway and pedestrian walkways, for water and sewage transport, as well as for storage and services. Tunnels are constructed in different locations, such as submerged in water, under rock and earth surfaces. Tunnels that are submerged under water include, for example the three Cross Harbour Tunnels (7.06 km in length in total) for vehicle transport, the tubes for the mass transit railway, the waste water discharge sewage tunnels, and the fresh water supply facilities, among others. Highway and pedestrian tunnels are mainly located on land and under rock, although a section of the Central-Wan Chai Bypass and Island Eastern Corridor Link under construction for the purpose of reducing traffic congestion in the northern shore of Hong Kong Island, the core of the city centre, is submerged in the Victoria Harbour. The other 12 road tunnels on land cover a total length of 24.83km.

There are also some unusual tunnels in Hong Kong. For example, there are about 90 unused tunnels which were bored deep into the hills during the Second World War. Those located in the densely populated urban area are occasionally inspected for safety reasons[1]. An illegal secret underpass, about 40m long, perhaps for smuggling purposes, was discovered recently across the border with the mainland[2].

### Mass transit related underground usage

The mass transit railway (MTR) system of Hong Kong was first proposed in the 1960s as part of the First Comprehensive Transport Study, completed by the London Transport Board and the Road Research Laboratory. It aimed to help ease the gradually worsening urban traffic situation - four lines totaling 52.7km in length were proposed. The first proposal was later modified into a much shorter "Initial System" version of only 20km. Even with a reduction in scale, the project was met with serious market constraints resulting from the oil crisis of the period, which led to the withdrawal of the first Japanese-led investment consortium. The project was further modified and finally completed. A detailed discussion of the development of the rail system in Hong Kong is provided by Yeung (2008).

The Mass Transit Railway Corporation (MTRC) is responsible for all investment and construction of the rail system. Presently, the MTR is a system of 175km with 82 stations. The corporation took over the operation management of the Kowloon Canton heavy rail in 2007 under a 50-year franchise. The MTRC also manages similar facilities in London, Stockholm, Melbourne and a few other Chinese cities. Other on-surface fixed tracks include the tramway and the Peak Tram which runs from the city centre to the peak of Hong Kong Island. Most of the MTR tracks run in tunnels. The high speed express rail link that is presently being constructed to connect Hong Kong with the mainland, will house the world's largest contemporary underground station (430,000 $m^2$) with 15 tracks in central Hong Kong. The high speed rail is expected to be in service in 2017. An underground road system is attached to the terminus.

One of the major considerations in the Hong Kong MTR development is related to the maximization of traffic and land use coordination. Each station serves as a major traffic and business hub. This allows the development of large shopping malls on the upper deck of most of the MTR stations, which in turn are surrounded with housing blocks forming a cohesive commercial-cum-residential neighborhood as shown in Figure 2. Pedestrian paths, either above or below ground, are provided to link the MTR hub.

According to the prevailing policy, buses and minibuses as well as taxis are urged to serve as supplementary lines to feed the mass transit system, which is arguably designated as the backbone of the public transport system. The full integration of the different modes of public transport services thus makes Hong Kong one of the most outstanding transit cities in the world.

1 See http://www.timeout.com.hk/around-town/features/8906/secret-hong-kong.html

2 See, for example, http://www.scmp.com/news/hong-kong/article/1389781/smugglers-built-secret-tunnel-leading-hong-kong-border-officials

## Shopping malls and vehicle parking

As a major shopping centre in Asia, Hong Kong has many large shopping malls, several of which are located underground, as explained earlier, either on top or in the close vicinity of MTR stations. MTR stations are provided with ample retail space. With shops and restaurants lined up along the underground space in and around the station, it becomes one of the focus points of social activities in the city.

Shopping malls normally provide customers with sufficient underground parking facilities and at concessional rates. This, however, is in direct contradiction to the parking policy of the Hong Kong Government, which purposely reduces car parks in the city centre in order to discourage private car use and promote public transport usage. Except for a few of the large shopping malls, most of the car parks in Hong Kong are small in size and attached to private buildings scattered around the urban area. Government provided car parks are multi-storeyed structures.

## Underground pedestrian walkways

One of the significant planning strategies in Hong Kong is the application of pedestrian walkways, either elevated or submerged underground, to avoid direct conflict between vehicle and pedestrian traffic. Pedestrian underpasses in Hong Kong are brightly-lit and with direct access to underground shopping facilities or the mass transit railway stations. A large scale pedestrian walkway is being constructed in Causeway Bay, a major shopping area on Hong Kong Island to the east of the Central District, to relieve the pedestrian pressure on the streets (Transport Department 2010). The emphasis of TOD in land use planning encourages the construction of a system of underground spaces for parking and other purposes in large residential areas as well as commercial blocks. This underground space network is normally linked to the nearby public transport facilities, wherever possible.

## The emergence of a new urban structure

The extension of the mass transit system inevitably rearranged the land use and activities of the urban sphere in such a way that those activities that require interpersonal contact came to be gradually grouped on top or close to mass transit lines. With the implementation of a highly successful metro system and the concept of adopting a HOPSCA (hotel, office, parking, shopping mall, convention, and apartment) urban architecture design on and around the mass transit hubs, Hong Kong has evidently reshaped its urban structure, highlighted with the emergence of a linear cityscape with the transit terminals serving as a string of focus points of social and economic interaction.

Through the "tubes", travel time becomes manageable, as traffic jams do not normally occur on mass transit lines. The high efficiency of the mass transit successfully transforms the urban production structure to such an extent that the general public depends on travel time instead of travel distance as a space measurement in their daily societal interaction.

Figure 2: The International Commercial Centre Complex, Hong Kong.
Source: http://www.luxuo.com/wp-content/uploads/2011/03/ICC-Hong-Kong.png

## CAVERN DEVELOPMENT IN HONG KONG

### Existing cavern development

In addition to acquiring land from the sea and the expansion of underground space, the city is now extending its planning in cavern development as well to meet the increasing demand for space to house especially public utility facilities. There are several public facilities in Hong Kong located inside caverns, such as the Island West refuse transfer plant, Stanley sewage treatment plant, and the Kau Shat Wan Government Explosives Depot. The latest on the list are salt water service reservoirs.

The Island West refuse transfer plant, which was built inside Mt. Davis, has been in service since 1997 under a design-build-operate contract (Cheng 1997). It has the capacity to handle 1000 tons of refuse per day. It is a modern facility with a computerized weighbridge system, exhaust ventilation system with odour removal unit, waste water treatment plant and vehicle wash system, among others. The plant confines all waste handling operations within the cavern, away from the main urban areas. Even the road leading to the entrance of the plant is carefully designed to avoid visual blight.

The Kau Shat Wan Government Explosives Depot is located on the south-eastern shore of Lantau Island. It has 18 magazines for a notional storage capacity of 500 tons of blasting explosives, and explosives accessories. All imported explosives and explosive accessories must first be kept in the depot under the Hong Kong Protected Place Ordinance (Cap. 260). The depot is classified as a protected place with a restricted flying zone of 1km in radius from the centre of the depot and a safety altitude of 3000 ft AMSL. Several precautions must be taken to ensure safety, as explained in Charmoille and Thoraval (2012). Safety precaution in fact remains a major consideration in all underground facilities.

Higher education institutions have also in recent years begun to promote the use of underground space for the provision of public utility facilities (Zhao 2000). Other than car parks, the University of Hong Kong, for example, in order to accommodate the development of their Centennial Campus, relocated two Water Supplies Department (WSD) salt water service reservoirs (12,000 $m^3$ capacity) within rock caverns, according to the Civil Engineering Development Department (CEDD) as reported in (Li 2014).

### The Harbour Area Treatment Scheme (HATS)

In addition to the three cross-harbour vehicle tunnels and another two for the mass transit system under the Victoria Harbour, there is a set of deep tunnels for the waste water discharge system under the large scale Phase I of the Harbour Area Treatment Scheme (HATS), known formerly as the Strategic Sewage Disposal Scheme to reduce water pollution in the urban area (McLearie et al. 2001). The Scheme is one of the major engineering projects proposed several years before the return of the territory to China. The first stage of the Scheme consists of a 24 km tunnel, 80-150 meters under the harbour. Wastewater from the western section of the city is collected for chemically enhanced primary treatment before being discharged at sea through the deep tunnels, which operate as a series of inverted siphons. Wastewater is first discharged into a vertical drop shaft at each of the preliminary treatment works and later raised from the tunnels by pumping. To date, the pumping facility is one of the largest in the world. Total treatment capacity of the plant is about 40$m^3$ per second. It is proposed that an additional 43km of deep tunnels will be required to complete the other three phrases of the Scheme.

In order to accommodate the sudden downpour of rainwater during the monsoon season, a large rainwater retention reservoir of about 60,000 $m^3$ is being constructed under the race course in Causeway Bay adjacent to the city core in order to avoid flooding. The city is equipped with several additional drainage tunnels to accommodate rapid rainwater discharge.

### Feasibility study on potential cavern development

Land reclamation is the most favoured method of creating space in urban Hong Kong. Given the various constraints facing land reclamation and serious social objections in recent decades, the Geotechnical Engineering Office carried out its first study of the city's underground potential in 1988. The city since then has housed several public facilities underground, as discussed above. A large scale feasibility study was also completed in 2011, proposing the relocating of, for example, power stations, fresh water reservoirs, a trash transfer station and more, into vast caverns drilled deep underneath the city.

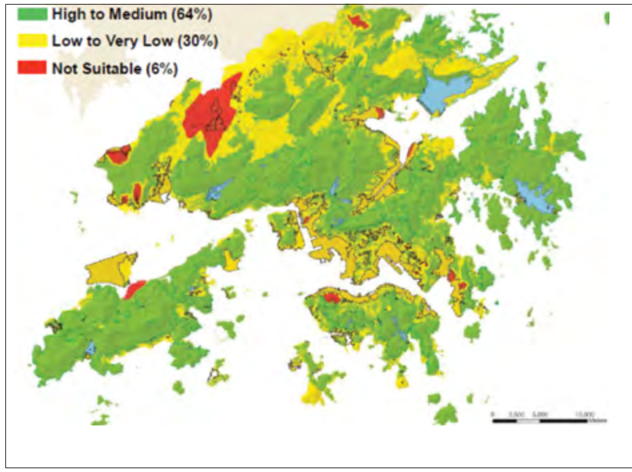

Figure 3: Cavern Suitability Map, Hong Kong
Source: http://www.hkie.org.hk/hkiehkip/pdf/presentation/Day2/Ir%20Raymond%20K%20S%20CHAN.pdf

The hilly Hong Kong has strong foundation bedrock suitable for cavern development, with a vast area of Mesozoic volcanic and granitic rocks spread across the territory. The said feasibility report concluded that two thirds of the landscape has a "high to medium suitability" for cave-digging, as shown in Figure 3. The Study also identified 400 potential government facilities for future relocation underground. Five areas with over 20 hectares of underground space have been identified for further exploration. One of the items that caught the attention of the media is the construction of underground data centres for the installation of sensitive IT data for both the private and the public sectors (Clark 2013). Land development as such lies in the hands of the private sector under the prevailing town planning legislation in Hong Kong. The private sector may take the opportunity to negotiate for possible concessions such as preferential land premiums and tax incentives for this new area of property development.

### Stanley underground sewage water treatment works

The Stanley Underground Sewage Water Treatment Works, on the other hand, comprises an underground construction of a 80,000$m^3$ cavern built on granite rocks to house a treatment plant 60m below the ground, as shown in Figures 4 and 5. The plant is located at the northern end of the Stanley Peninsula of Hong Kong Island. The cavern has an unlined roof and unlined walls above the level of the tanks. The main caverns have a maximum dimension of 17m span and 17m high (Oswell et al. 1994). The plant is built to serve a residential population of 27,000 people.

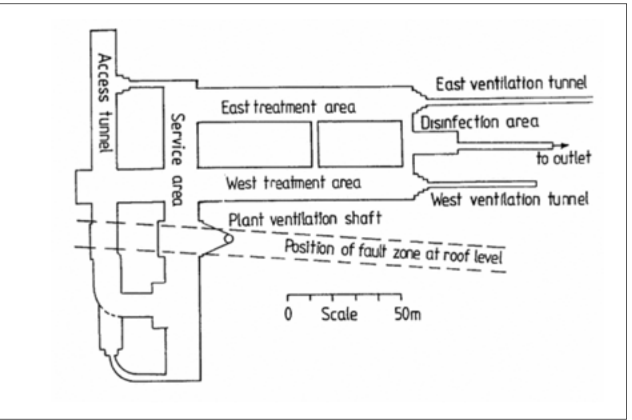


Figure 4: Layout Plan of the Stanley Underground Sewage Water Treatment Works
Source: Oswell et al. (1994), p. 118.

Figure 5: Inside the Stanley Underground Sewage Water Treatment Works
Source: http://wqrc.epd.gov.hk/en/gallery/photo-sewerage-infrastructure.aspx

Figure 6: Existing Site of Shatin Waste Water Treatment Plant
Source: http://en.wikipedia.org/wiki/File:Sha_Tin_Sewage_Treatment_Works.jpg

Figure 7: Government Proposal to Relocate the Existing Plant to the Valley Near By.

### Shatin underground sewage water treatment plants

Sewage Water Treatment Plants are indeed unpleasant sites in the crowded residential area in Hong Kong, as anywhere in the world, and their relocation underground provides an alternative solution addressing both environmental and urban blight considerations. The government is planning to relocate the Sha Tin Sewage Treatment Plant (as shown in Figures 6 and 7) in Shatin New Town in the New Territories. The relocation of the plant into the cavern under the Nui Bo Shan (Mountain) on the opposite side of the Shing Mun River will free up the 27 hectare site for housing development. The relocation of the plant to a nearby cavern allows the continued usage of the existing downstream disposal network, thereby reducing the disturbance to the local community, reducing the construction time and cost, as well as achieving operational cost efficiency. Deodorizing facilities are required to filter odorous air inside caverns before discharging into the atmosphere from a ventilation shaft. The project is expected to be completed in 2017.

## ISSUES RELATED TO UNDERGROUND CAVERN DEVELOPMENT

### Cavern construction challenges in Hong Kong

Being one of the most crowded built-up areas in Asia, executing engineering construction works in downtown Hong Kong is a serious challenge. The narrow streets restrict the movement of construction equipment, the built-up area restricts shaft access to the underground works, and special care must be taken to minimize the impact of construction on the hydro-geological regime and the buildings on the surface, let alone any negative traffic and noise externalities. Selected buildings or facilities may need to be relocated to create temporary works sites. The removal of tunnel spoil requires an alternative solution to the normal transport on streets, due to traffic and environmental considerations. The location of temporary underground explosives magazines must be specially selected within the urban area close to the tunnel access points. The use of explosives also has to ensure maximum safety.

As explained earlier in the paper, an extensive part of the urban area is built on land reclaimed in phases since the 1930s. According to Chui (2011), most structures are built on pile foundations. In certain parts of the city, buildings stand on soft ground. This means that the preferred tunnel would have to avoid being too close to the buildings on the surface on one hand, and prevailing underground facilities including existing rail tunnels on the other. Detailed analysis needs to be undertaken to assess any impacts of the new construction on the existing facilities, including existing tunnels and train operations. Groundwater inflow and ground settlement need to be avoided.

For much of the length of the tunnel, drill-and-blast excavation methods are normally applied where rock conditions allow. Nevertheless, deep rock tunnelling may provide additional challenges. For example the tunnelling of the rapid rail link has to be carried out 680m beneath ground level under the Tai Mo Shan, the highest mountain in Hong Kong. This does not allow the use of closely spaced boreholes and the ground conditions could only be inferred from existing parallel tunnels, if any. The nearest West Rail Tai Lam tunnels in this case are more than 150m shallower. The construction of the high speed rail terminus also faced similar rock excavation challenges, causing a delay of completion for at least up to two years[3].

Unexpected geotechnical consequences may also emerge during underground construction. According to the prevailing practice in Hong Kong, the risk lies with the contractor and not the government or the MTRC. When submitting a bid for the project, the contractor is assumed "to be experienced, to have foreseen a particular condition or obstruction" even if "the contractor was misled by insufficient and inaccurate information given to him by Government" (Longbottom 2011:2). He further argues that the Geotechnical Baseline Reports (GBR) introduced into the contract, ostensibly to alleviate some of the confusion, actually serve no purposes as the baseline parameters do not always reflect the anticipated ground conditions and are not measurable. Thus the bidding price in most of the construction projects does not necessarily reflect the actual business decision on costing, and furthermore, a contractor may face serious losses if the ground conditions are not in his favour. Richards and Nilsen (2007) discuss some of the critical risks in tunnel construction which must be taken into consideration and properly evaluated, as such risks may significantly affect the cost estimate, which always remains a difficult issue in tunneling costing (Efron and Read, 2012).

### Planning issues related to cavern development

When dealing with the use of underground space, it is important to first of all determine the functions and facilities which are best suitable for locating underground. This is followed by exploring how to maximize the potential use of underground space, and how to blend the underground facilities with the surface environment. In some cases, a total blocking of the negative environmental interference of the underground facilities from the surface environment may be required. Careful planning may allow some underground facilities to be located side by side with surface settlement in such a way that it allows the residents to ignore the negative impacts of the existence of the facilities nearby. Such an arrangement is considered essential especially in a highly densely populated area like Hong Kong where a direct separation of such facilities may prove difficult if not impossible.

When dealing with the location of underground space, several factors need to be considered (Nishi et al. 2000). For example, it is difficult to locate new urban underground facilities in a densely populated area as the space may involve a number of stakeholders. The willingness of people to pay for the location, socially or otherwise, remains the key issue in their response to project proposal. In addition to the NIMBY site syndrome, the interior and exterior value of the underground space is also essential to the residents in general, for aesthetic reasons at least, and to the developers and contractors in particular. It is also essential to synergize above and underground developments to avoid unnecessary spatial and social conflicts in public utility allocation as well as in traffic and environmental management. On the other hand, developers may tend to keep construction costs low. Experience in Hong Kong proves that the search for a consensus or compromise among stakeholders is always a challenge to the decision makers.

Other than issues related to public opinion and public participation, there remain difficulties in project implementation as well. For example, existing laws and regulations may not necessarily allow a smooth planning and engineering operation. Cavern development may require a more detailed/comprehensive set of planning and construction procedures than the normal engineering projects to ensure a higher standard of safety, operation and cost efficiency than otherwise, among others. A revision of the existing laws may be required (Nishioka et al. 2007) in order to facilitate a reorientation of the planning vision and the support of fully designed planning procedures and regulations (Parriaux et al. 2006). The following items proposed by Barker (1991) may be included in the drawing of a workable planning regulation of underground space usage, according to the International Tunneling Association (ITA):

1. Limits of surface property ownership;
2. Restrictions on natural and mineral resource exploitation;
3. Ownership and the right to develop subsurface space;
4. Major permits required;
5. Application of surface land use regulations;
6. Environmental controls; and
7. Restrictions due to surface and subsurface structures.

It is to be noted that a full set of regulations and procedures for participation from the private sector is yet to be enlisted in Hong Kong. The prevailing regulations in Hong Kong do take into consideration the need for co-existence of the underground space usage and surface development, although objections from the general public to the location of certain underground facilities nearby is not an uncommon occurrence when a public consultation on a proposed underground project is carried out. To ensure construction safety in a crowded environment, technical guidelines and standards on planning are available in Hong Kong[4] In addition, a long specified public consultation period is a mandatory requirement. Cavern development with private involvement is required to adhere to the various published guidelines, but in addition, certain requirements need to be ironed out on a case-by-case basis to ensure a high standard of safety and construction quality is maintained. Stringent requirements and precautions are justified and necessary when taking into consideration the density of the Hong Kong developmental environment. ■

3 See, for example, news report of the South China Morning Post on 15th April 2014. https://customerservice.scmp.com/meter/1/1?destination=http%3A%2F%2Fwww.scmp.com%2Fnews%2Fhong-kong%2Farticle%2F1482898%2Fhk67b-cross-border-rail-link-fails-meet-completion-schedule%3Fpage%3Dall&referer=http%3A%2F%2Fwww.scmp.com%2Fnews%2Fhong-kong%2Farticle%2F1482898%2Fhk67b-cross-border-rail-link-fails-meet-completion-schedule%3Fpage%3Dall

4 Various planning guidelines covering various areas related to underground development are available in Hong Kong, including, for example, Chapter 12 of the Hong Kong Planning Standards and Guidelines of the Planning Department, the Guide to Cavern Engineering prepared by the Geotechnical Engineering Office of the Civil Engineering Department and the Guide to Fire Safety Design for Caverns by the Building Authority and Fire Services Department, among others. The Occupational Health Division of the Labour Department issues a Code of Practice for the Protection of Tunnel Workers from Silicosis. Fire Safety of cavern space also is an issue of concern (Luo, undated). The Environmental Impact Assessment Ordinance (EIAO) applies to cavern development as a designated project. Transport Impact Assessment is also required before its construction and operation.

## AUTHOR

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# THE UTILIZATION OF UNDERGROUND SPACE PLANNING IN TIANJIN (CHINA) CENTRAL CITY (2013-2020)

Shi Wujun · Xiao Yu · Gong Yuan · Zhao Guang · Liu Wei

## OVERVIEW OF TIANJIN CITY UNDERGROUND SPACE PLANNING

### An introduction to Tianjin

Tianjin City is located in the northeast of the North China plain, in the Bohai Gulf in the Pacific West Coast, in North latitude 38°34'to 40°15', East longitude 116°43' to 118°04'. To the north of the city is Yan-Shan, to the east, Bohai Bay, and to the west lies Beijing. Tianjin is the gateway to the sea from Beijing, North and Northwest China, and is the nearest city from the Eurasian Continental Bridge railway transportation. It has a total land area 11,917.3 square kilometers and a population of 14 million (year 2012).

Figure 1: The location of Tianjin


Tianjin is the economic center of the Bohai Rim[1], but also an important economic center in North China. In terms of the city size and comprehensive strength, Tianjin is the second largest city in North China. Its role is especially significant due to advantages in the import and export trade, port logistics, manufacturing and other industries. Furthermore, Tianjin is an important transportation hub in the North. Tianjin Port, an international, multi-functional, comprehensive and modern deep-water port, is an important shipping center in North China and ranked among the top 20 ports in the world.

### Urban planning system of Tianjin

In China, the urban and rural planning system covers the urban planning system, urban planning, town planning, rural planning and village planning. Of these, the urban planning and town planning are carried out through master planning and detailed planning, and the detailed planning includes regulatory and site plans.

The Urban Master Plan of Tianjin (2005-2020), reviewed and approved by the State Council in 2006, clearly identifies the development layout of cities and towns, functional districts, land layout, integrated transport system, etc. It also indicates geographical area banned, limited and suitable for construction, as well as the contents of various special plans. It acts as the basis for all plans within the scope of Tianjin.

The regulatory plan of Tianjin is prepared by the competent urban and rural planning department under the Municipal Government, in accordance with the provisions of the urban master plan. It is composed of various units and clearly presents the dominant function of each unit, main land use, green rate, total construction area, location and size of public green space, public supporting facilities and requirements of various planning regulatory standards in the form of guidelines. With respect to core contents of urban construction, the building height, building volume, architectural style, color and other instructional contents are included. The regulatory plan of Tianjin is presented in the form of "one regulatory plan and two guidelines"[2].

### Tianjin's planning for underground space utilization

In the 21st century, the urban development of Tianjin is accelerating. With the development and opening of Binhai New Area[3] and improvement of the central city, the development and utilization of urban underground space in Tianjin has entered into a rapid development stage. In order to better integrate the existing resources, scientifically and moderately develop underground space and establish a well-developed system of underground space use, Tianjin has carried out extensive research on the development and utilization of underground space since 2004. This has resulted in the document "Comprehensive Utilization of Underground Space Planning in Tianjin Central City (2006-2020)", which is aligned to the Urban Master Plan of Tianjin (2005-2020). A comprehensive survey on the underground space in Tianjin central city has

1 The Bohai Rim is mainly composed of two municipalities and three provinces, including Beijing, Tianjin, Hebei, Shandong and Liaoning, covering an area of 518,000 square kilometers.

2 Two guidelines consist of the land subdivision guideline and urban design guideline.

3 Binhai New Area is an eastern coastal area in Tianjin, covering 2,270 square kilometers with 153 kilometers of coastline. After 10 years of independent development of Tianjin, Binhai New Area has been incorporated into China's national development strategy in 2005 and become a national new area for development and opening under state support.

been conducted and a preliminary analysis carried out on problems and difficulties in underground space utilization. In order to address these issues, the underground space resource assessment, size forecasting, spatial distribution, transport and municipal facilities etc. have been studied and an indicator system for the underground space planning and regulatory framework has been initially explored. However, limited by our knowledge on the development and utilization of underground space at this stage, the overall planning is not very systematic and coordinated. Therefore, there are significant differences between conclusions on size projections based on which the 2006 plan was developed, and the actual construction. So, this plan is not updated or detailed enough to guide the underground space construction.

Since 2009, the urban development orientation and spatial layout of Tianjin has been improved on the basis of initial results obtained before 2006 and combined with the Strategic Planning of Spatial Development in Tianjin, Orbital Comprehensive Transportation Planning in Tianjin, Overall Urban Design of Tianjin Central City, Regulatory Plan of Tianjin Central City. The Tianjin Master Planning of Underground Space (2009-2020) has also been prepared. Through intensive study and research on the overall situation of underground space in Tianjin, this improvement has initially identified the ideas and framework to make a master plan for underground space and has extended the planning of underground space from the central city to the whole of Tianjin.

In 2011, with the commencement of large-scale development and construction of underground space in Tianjin, the shortage of overall underground space was highlighted in the master plan: the incomplete planning framework and absence of clear preparation method resulted in the fact that the underground space planning can't effectively meet the regulatory plan of the surface level. In order to promote the orderly and rational development and utilization of underground space, Tianjin launched a comprehensive study on underground space planning. Also, in order to ensure effective transformation of research results, the city re-examined and deepened the initial results made in the 2009 version and prepared the Utilization of Underground Space Planning in Tianjin Central City (2011-2020). In this document, the planning area was adjusted, the size forecast amended, and the spatial layout, function distribution and other contents with significant impact on the underground space planning, restructured. In this way, it is proposed to mainly utilize the shallow and middle layer[4] of the underground space in the central city to construct underground nodes relying on primary subway stations and public centers for commercial and parking purposes. The underground spaces should be connected with each other as much as possible to form a system of underground space by adhering to the principle of agglomeration and integrated development. In addition, the comprehensive disaster prevention and safety requirements should be strengthened and the design scheme must meet the Regulations on the Development and Utilization of Urban Underground Space, Regulations of Tianjin on the Underground Space Planning and Management and other regulatory requirements.

4 The underground space is divided by development depth: shallow layer ranges from 0 to -10 meters; middle layer ranges from -10 to -20 meters; and the deep layer ranges from -20 meters below.



## EVOLUTION OF UNDERGROUND SPACE USE IN THE TIANJIN

### Process of development of underground space utilization in Tianjin

The development and utilization of underground space in Tianjin can be traced back to 1950s.

- 1950s – 1980s - large-scale air defense fortifications built, but which were separate from the urban construction;
- 1970 – 1984 - Metro Line 1 (Tianjin West Railway Station to Xinhua Road) constructed, 7.4 km long but in fact too short to effectively support urban public transport;
- Late 1980s – Air defense projects transformed into "peacetime" civil projects, creating certain social benefits;
- Since 1990s – Underground space removed from air defense projects and a number of new underground projects constructed, including subways, underground car parks and other public facilities, which play an important role in solving urban public transport, traffic congestion and other issues. Meanwhile, the underground commercial space applications gradually increased.

In the 21st century, with the rapid urban development of Tianjin, especially after Metro Line 2 and 3 were put into operation in 2011, a series of comprehensive ground and underground development projects were initiated. The development pace of underground space significantly accelerated, while the functional type of development and utilization was also enriched and expanded from previous air defense construction and underground municipal pipelines. Currently, the total construction area of underground space in Tianjin central city has exceeded 15 million square meters, but this is still focusing on the basic level.

| | Initial stage | Scale stage | Networked stage | Underground city stage |
|---|---|---|---|---|
| Function type | Underground parking, air defense | Underground business, entertainment, etc. | Underground rail traffic | Integrated pipe gallery, modern underground drainage system |
| Development characteristics | Single building, single function | Focus on key projects and take comprehensive utilization as a symbol | An underground network taking the subway system as the skeleton and the comprehensive development of subway stations as nodes | An urban lifeline system composed of systematic underground transportation, municipal and logistics lines |
| Layout form | Scattered | Base extension | Network extension | Three-dimensional city |
| Comprehensive evaluation | Basic level | Basic and key level | Network level | Systematic underground functional level |

Table 1: Stage Characteristics of Underground Space Development

| Name | Length (km) | Length underground (km) | Station number/Station underground |
|---|---|---|---|
| Line1 | 26.2 | 16.1 | 22/13 |
| Line2 | 22.6 | 19.8 | 19/17 |
| Line3 | 29.6 | 20.5 | 23/18 |
| Line9 | 12.1 | 5.8 | 9/5 |
| Total | 90.5 | 62.2 | / |

Table 2: Length of subway line built in Tianjin

### Problems in Tianjin underground space utilization

The development and utilization of underground space in Tianjin could have started earlier, but the construction costs of creating underground space are high due to the special geological conditions, which significantly impact the development. Compared with Beijing, Shanghai and other cities, there is a big gap in terms of the utilization scale and level. The key problems are described below:

*(1) The total amount is growing rapidly with lower overall development level*
During 2009-2011, the underground space in Tianjin central city maintained a rapid growth rate mainly in underground commercial facilities and underground parking facilities, and increased by 55% and 72% over 2009 respectively. This fact shows that there is a growing demand for the underground space in Tianjin central city, but also a strong demand for underground space in Tianjin. However, compared with other municipalities, there is already large scale utilization of underground space in Beijing and Shanghai central city, and a networked underground space system is being constructed based on the underground rail system. Now, there are large-scale underground space projects in Tianjin, such as the Cultural Center and the underground space of its surrounding areas. But, there are still problems of shallow utilization depth and small single projects in the construction of underground space across Tianjin. With respect to the development stage, Beijing and Shanghai are constructing a networked underground space system, while Tianjin is still focusing on the basic construction of underground space.

*(2) There is insufficient utilization and unreasonable functional composition of underground space*
At present, the underground space development pattern in Tianjin mainly focuses on independent basement development of buildings primarily for business and parking. Lack of unified planning of the underground space of land plots and surrounding areas means that the underground spaces can't connect with each other, resulting in low utilization rate, which adversely impacts the development and utilization of underground space.



In terms of functional composition of underground space, parking and traffic space take 74%, underground public space 5%, and other functions 21%. In some domestic cities with well-developed underground spaces such as Beijing, Shanghai and Chongqing, there are stringent requirements for underground public space. Generally, public space takes 10-15% of the total underground space. Therefore, in the future, Tianjin should gradually increase underground public space to enhance the value of land use.

### Ideas for Tianjin underground space planning

In order to solve these problems, we have re-inspected the technology route for underground space planning to focus on the combination of underground space planning with recent construction projects and appropriately control the long-term development and utilization of underground space. With respect to the underground space size forecast, the development trend and objective of various functional types have been put forward based on different uses of underground space, while the layout of underground space is mainly determined by the ground urban structure, subway lines and other factors.

## THE ROLE OF PLANNING IN THE DEVELOPMENT OF UNDERGROUND SPACE

In China, especially in Tianjin, the current underground space plan is prepared as a special plan at the master planning stage. However, both the specific land use approval and urban construction requires detailed plans. It is a contradiction, but also a direction for us to explore. In recent years, Tianjin has gradually developed a few detailed deep underground space plans to detail the boundary and depth of underground space and interfaces with other plots, enabling the underground space planning content to be closer to the actual use.

Looking at the actual situation in Tianjin, the Tianjin underground space plan has been prepared at the macro, meso and micro level corresponding to the underground space use planning, underground space planning guideline and constructional detailed underground space planning (or including architectural design of the underground space). Among these, the underground space planning guidelines are used to control and implement various elements of the construction of underground space and incorporate the controlled contents of underground space into the urban regulatory detailed planning system, and to guide the urban construction as a basis for urban management.

### Underground space utilization planning

The macro planning of underground space utilization corresponds to the master urban and rural planning, aiming at the resource allocation of underground space in the region. It covers the underground space resource assessment, forecast of demand for underground space and its total utilization, key areas of underground space utilization, analysis and study on the subway frame, co-ordination of recent construction of underground space with the future utilization and other contents. Practices in Tianjin include the *Utilization of Underground Space Planning in Tianjin Central City* and *Underground Space Planning of Binhai New Area in Tianjin*.

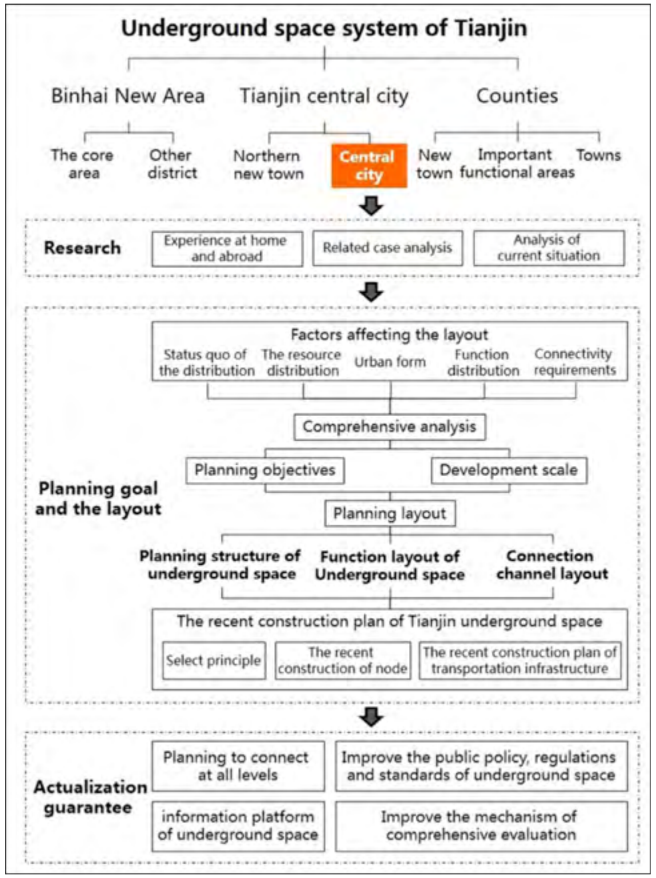
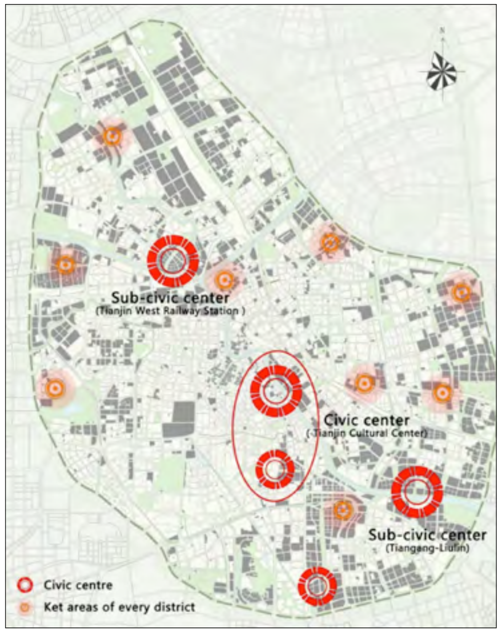
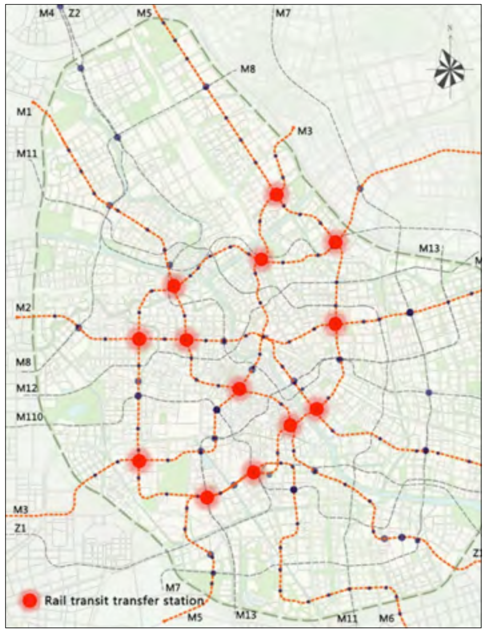



Figure 2: Technical route of The Utilization of Underground Space Planning in Tianjin central city (2011-2020)

Figure 3: The ground public center in Tianjin central city

Figure 4: Rail transit transfer station in Tianjin central city



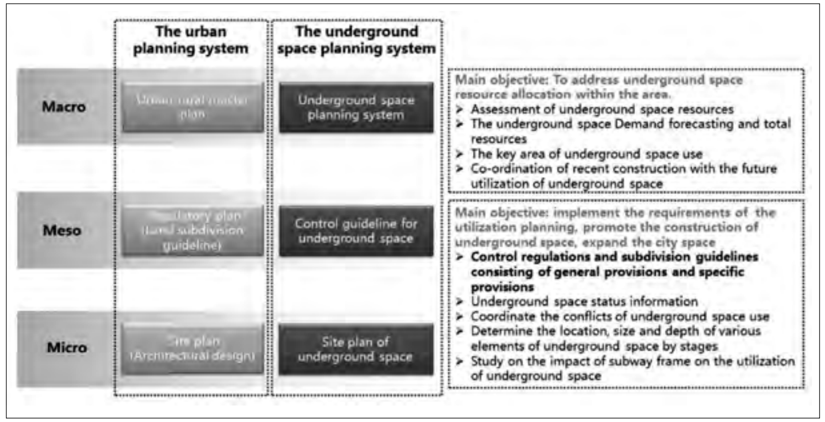




Figure 5: Preparation Levels of Tianjin Underground Space Planning

## Underground space planning control guideline

The meso underground space planning guideline corresponds to the regulatory detailed planning (including the land subdivision guideline), consisting of the general control provisions and specific control provisions for underground space planning. It is prepared to implement the underground city, underground complex and other key construction areas of underground space identified in the *Utilization of Underground Space Planning in Tianjin Central City*, apply the scope, depth, interface position, number of channels and other technical indicators of underground space to the land use and combine with the data from the underground spatial information management department, so as to become a necessary extension of Tianjin regulatory detailed planning.

The guideline for underground space planning consists of general control provisions and specific provisions. The general provisions propose control requirements against elements of the underground space within the unit and guides to determine control elements of specific provisions. In general, the control elements are composed of five parts, including underground space resource utilization and distribution, overall layout of special facilities for underground space, the underground public space system, and the overall requirements of air defense projects and key construction areas. The specific provisions are prepared to implement the underground space utilization planning and intentions of the general guideline. According to various control requirements specified in the regulatory detailed planning of underground space, it is necessary/compulsory/mandatory to carry out in-depth research on the layout, spatial integration, public events, transport system, main entrances and exits, landscape environment, safety and disaster prevention of the underground space within the planning area, coordinate the relationship between the public parts and the development sites, as well as that between underground transportation, municipal, air defense and other facilities, and propose various control indicators and other planning and management requirements for the comprehensive development and utilization of underground space resources.

### Site plan of underground space

The micro underground space planning corresponds to the site plan and combined architectural design. It is an implementation-oriented underground space design stage.

## KEY PLANNING ISSUES AND CHALLENGES FACED

### Assessment of total underground space resources and division of available areas

Urban underground space has large and rich space resources. In order to correctly estimate and assess the potential, value and distribution of underground space in Tianjin central city, it is necessary to divide the distribution scope of underground space for development and limited development, rationally allocate, use and protect underground space resources, and assess underground space resources in Tianjin central city.

Through analysis of engineering and hydrogeological conditions, existing underground space utilization in Tianjin central city, the impact and mechanism of the ecological system on the development and protection of urban underground space resources, it is able to comprehensively evaluate the engineering suitability, scope for reasonable development, potential values and overall quality of underground space in Tianjin central city available for development and utilization, so as to determine the overall strategic direction and overall positioning of underground space development, utilization and protection.

According to the different influence on the development of underground space, the underground space resources can be divided into three categories, the one not available for development, the one available for limited development and the one available for full development. On the basis of the evaluation findings of appropriate geological conditions, combined with the limitation of ground architectural conservation status and special land, we can get the scope and overall distribution of underground space resources available for reasonable development.

The resource assessment work has provided macro basic data on quality characteristics and classification basis for Tianjin central city to develop overall development and utilization objective, layout and development schedule of the underground space, which has important significance and application value for the orderly and sustainable use of underground space, as well as the ecological and geological protection.

### To determine the scale of the underground space requirements

The forecast for the underground space development scale is a kind of scientific and rational forecast for the amount of construction proposed against development objectives based on the assessment of underground space resources. Currently, the preparation of plans for development and utilization of underground space both at home and abroad has made considerable progress. Especially, in the development scale forecast, various forecasting methods, including the comprehensive index evaluation method, analytic hierarchy process and land use classification method have been put forward with the deepening of new urban planning ideas and study of new methods.

| Assessment system | Subjects | Grade I indicators | Grade II indicators /Notes |
|---|---|---|---|
| Investigation of underground space resources | Not available for development | Serious adverse geological structure | Large and active fault zone and fracture zone |
| | | Serious geological disasters | Sand liquefaction |
| | | Water resources | Water source protection, confined water veins |
| | | Ground conserved buildings | Historic buildings, important buildings, general buildings |
| | | Developed underground space | Underground building, municipal pipelines, transport facilities |
| | | Underground treasure troves | Underground mines, underground cultural relics |
| | Available for limited development | Greenland, water, mountains | Corresponding development depth and proportionality coefficient |
| | | Space under foundation of buildings and structures | Corresponding influence depth and scope |
| | Available for full development | Area planned to be removed | |
| | | Square, open space | |
| | | Roads | (A certain depth below) |
| | | Construction area newly planned to develop | |
| Evaluation of underground space resources | Difficulties in resource development | Engineering geological suitability | Geological lithology |
| | | Hydrogeological suitability | Type and depth of groundwater |
| | | | Groundwater moisture |
| | | | Corrosion of groundwater |
| | | Development depth | Depth of 0-10 meters; 10-20 meters; 20-30 meters |
| | Potential development value | Spatial location and transportation convenience | Business center |
| | | | Urban landscape attractions and cultural centers |
| | | | Metro stations and transportation hubs |
| | | Land price | Commercial benchmark price of land |
| | | Land use type | |
| Estimation of underground space resources | Available for limited development | Greenland, water, mountains | Corresponding development depth and proportionality coefficient |
| | | Space under foundation of buildings and structures | Corresponding influence depth and scope |
| | Available for full development | Area planned to be removed | Corresponding coefficient, level and scope available for effective development |
| | | Square, open space | |
| | | Roads (a certain depth below) | |
| | | Construction area newly planned to develop | |

Table 3: Item-indicator System for Underground Space Resources Investigation and Assessment in Tianjin Central City

The demand for underground space in Tianjin central city is forecast by using the land use classification method model and corrected with various parameters of urban functional systems and land characteristics in Tianjin. In addition, the statistical analysis standard data and relevant planning indicators of local underground space development instances in Tianjin are adopted as the fundamental basis to correct and determine the strength of underground space development. Based on such an idea and model, a forecasting framework system for urban underground space demand has been proposed based on the land classification and subsystems in Tianjin.

*(1) Underground space scale of residential land*

According to the *Urban Master Plan of Tianjin* (2005-2020) and *Parking Standard for Construction Projects in Tianjin*, the ratio of underground space scale of residential land to the ground construction quantities is deduced 18% -28% by referring to the ratio of existing ground buildings to the underground parking construction area of residential quarters.

According to the latest version of regulatory results, there were about 5,140 hectares of new residential land in 2020 with an average floor area ratio[5] of 1.8 and a construction area of 92 million square meters. By 2020, the demand for underground space will reach 16-25 million square meters or so.

*(2) Underground space scale of land for public facilities*

The land for public facilities includes land for administrative offices (C1), commercial and financial use (C2), culture and entertainment (C3), sports (C4), health care (C5), as well as education and scientific research design (C6). The underground space scale is forecast according to the following principle:

Underground construction area of public utilities = Σ {scale of classification construction land × proportion of land for public facilities (Z) × floor area ratio of ground buildings (R) × proportion of underground buildings to ground buildings (L)}.

From the above, we can see that when the scale of land for urban public facilities and floor area ratio (R) are known, the utilization scale of underground space is mainly determined by the ratio of underground building of various public facilities within a specific area to the total area of underground buildings, that is, the unit strength of underground space accounting for the overall area of construction.

Combined with the latest land price distribution and the distribution of various types of land in the central city, the ratio of underground buildings to ground area of construction of various types of public facilities is calculated. According to different stages of development, the indicators can be divided into three grades.

| land usage | Underground ratio of building construction (%) | Objective (%) | | |
|---|---|---|---|---|
| | | Low | Middle | High |
| C1 | 8-15 | 8 | 10 | 15 |
| C2 | 10-20 | 10 | 15 | 20 |
| C3 | 18-22 | 18 | 20 | 22 |
| C4 | 10-20 | 10 | 15 | 20 |
| C5 | 10-18 | 10 | 15 | 18 |
| C6 | 8-15 | 8 | 10 | 15 |

Table 4: Underground building covers an area of public facilities construction scale proportional in Tianjin central city

5 The ratio of a total construction area and the total land area within the scope of land

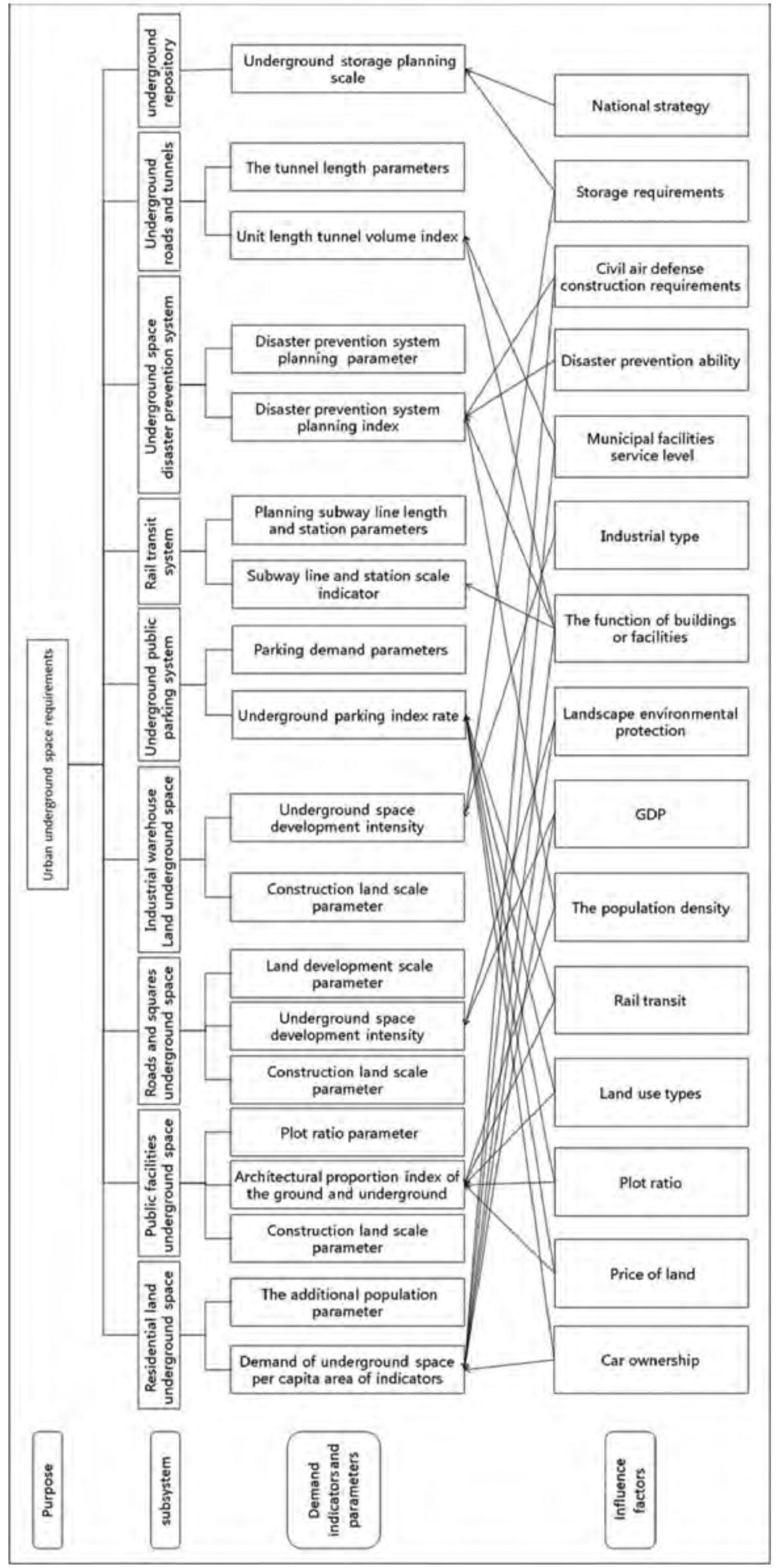



Figure 6: Underground space demand forecasting model based on the urban land and subsystem


Figure 7: The plot which can be used for building underground space in Tianjin central city

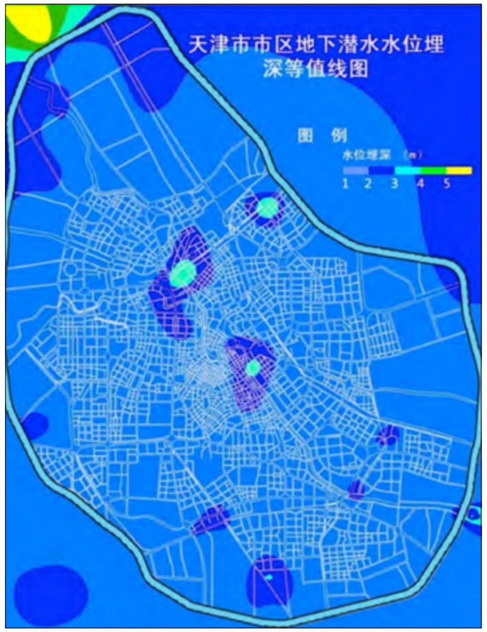



Figure 8: Underground diving depth contour map

*(3) Total size of underground space development in the central city*

According to the master plan of Tianjin, we have forecast and estimated the demand for underground space of residential land, public facilities, public green space, industrial and warehouse land and transportation land in central city within the planning period. By 2020, the total area of underground space in Tianjin central city will reach 50 million square meters approximately.

## The engineering difficulty of the underground space utilization project

The development and utilization of underground space in Tianjin are mainly limited by poor engineering geological conditions. Poor engineering geological conditions usually refers to engineering geological conditions that may directly or indirectly threaten the engineering security and cannot be directly used during construction, but have to be handled with appropriate measures. Tianjin central city is an alluvial and coast plain formed under the joint effect of river and ocean motion and human transformation. The land is flat with a gentle slope. Influenced by the intersection of rivers, there are a few small hills and ponds alternating each other. According to available information, poor engineering geological conditions in Tianjin central city include ground subsidence, seismic sand liquefaction, fracture structures and so on. Meanwhile, the shallow groundwater depth raises higher waterproofing and anti-floating requirements for underground space.

Therefore, special attention needs to be paid to the influence of adverse geological impact during the development and utilization of underground space resources in Tianjin, and large municipal integrated tunnels, underground express ways, subway tunnels and other linear and large critical infrastructures in the area of fault structure should be carefully planned and constructed. In the actual construction process, appropriate structure and technical measures should be adopted to mitigate uncertain geological risks based on characteristics and ability to resist risks of specific projects.

In areas with poor groundwater conditions in the central city, the waterproofing work, floor weight, anti-floating anchor, floor overhanging and other anti-floating treatment measures should be adopted to prevent piping, leak and other problems caused by improper water sealing and isolation, thus avoiding a great impact on the underground space development.



## To provide sufficient parking spaces to meet the growing urban center parking demand

Underground parking usually takes the shallow underground space and connects with surrounding buildings and transportation hubs through underground passages to guide people to the underground transportation system, so as to reduce the pressure on urban traffic. The underground parking is composed of residential underground parking depots and underground public parking garages.

The residential underground parking should provide more than 85% of the supporting parking rate for a residential district. By 2020, it is expected that approximately 23 million square meters of residential underground parking and about 657,000 parking lots will have been constructed.

Underground public parking garages refers to the underground parking garages available for the public, also commonly known as underground parking spaces. Different from underground parking garage for internal use of some units, it is an integral part of the underground public space system and able to support ground public activities, increase the parking space efficiency and promote the use of subways. Currently, the underground space in Tianjin central city is mainly used for parking. According to the plan, it is expected that the underground public parking scale will reach 17 million square meters (approximately 486,000 parking lots) in the future to meet the growing demand for parking in the central city.

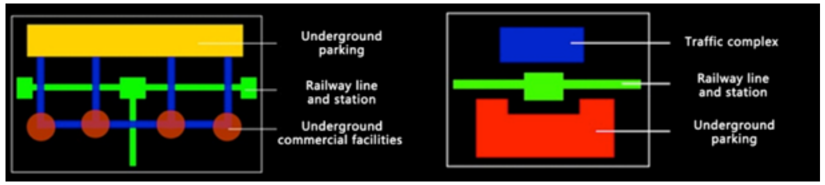



Figure 9: Underground parking lot unicom schematic

## Subway construction and urban development speed does not match

Urban land utilization efficiency and transportation system efficiency are two basic indicators of urban modernization and sustainable development. Especially, the impact of subway planning and construction on the land use, transportation efficiency and underground space development is the most significant. In the future, Tianjin will be oriented on subway construction and vigorously develop underground space focusing on the subway construction, especially transportation hubs and urban public centers.

Now, there are 4 subway lines under operation in Tianjin, namely Metro Line 1, 2, 3 and 9 with a total length of 90.5 km and a total of 73 subway stations. They are an important part of the underground transportation facilities. Currently, Metro Line 5 and 6 are under construction. By 2015, Tianjin will complete Metro Line 1,

Figure10: Rail transit planning of Tianjin central city in 2020

2, 3, 4, 5, 6, 7 (north section), 9 and intra-city express way and Binhai New Area Line 1 and 2 to reach a total underground mileage of 410 km; while by 2020, Binhai New Area Line 3, 4, 5 and Haihe Middle-streams Line 1 will be completed to reach a total mileage of 470 kilometers.

Overall, the rail transit construction in Tianjin has entered a rapid development stage. But, there is still a gap compared with Beijing and Shanghai. As of 2013, there are a total of 17 subway lines operational in Beijing with a total length of 465km and 273 stations. By the end of 2016, the total subway mileage under operation in Beijing is expected to reach 660km or more. Also, the rail transit line in Shanghai has reached more than 500km and is planned to reach 660km in the near future. As one of four municipalities in China, the construction of rail transit in Tianjin cannot keep pace with its urban construction and fails to meet the demands of urban people for diversified travel and green travel.

## THE RIGHT DEFINITIONS AND DEVELOPMENT MODEL

### Underground space right definitions

China is a country based on public ownership, where the land is owned by the state, but the land use right can be transferred and assigned. In Tianjin, the ownership and use right of underground commercial, office, parking and other facilities within the boundary line of land plots except air defense and municipal facilities are attributed to the property unit. The underground space developed by occupying municipal roads and urban public green land is owned by the People's Government, but its use right is determined by the constructor and People's Government through negotiation.

The utilization boundary of underground space with a specific land plot include the horizontal and vertical boundary and the underground space planning guideline should clearly specify the relationship between the utilization boundary of underground space and various boundaries of the ground planning. In general, the horizontal boundary of underground space is subject to the land use boundary of plots. However, where two adjacent land plots are owned and developed by the same person, such a boundary can be integrated as the case may be. Meanwhile, the vertical boundary of underground space is affected by geological conditions, development difficulties and the necessity to develop underground space and other factors. There are three levels of underground space utilization subsurface domain in Tianjin, namely the shallow, middle and deep corresponding to more than 10 meters, more than 20 meters and more than 30 meters respectively. The vertical boundary of underground space at the deeper layer may incorporate that for the shallow layer. In the case of different vertical boundaries due to different underground space utilization conditions, the boundary should be clearly specified in the planning drawing.

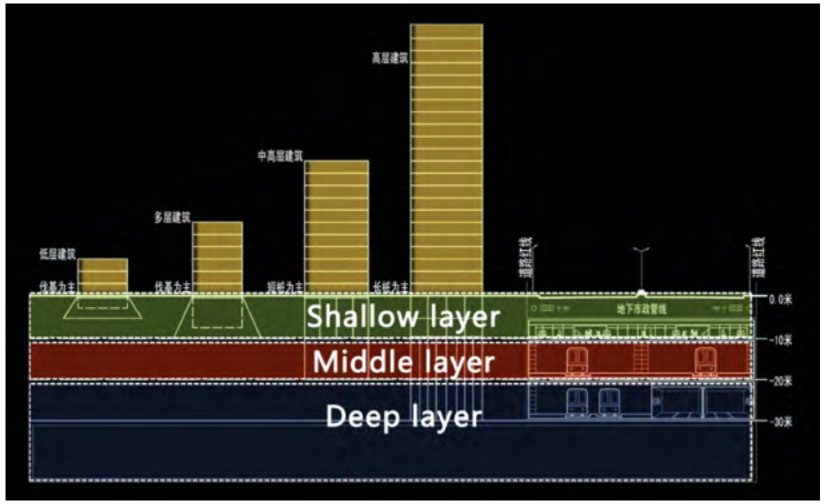



Figure11: Vertical stratification of underground space

### Development model of underground space

The development model of underground space is related to ground building or a combination of group buildings, while such a combination largely determines the development model of underground space. First of all, the development model of underground space in Tianjin is limited by geological conditions, followed by the current stage of economic development.

Relying on the subway framework, Tianjin central city has constructed a hierarchical underground public service system corresponding to the level and scale of surface public space. Specifically, the underground space is constructed as an underground city, underground complex and basement independently developed. Among them, the underground city and underground complex are determined by the importance of corresponding ground nodes in the city and their specific control requirements are shown in the table 6. In terms of the development and utilization of underground space in Tianjin, only the Cultural Center and its surrounding area, West Station Sub-center and the area five kilometers behind Haihe River can rival the size of the underground city. For the underground complex, there are 23 underground complexes with a commercial construction area of about 2,500,000 square meters under planning in Tianjin.

| Types | Geographical location | Function and scale | Typical case |
|---|---|---|---|
| Comprehensive development | CBD area, urban core area | Integrated administrative office, commercial business, culture and entertainment space and parking and public transport facilities to form agglomeration and integration of the underground and ground buildings | Beijing CBD, Zhujiang New Town Core Area, Shenzhen Urban Center, Qianjiang New Town |
| | Sub-center, headquarters economic zone | High-end cluster development core and high-density underground city integrating financial, business, commercial and other functions. | Beijing West Zhongguancun, Beijing Financial Street, Wangfujing, Xiaobailou Tianjin, Tianjin Cultural Center |
| Mixed development | Urban transport hubs | Integration of underground business, entertainment, parking and other functions based on train stations and metro hubs to form underground complex and complex hub combined with urban squares, bus stations and others. | Tianjin West Railway Station transportation hub, Xizhimen Beijing, Dongzhimen integrated hub, Guangzhou Railway Station |
| | Underground business district | Combined with underground commercial streets, underground passage and surrounding buildings to form an underground system focusing on passage but with business, commercial, parking and other functions. | Shenyang, Harbin and other air defense commercial Streets, First Avenue Underground Commercial Street in Chengdu, Yingxiongshan Road Underground Commercial Street in Jinan |
| Single development | Large underground commercial center | Combined independent underground shopping malls or underground parking facilities. Taking large squares and green land as the carrier to form major ground shopping malls with excellent location advantages. | Beijing Xidan Plaza, Jinan Springs Plaza, Tianjin Joy City, Tianjin Aqua City |
| | Underground public parking facilities | To construct multi-storey underground parking depot combined parking lots under squares and open land with interior space of high-rise buildings to improve the public parking. | Aocheng Underground Parking, Xi'an Road Underground Parking in Tianjin |
| | Single large air defense projects | Singly or jointly construct air defense projects, including that for command, specialties, personnel masking, material reserves, evacuation roads, etc., which are used as shops, parking garages and warehouses in peace time. | Jinan Qianfoshan Air Defense Project |
| | Integrated underground municipal facilities | Such as underground substations, sewage treatment plants, underground garbage collection stations, underground municipal pipe gallery and utility tunnels. | Tianjin Haihe Pipe Gallery, Ring Municipal Pipe Rack of Guangzhou University Town |
| | Single underground large building | Singly built underground buildings, including museums, libraries, gymnasiums, laboratories and so on. | Tianjin Museum, Tianjin Library, Libraries of the University of Minnesota |

Table5: Development Mode of Underground Space

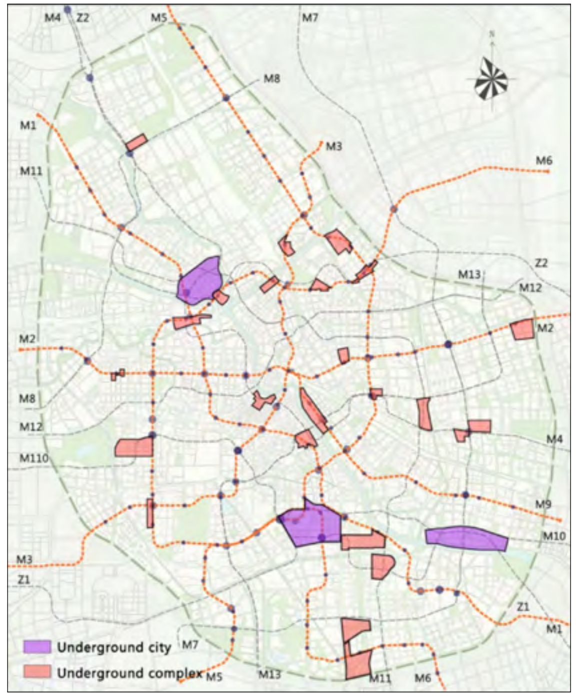
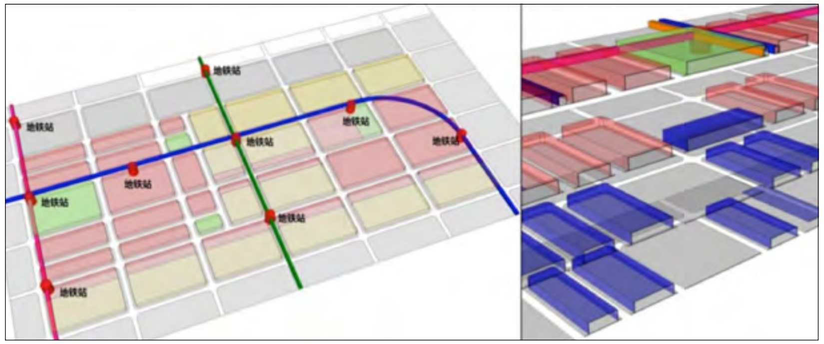
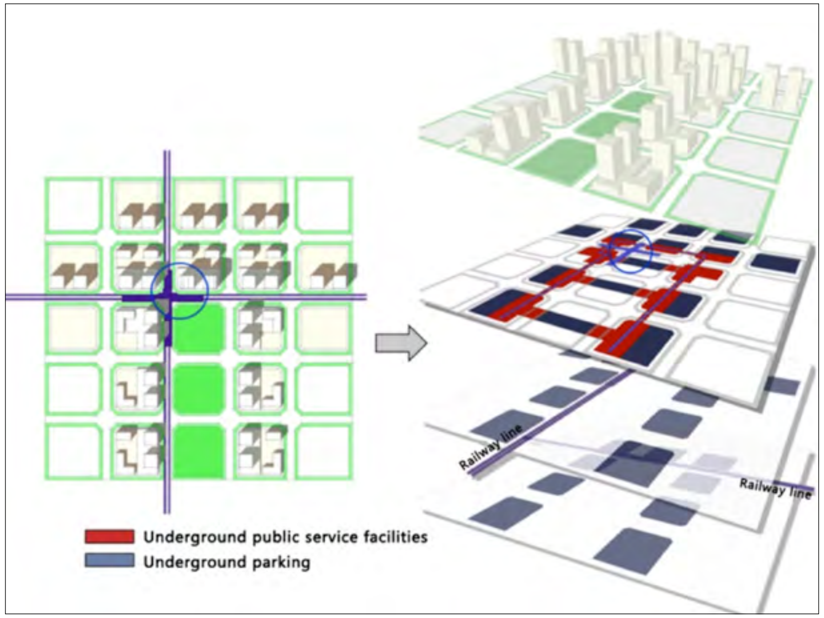



Figure 12: Underground space layout of public service in Tianjin central city

| Categories | Spatial form | Functional characteristics | General scale | Utilization depth | Underground transport organization |
|---|---|---|---|---|---|
| Underground city | It is jointly constituted by a few underground complexes, connected via underground transport and develops in groups with more than three subway stations. | The functional layout is based on each complex and functional core; Corresponding to ground features, it is mainly for business and underground parking | In general, it covers an area of 20,000 square kilometers with an underground commercial area of more than 150,000 square meters. | Usually, the middle layer is utilized to underground storey 3 and 4 | The pedestrian system combines all complexes in network layout; Large public parking depots are provided to share parking lots through an underground traffic passage. |
| Underground complex | Corresponding to the ground function, there are clear public cores, integrated development of the underground and ground with 1 to 3 subway stations. | The functional layout is based on subway stations; Corresponding to ground features, it is mainly for business and underground parking | In general, it covers an area of 20 to 60 hectares with an underground commercial area of about 150,000 square meters or less. | Usually, the middle layer is utilized to underground storey 3 | The pedestrian system develop in clusters by relying on subway stations and business; There are mainly supporting parking garages, which are partially connected to share parking spaces. |

Table 6: Hierarchical Control Requirements for Underground Public Service Space





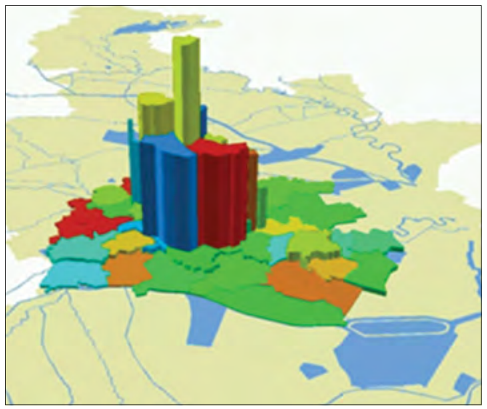



Figure13: Schematic diagram of the underground city

Figure14: Schematic diagram of the underground complex

Figure15: The population density diagram in Tianjin central city



## DEMONSTRATED ADVANTAGES OF UNDERGROUND SPACE PLANNING AND DEVELOPMENT

### Effective expansion of urban space

In the 21st century, with the acceleration of Tianjin, the urban land use and population size grew rapidly and demonstrated/produced/resulted in a "blowout" growth trend. The population density in six districts has grown to 25,000/km$^2$ in 2011 from 21,000/km$^2$ in 2001. The highest population density occurs in Heping District, reaching 38,700/km$^2$. The high population density, excessive aggregation of functions, centralized building layout and saturated floor space capacity have led to a series of urban conflicts. However, making full use of underground space can provide a lot of urban space resources to effectively alleviate the urban pressure.

### Improvement in the intensification of land utilization

Since 2003, the land price in central city has risen sharply with the land transaction price index growing at an average annual rate of 10%. In 2007, it increased by 152.6% over 2003. However, the development of underground space can compensate for part of the ground functions and effectively and intensively utilize the urban land to save land resources and alleviate the stress of urban development on the land. Therefore, how to develop underground space to improve the land-use efficiency and intensification and give full play to the land value has become an urgent requirement for urban development.

### Effective alleviation of the traffic pressure

Currently, the traffic congestion is worsening in Tianjin. By the end of 2008, the average pressure load of the urban trunk road in the central city had become saturated. With the continuous increase of vehicles, ground transportation is expected to be overwhelmed by 2020, which will seriously impede the urban development.

Making full use of underground space, vigorous development of rail transport, underground roads and other urban underground transport systems and construction of underground parking to solve the parking problem can effectively ease the ground traffic pressure; thus, they have become an important means of solving the urban traffic problem in Tianjin.

Figure16: Park difficulties

Figure17: Traffic jam

## Building an eco-city via energy saving

The development of underground space is conducive to improving the urban environment. With the recent large-scale construction in Tianjin, the urban ecological environment problems have become increasingly prominent. By the end of 2008, the green space per capita in the central city had become less than 10 square meters. According to the plan, it is expected to reach 15 square meters by the end of 2020. Through the utilization of underground space and consequent transfer of some functions underground, the ecological quality of the urban ground environment will be greatly improved and the urban green coverage will also be enhanced to expand the open space. Meanwhile, the development and utilization of underground space can take full advantage of underground space resources in insulation and energy-saving to effectively reduce energy consumption and promote energy conservation.

## Improvement in the comprehensive disaster prevention capability

As an economic center and a large city in the north, Tianjin should be equipped with sound infrastructures to meet the normal operation, while the development of underground space is helpful to build a sound urban infrastructure system and improve the capability of infrastructures to cope with natural disasters and other emergencies, so as to provide an efficient support for the operation of the city.

# REPLICABILITY AND SUSTAINABILITY

The sustainability of underground space planning and construction case in Tianjin is reflected in two aspects, namely the compatibility of the underground space planning guideline and scalability of the underground space planning database.

## Compatibility of underground space planning guidelines

According to our analysis of preparation methods of underground space planning in Tianjin, the underground space planning guidelines can be integrated into the regulatory planning system of the ground planning. By expanding the indicators of the preparation system, the control requirements for underground space and land-transfer conditions can be combined to promote the development and utilization of underground space.

## Scalability of the underground space planning database [6]

Currently, there are regulations on the information management of underground buildings in Tianjin and the authorities are working on a general survey of the underground space information across the city. In the future, the underground space information can be combined with planning to create an urban planning database system linking the ground and underground construction. Such a system may dynamically vary with changes in the ground and underground construction to provide strong data support for urban planning management and preparation.

6 The status and planning information of underground buildings in Tianjin should comply with the *Measures of Tianjin on the Information Management of Underground Space issued* by Tianjin Municipal Government.



# LESSONS LEARNT

## A typical case of urban underground space utilization in the plain regions

Tianjin, located in North China, is an alluvial plain with low elevation. In the space layout, the underground space resources are central to Haihe River and flexibly dispersed, while the sections most valuable for development are mainly located in the heart of the planning area and key areas along the planning rail transit. However, there are complex geological and groundwater conditions in these areas. The utilization of underground space in Tianjin central city is a typical case of urban underground space utilization in the plain areas; thus it can provide similar cities (in plain region, with high groundwater level and low average elevation) with some reference points.

## Provision of experience in utilization of underground space for large cities in developing countries

China is the world's largest developing country, while Tianjin is one of four municipalities in China, but also an economic center of North China and the Bohai Rim, an international shipping center and logistics center, and an internal port in the north. Since the development and opening of Binhai New Area was incorporated into a national strategy in 2009, the Tianjin economy has entered an era of rapid development, playing a leading role in the growth rate over the country for many years. And rail transit construction and underground space development have also been in full swing with urban development. Based on an in-depth study of the advanced experience of developed countries, we should explore a new utilization pattern of underground space in Tianjin from several perspectives to meet the needs of exploitation, environmental protection and efficient use of underground space resources with a full consideration of the current conditions and economic development level. Furthermore, the experience in and lessons from the utilization of underground space in Tianjin will provide some reference points for large cities in developing countries to develop underground space.

## Exploration of the development against the background of public ownership

China is a country based on public ownership, while the development and construction of underground space in Tianjin is mainly dominated by the government and invested in by land developers with each land plot being independently managed. Tianjin encourages the development of underground space, adopts preferential policy on land-transfer fees of underground space for business and provides government incentives for underground space being opened for public purposes. As for the development and utilization of underground space in key areas of the city, plans have to make detailed provisions on the construction area, functional combination, location of public access and entrances and exits, air defense requirements and connectivity between construction units.

The forecast on the demand for and the development and management model of underground space in Tianjin central city are applicable to urban development under the Chinese system, but not applicable to all cities in other countries with different social systems.

**Poor connectivity, low utilization rate and other problem**

The owner of land use rights possesses the use rights of the underground space and finances its construction. For the underground space developed by occupying municipal roads and urban public green space, it is owned by the People's Governments and its use right is determined by the constructor and People's Government through negotiation. However, there are poor connectivity, low utilization rates and other problems between different land plots due to different development timescales and construction schedules. Therefore, on the one hand, we explicitly specify the convergence and connectivity of underground space in the form of a statutory plan from the planning level; on the other hand, we try to solve problems in conversion of building structure, simultaneous construction and other aspects involved in the design of underground space from the construction level. ▪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ISOCARP

ISOCARP

The International Society of City and Regional Planners is a professional association of planners. Celebrating its golden jubilee this year, ISOCARP includes over 800 members from 80+ countries. As its motto "Knowledge for Better Cities" suggests, ISOCARP aims to build and share knowledge for a more sustainable, resilient and inclusive urban future based on first hand case studies, field projects and top quality research in the field of city and regional planning. In doing so, it works closely with international organisations such as UN-HABITAT, UNESCO, UN-ECE etc, as well as other networks of urban professionals, academics, and researchers.

The theme of underground space is one of the new frontiers being explored by ISOCARP in recent years, in close collaboration with ITACUS. We are certain that this area will rapidly gain greater significance and acceptability, and we hope to stimulate both through this collection of case studies.

ITACUS

As the International Tunnelling and Underground Space Association's Committee on Underground Space, ITACUS is one of four permanent committees. ITA was founded in 1974 and is based in Lausanne, Switzerland. ITACUS works closely together with its global partners ISOCARP, ICLEI and IFME. We also contribute to the work of UNISDR and UN Habitat.

At ITACUS we believe in an urban underground future. The urban underground space in our experience is often an overlooked asset of cities. An asset that could play a vital role in the quest many cities are undertaking to combat lack of space. Cities need space for housing, for infrastructure but also for public spaces. As demands on cities grow in terms of spatial requirements, they also have to cope with climate change, in terms of both mitigation and adaptation, and need to become more resilient in terms of natural disasters. The urban underground can be a solution to a lot of these issues.

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