Unveiling Hidden Potential. A Typological Approach for the Underground Landscape.

Caterina Juric
Affiliation: Department of Architecture and Design,
Politecnico di Torino, 10125 Torino (Italy)
Email: caterina.juric@polito.it

Abstract
Urbanization and environmental challenges underscore the importance of utilizing underground spaces as strategic resources for future cities. However, a systematic framework for analysing the complexity of these spaces is missing. This research proposes a typological analysis of underground environments, categorizing them into four layers: surface, medium, deep, and ultra-deep—each with distinct functionalities. While the underground is recognized for its potential in stabilizing temperatures and reducing energy consumption, it remains fragmented mainly in analysis. The article proposes an underground taxonomy generating a hierarchy of configurations, divided into geometrical and topological, and networks, divided into vertical, nodal and horizontal, helping to understand better how underground layers influence above-ground development and emphasizing the need for a robust urban planning theory.

Keywords: Underground Urbanism, Typological approach, Subterranean Taxonomy, Three-dimensional city, Layered Urban Landscape.

Introduction
The city should be considered a unique entity defined by combining different objects and (Hillier, 1984) considering a three-dimensional perspective, the connection between the above and below-ground realm. However, even if these two spaces have a different structure and forms, their point of connection defines the relationship between them. The encounter between the superficial city and the ground is usually reduced to a simple line, while it is a thick object container of activities and transformations (Berlanda, 2014). This complex object is the catalyser of motion, transforming the horizontal movement to the vertical and again to the horizontal in a continuous circle. Already, this concept divides the city into three principal stratus: the city above the ground, the one below it, and what we find in the middle, the ground itself. This last term does not refer to a static plane but a negotiable, permeable membrane that can be traversed, penetrated, and reinterpreted. Therefore, today's subterranean realm cannot be considered only a tunnel network or utility corridor but a complex system answering to the urban metabolism.

The lack of understanding of how the underground landscape is structured prevents us from projecting its coherent and strategic management into the future. As a result, planning below the surface tends to be treated as a subordinate extension of what is planned above ground. The absence of a holistic vision capable of harmonising design between ground-level and underground areas limits the functional and ecological potential of these spaces and reflects a short-term vision. This article analyses the subterranean landscape as a component of urban morphology that has not been explored due to its difficulty in extending the above-ground analysis to the underground realm.

Methodology
The article is structured in two phases: one theoretical, where the underground realm is analysed in its urban development, and one practical, classified in its possible typological components.

Firstly, the theoretical background defines a historical excursus of how the underground realm has been considered from the birth of modern cities until now. From the chronological analysis, the subterranean results as a non-liu, unconnected to the superficial space and, therefore, not easy to analyse. That brings the author to the first classification of the below-ground layers, described by the depth, the location of the activities and the actual use of the underground realm in today's urban planning. Then, a typological approach is provided after describing Henry Beck's Diagram and understanding a new abstraction method for defining the subterranean which is analysed in terms of its taxonomy, spatial, and network configuration.

The outcome mirrors how the underground realm can be described and classified.

State of the Art

Ground Strata

Although the Earth's complex structure extends deep below the surface, human activities have primarily focused on the upper layers for urban development. This preference is mainly due to the temperature and material conditions in these shallow strata (Admiraal, 2018). As one descends closer to the Earth's core, temperatures increase significantly, complicating infrastructure construction and costs. The soil consists of several horizontal layers, and its structure and quality depend on the climate, temperature, geological, and hydrographic local conditions. The most superficial layer is the litter of undecomposed or partially decomposed organic plant and animal residues. Beneath this lies humus, rich in organic matter that is actively decomposing, where intense biological and chemical activity occurs to transform the soil. Further down, the layers become increasingly solid, consisting of silt, sand, and clay, with the deepest layer being inert rock, often referred to as the mother rock (Parisi, 2019).

Therefore, this article will concentrate on the top forty meters below ground level. As we explore underground layers, the characteristics of each stratum, the infrastructure and activities present within them, and the geological and structural factors that shape their development will be examined. This analysis aims to enhance our understanding of subterranean environments by proposing a classification system with five distinct strata, each typically linked to particular urban activities.

- The Surface and Shallow Layer, extend up to 10 meters deep, crucial for building construction and underground basements, as it maintains surface integrity. It supports underground parking, shopping malls, sewer systems, utility facilities, and service tunnels, which are affected by weather and urban activities.
- The Mid-depth Layer, 10 to 40 meters underground, contains more complex security and environmental protection infrastructure. It supports metropolitan transport networks, rail tunnels, underground warehouses, power distribution networks, and environmental control systems.
- The Deep Layer, from 40 to 100 meters deep, features denser and more stable soil with increased temperature and pressure. It supports specialized infrastructure, such as rail and road tunnels, geothermal plants, underground storage facilities, research laboratories, and water treatment systems.
- Finally, extending beyond 100 meters, the Ultra-deep Layer presents extreme geological and environmental challenges. At such depths, temperature and pressure are significant, complicating access. This layer is utilized for specialized activities, including mining, oil and gas storage, seismic monitoring, and communication networks.

It is essential to note that these divisions are not rigid; various processes can overlap within the same layer, leading to a mixture of different infrastructures existing together in a single space.

Surface-Subsurface Representation

Today, the architectural approach considered the division of what was happening above and below as a fixed object, simple to analyse due to its minimal dimension. The way of representing the vertical city led to three main methods. The section (Figure 1) is the most used solution[1], where the city is presented as an iceberg, and what we see above and below is divided by a simple linear object without form (Berlanda, 2014). The result emphasises the division between the two elements that define the city: what lies above and below. Then, the axonometry[2] (Figure 2) creates a more holistic overview of the city (Frampton et al., 2012). This solution creates a three-dimensional perspective of the metropolis but needs a fundamental comprehension of how the space is made. The result is a unique, indistinct object.

Finally, the scheme[3] (Figure 3) is a representation method that synthesises concepts and helps comprehension

1 Representations in the book: Berlanda, T., (2014). Architectural Topographies. A graphic lexicon of how buildings touch the ground, Routledge: New York.

2 Representations in the book: Frampton, A., Solomon, J. D., Wong C., (2012). Cities Without Ground. A Hong Kong Guidebook, ORO.

3 Representations in the book: Reynolds, E., (2020). Underground Urbanism, Routledge.

(Reynolds, 2019).


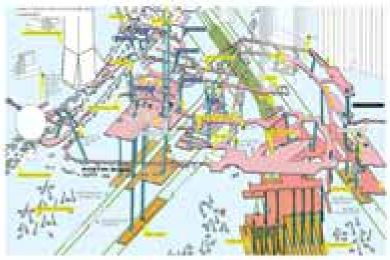
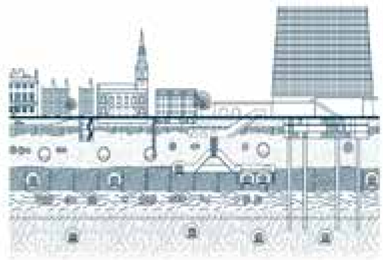

Figure 1 (left): Section of J. M. Tjibaou Cultural centre in Noumea (New Caledonia) by Renzo Piano 1991-1998 (Source: Berlanda, 2014)
Figure 2 (centre): Axonometry of the city of Hong Kong (Source: Framptonet al., 2012).
Figure 3 (right): Schematic representation of the underground (Source: Reynolds, 2019).

To understand correctly the transition between above and below urban landscapes, we have to start from its role in the urban composition. The shift from below ground to above ground connects two distinct urban flows: one that moves through a horizontal underground city layout and the other that aligns with a horizontal aboveground city layout, traversing a substantial element known as the groundline. Furthermore, this element defines the vertical relationship between different parts of the three-dimensional city and can be analysed by three variables:

• Altimetry, which considers the different heights it has to connect;
• Orography, which defines the natural conformation of the environment under study;
• and Topography, which represents the form and movement of the earth's surface.

This space's final design can create separation or promote inclusion among different city areas, enhancing accessibility, reducing barriers, or potentially leading to the opposite outcomes (Berlanda, 2014).

Another essential role of this transition is determined by its social effect in the city and can be classified as invisible (or passive) or visible (or active).

The passive purpose addresses the practical requirements for constructing the city: it is essential to consider the transition layers as key areas shaped by the foundation technology. The deeper the foundations are for the structures above ground, the stronger the connection between the surface and underground environments. These layers define how dependent different parts of the city are on one another. This solution is also described as invisible since we do not consider it in everyday life but instead create the structural basis for the city itself.

On the other hand, the visible transition emphasises vertical layering in the metropolis and determines how we move around it. This solution is well represented in the axonometric views of Hong Kong by Frampton et al. (2012), who creates an actual layering in the city according to the different activities. Taking these drawings as a reference, the metropolis can be organized into three distinct movement levels: a lower level for vehicles, a middle level for pedestrian pathways, and an upper level for high-speed public transport. In this design, the traditional concept of the ground takes on new significance as individuals primarily navigate one of these three layers, depending on their roles in transportation. With this in mind, the ground moves up or down with the user and its needs.

When we look at technology, the lines between physical infrastructure and digital interfaces are becoming less distinct, creating a seamless technological environment. Underground spaces are becoming vital technological hubs that significantly change how we experience urban areas. They are more than just physical structures; they function as dynamic systems facilitating communication, movement, and social interaction. As technology influences our understanding of urban spaces, underground infrastructure has shifted from a passive element to an active part of urban life. It engages with us, changes our experiences, and continually shapes our interactions with technology. In this new perspective, the underground is not just below the city. Again, what 'ground' means shifts depending on the user's experience (Kim, 2016).

The division between private and public spaces becomes essential in the active transitions. This separation clarifies the level of accessibility in space, defining what is reachable and what is not and to who (Admiral et al., 2018). The result is a different perception among inhabitants of the city's depth, and again, the ground level moves according to this perception.

Michel Foucault's idea of heterotopia is relevant here, as it helps explain the complex interactions within urban spaces (Foucault, 1967). These spaces are not fixed or stable. They are dynamic environments where social and technological factors continuously reshape our experiences. The ground transforms into a lively realm where various spatial principles coexist and interact. This perspective challenges our fundamental beliefs about city dimensions, influencing urban dynamics and morphology: architectural forms, infrastructure, and human experiences are blended into a complex, 3D system that defines the city. In this context, every urban layer influences the metropolitan dynamics.

Subsurface Conceptualization
In the early years of the nineteenth century, navigating the underground city was challenging due to its lack of design planning. The first underground maps, introduced in 1908 (Figure 4), were created for the London subways to aid travellers in finding their way to address this issue and make them orientate in a space without an apparent coherent form.

The English maps of the 20s were folded and sold in shops, railway stations, or companies as an orientation device. The standard dimensions were 14,7x22,1 cm, and the paper was folded twice to obtain a pocket size. All provided the 'Underground Map of London' title (Burwood et al., 1982).

Figure 4 - Underground Map of London, 1908 (Source: Garland, 1994)

Figure 5 - Underground Map of London, 1923 (Source: Garland, 1994).

While the first maps did not directly guide users, they were essential in connecting the above-ground and underground public transport networks. They helped create a sense of unity among the different layers of the city by illustrating concurrent activities both on the surface and underground. Additionally, the maps aligned the transport routes with the city's geography, allowing users to quickly understand the relationship between the station locations and the city's overall layout. However, looking carefully, the geographical coordinates also needed to be more precise to guarantee the integration of the above-below network, resulting in the distortion of some lines: few maps were accurate to scale (Toor, 2013).

The first colours used distinguished only the surface network (red) from the subterranean one (blue) as visible in the map of 1923 (Figure 5): different palettes were used in the various editions. As visible in the image, the lettering needed to be more precise, overlapping, or directly omitted (Gerland, 1994).

As the city grew, the public transport network became more complicated, making it harder for people to read the map and find their way around. In an attempt to address this issue, symbols were added to the map in 1927, but more was needed to improve the situation significantly.

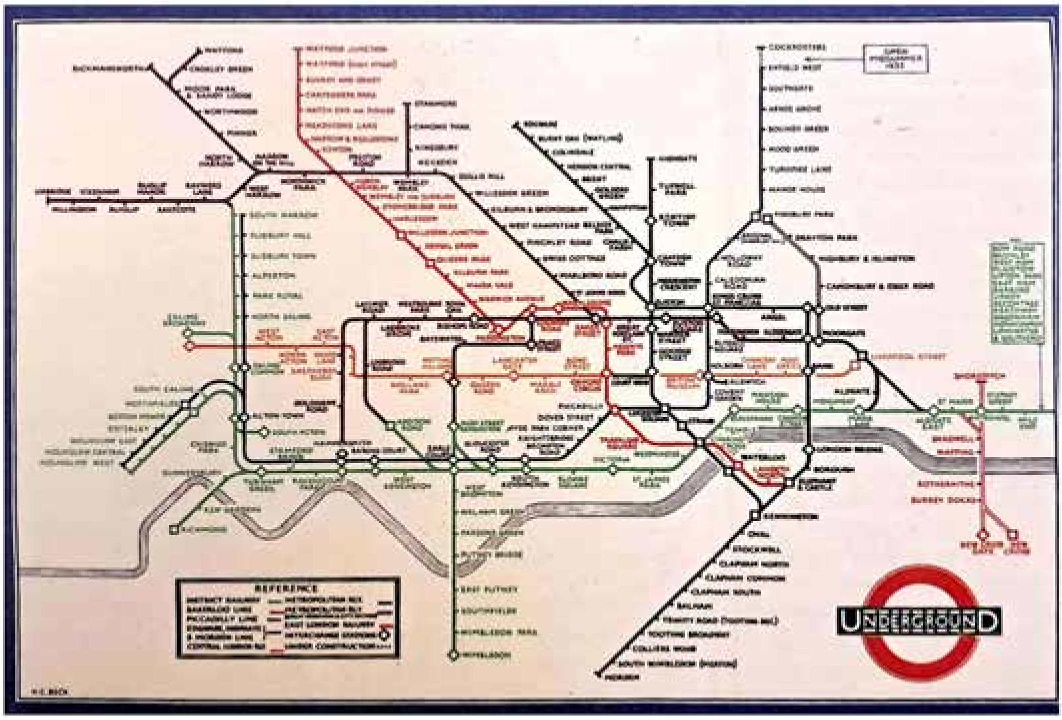

Figure 6 - Underground Map of London, January 1933 (Source: Garland, 1994).

The chaotic, incomprehensible reality of the modern underground city was simplified by the design of the Diagram (Figure 6), the new map of the London Underground network published in 1933. In the previous editions, the geographical approach created difficulty in comprehending the devices, which entailed concerns about orientation in the subterranean network. Therefore, it is no coincidence that Beck's Map was so highly appreciated in its foldable, pocket-sized form and practical use. The defined colours, orderly lines, rational rigor, and structural grid stayed within a reasonable conceptual distance from those of Mondrian, so beloved at the time. All these elements helped to define the Diagram, one of the great modernist aesthetics inventions of the London Subways (Ashford, 2013).

> "Looking at the old map of the Underground railways, it occurred to me that it might be possible to tidy it up by straightening the lines, experimenting with diagonals and evening out the distance between stations. The more I thought about it the more convinced I become that the idea was worth trying, so, selecting the Central London Railways as my horizontal base line I made a rough sketch. I tried to image that I was using a

> convex lens or mirror, so as to present the central area on a large scale. This, I thought, would give a needed clarity to interchange information." (Ashford, 2013)

From these assumptions, he decided to convert the old 'vermicelli' (what he used to call the previous geographic network setting) into a new solution.

When he designed the first proposal, Henry Beck was a 29-year-old engineer of the London Underground Railway who remained impressed by the complexity of the maps published before and wanted to get involved to create a more effective solution (Gerland, 1994).

Already in the first sketches and the first map from 1931, the background usually used in the previous editions disappeared, and only the River Themes remained as an orientation reference. The colours were the same as the Stingemore solution, while the map structure was defined by horizontal, vertical, and 45- or 90-degree diagonal lines (Garland, 1994).

A new non-lieu

What emerges is an underground realm analysed in its forms of abstraction and an undefined entity, which seems unconnected to the surroundings and the city as a whole. In fact, before Henry Beck's Diagram, the first underground experience in the nineteenth century was noisy, chaotic, and confusing. The fear of the first travellers in the underground was the perception of being compared to goods where passengers were left or picked up at the stations in what was instead shown by the government of all of Europe as the most revolutionary discovery of the century. In the environment, contact with the landscape was lost, and without a map, only those familiar with the lines and underground structure could orientate themselves below ground (Ashford, 2013).

Marc Augè (1992) defined a non-place as a space lacking connection to the surrounding landscape, where it is difficult to move without signals or indicators. Based on this definition, the subterranean realm can be considered a non-lieu. Its complex structure and distinct characteristics compared to the surface require guides—such as colours, lighting, and design elements—to help individuals orient themselves within this environment.

We analyse our space at three levels that, little by little, help us understand and experience it. The first level is perceived space, representing what is captured from the outside. This space is not conveyed by reason; our senses determine it, and it is innate. Once inserted into an environment, our body automatically perceives temperature, colours, and lights and transforms them into physical or mental sensations. Then there is the second layer, defined by society and the need to live in the same space governed and determined by rules and ways of behaving: the conceived space. It is abstract, presupposes knowledge of basic concepts of representation (symbols, signs, colours to which a meaning is associated), and is structured according to the logic of the dominant social power. The conceived space is built by specialists (engineers, architects, artists, etc.) who, with their representations of space, try to reduce the environment to rational and geometrical solutions, thinking technically and logically, creating a standardisation of the space. Finally, the lived space is chaotic and full of personal memories and conflicts. This space escapes social rules and constraints, preserving a more authentic and personal dimension of human experience. Here, the imagination plays a fundamental role in creating representational spaces, images of reality, then transformed by the human mind to appropriate and personify them (Lefebvre, 1974).

In the first forty years of the subway, the subterranean realm was not understood by travellers and was considered abstract and not comprehensible by the majority. They needed to wait at least two decades after the opening of the first line for the first station interiors and the first underground map in 1933 designed in the UK. Advertisements were not immediately all around, and the first solutions were provided in case of emergency (escape exits or personal support) (Ashford, 2013).

Results

How it has emerged, the city is usually analysed without connecting what lies below the ground layer with the superficial realm, with consequent difficulty in understanding the city as a whole. Moreover, the approach is usually typographical since it is considered the point of departure and the one of arrival, not the space between them. Harry Charles Beck introduced this method in 1908 to help Londoners navigate the city's underground transit system more effectively. His approach made it easier for users to understand the network quickly and logically. It improved subway navigation and provided a clearer overall view of the city, allowing people to describe the urban morphology from perspectives beyond just the surface.

Although the underground is integrated into the urban environment through its four layers of stratification, which create a vital foundation for surface functioning, capturing it as a cohesive entity remains challenging. The concept of the underground revolves around human experiences related to what lies beneath our feet. This contrasts the idea of landscape, which evokes a sense of frontality and represents everything within our line of sight. The subterranean, however, is largely hidden; it can only be imagined or described metaphorically. As a result, a clear opposition exists between landscape and underground: the landscape encompasses the spaces we can immediately perceive and articulate, while the underground necessitates time and exploration to uncover. Therefore, it is essential to consider how underground spaces can be classified and described to ensure their connection to the city as a whole system.

Discussion

Typological Analysis of Underground Spaces

The following paragraph explores the typological characteristics of the space beneath us, trying to encompass the previous studies for the subterranean landscape: architectural planning often overlooks the complexity of the underground realm, focusing on engineering and geological assessments. This approach creates a disconnect between the subterranean and the surface, leading to a predominantly two-dimensional perspective on urban design. The following classification will categorise underground spaces to enhance our understanding.

Typological Taxonomy

The urban underground represents a complex and multifaceted spatial realm that goes far beyond the stereotypical image of dark, damp tunnels. Delving into this subterranean dimension reveals a diverse tapestry of spaces, each shaped by distinct functional, architectural, and experiential characteristics. Drawing from the taxonomic framework, the first categorization of the underground world that immediately results in our mind is the division between what can be considered a mere excavation in the underground and what needs a more structured architectural and engine eristic background. Starting from this point, we can examine three primary typologies that encapsulate the richness of the urban subsurface.

The first category will be the excavated spaces - subterranean environments carved out through deliberate human intervention or natural geological processes. These solutions range from ancient underground cities, such as the remarkable Uchisar complex in Cappadocia, Turkey, to more contemporary forms of spontaneous, adaptive reuse. Excavated spaces demonstrate the noteworthy adaptability of the urban underground, as well as its ability to accommodate alternative modes of inhabitation. The Cappadocia region is characterized by lava material solidified after an eruption, creating interesting plastic objects called "fairy chimney" that differ in depth, dimensions, and colour. Initially, these spaces were used for shelter, but then, thanks to the handwork of the area's inhabitants, it was transformed into an actual caved city where all the natural rocks called 'fairy chimney' were converted into churches, houses, or collective spaces simulating stone houses with decorations, columns, vaults, and arches. These spaces, which could not contain more than 15-20 people at a time, guaranteed isolation and protection for other civilizations surviving during the time. According to the architectural elements used for the construction, the fairy chimney was used for different purposes, as seen in the image below (Erdem, 2008).

Then, there are the infrastructure spaces that represent the critical technological arteries that sustain the functional operations of the city above. These spaces include extensive transportation networks, such as the renowned subway systems of global metropolises and intricate utility distribution systems for water, electricity, telecommunications, and other essential services. These infrastructure spaces facilitate the efficient flow of people, resources, and information, incorporating advanced engineering solutions and cutting-edge technologies. They transcend their purely utilitarian role, becoming integral to the urban experience. Even if these spaces are used only for the flow of utilities (water pipes, gas pipes, electricity pipes, etc.) or people and can be defined as places of movement, they are characterized by designed features mostly in spaces where citizens can walk. The Moscow Metropolitan Line, for example, was designed not only to exhibit the city's technological development but also as a manifesto of traditional socialism aesthetics. The stations should be attractive for those who pass through them with long corridors with vaulting breakthroughs, recesses, coffers, false skylights, projecting cornices, dividing piers into orders, creating niches, and blind windows (Toson, 2024).

The third type of underground space includes architectural spaces designed for human use in subterranean environments. These solutions are intentionally created to support various activities, such as recreation, commerce, education, and cultural exchange. Unlike infrastructure spaces, which are characterized by a continuous flow of movement, these architectural spaces focus on specific activities within the underground environment. Infrastructure spaces serve as pathways to these architectural areas, aiming to enhance the environmental qualities of the surface and offering experiences that reflect traditional urban layouts. They also differ from excavated spaces because they need a more structured and planned to characterize today's cities.

As urban populations grow and land use becomes more intense, many cities are exploring innovative solutions to meet the basic needs of their residents. In Beijing, for instance, some individuals live underground to stay close to the city centre while keeping costs manageable[4] (Kim, 2016). The city contains over 10,000 bunkers initially built during the Cold War for protection against bombings: these bunkers have now been repurposed as homes. It is estimated that around 1 million residents in Beijing live underground. Typically, these apartments are small, averaging about 10 square meters, and often shared by multiple occupants. Residents have access to shared bathrooms, centralized heating, gas air conditioning, internet services, and some retail spaces below ground. To foster a sense of community, those living underground have formed groups like the "Rat Tube" and Digua Shequ ("Sweet Potato"). These communities provide shared amenities such as gyms, cinemas, theatres, and cafes, enhancing the living experience for their residents. The spaces are intentionally designed with colourful decor, specific lighting, and materials that aim to minimize a cave-like atmosphere (Reynolds, 2018).

In **Table 1**, the principal activities that can located underground are defined.

Table 1 – Underground principal activities

Commercial	***Civic & Public***	***Industrial***	***Specialised Environment***	***Technological Interfaces***
Shopping Complexes	Cultural Spaces	Data Centres	Military Installations	Communication Networks
Retail Arcades	Government Facilities	Manufacturing Spaces	Scientific Research Facilities	Sensor and Monitoring Systems
Commercial Galleries	Emergency Shelters	Research Laboratories	Archaeological Preservation Zones	Automation Infrastructure
Service Tunnels	Public Amenities	Utility Management Zones	Climate-Controlled Repositories	Energy Management
Storage Facilities	Educational Complexes	Technical Infrastructure Hubs	Secure Storage Facilities	Smart Control Systems

Spatial Configuration
The underground landscape has yet to be analysed from a morphological point of view, creating difficulty in defining, describing, and understanding it. Many solutions have been brought to the catalogue between objects

4 Distance to the centre is the principal element that creates the price of these spaces, and the data provided by the www.ganji.com website show that depth is not a factor influencing the value of the apartment.

and networks, otherwise defined as containers of activities and connections between receptacles. In addition, it is also possible to distinguish between private and public spaces according to the ownership of the space it is looked at (Admiral et al., 2018). Specifically, objects are all spaces that represent an area of being, while networks represent movement (what was divided between architectural spaces and infrastructure space before).

Even if it is easy to understand and describe, this definition still needs to tell the form of the underground and the possible configuration it can assume according to the city and the environment analysed. In the following chapter, the analysis will consider the possible morphological arrangements the underground can acquire. The metropolitan network will be used as an example to make the study more comprehensible and connected to reality. The same considerations can be repurposed to people, vehicle flows, networks, utilities, and fluid movement.

The analysis will start with a division between geometrical and topological configurations. The first ones refer to structures' physical form and spatial disposition, and their measurable characteristics define them. These solutions find linear, radial, or grid patterns following precise geometrical roles, explaining the physical organization of space and its proposition and dimension. The topological configurations refer to how spaces are connected and related: connection networks, hierarchy, functional relations, flow and way of movement through space, and logical and relational organization between different systems.

If we take the metropolitan line as an example, its geometrical configuration will explain the tunnels' physical layout, dimensions, and forms. At the same time, the topological characteristics will analyse how different lines are connecting, which are the principal nodes, and how people are moving inside.

This distinction is fundamental to understanding the underground landscape's physical form and how it functions as an interconnected system of spaces and relations.

The geometrical configuration can be divided into three subcategories.

The linear configuration represents the simplest type of metropolitan configuration, defined by main routes connecting to the nodal points of the city. This solution may represent the first stage in constructing an underground network, thus symbolizing a city in the development process or not too large to need a more articulated network. This simple solution guarantees rapid movement around the metropolis without the need for other intermediate connections.

The second configuration is the radial one. It develops from a centre outwards, creating a radial structure. This configuration is particularly effective in the historic centres of European cities, where a central core serves as a distribution hub and aims to keep the landmark centre as intact as possible. This solution also had a significant following during the post-war period because, through a well-known external connection for all lines, it was possible to keep the underground city well-connected and ensure a greater connection between the various lines.

Underground grids often reflect the surface urban structure, creating an ordered system of interconnections, the grid configuration. They are solutions that require careful and orderly planning at the base and, therefore, were not found in early metro solutions, where it was essential to combine planning with technologies and construction methods that had never been applied before. These solutions are seen again in often very extensive underground landscapes related to metropolises of considerable size. The underground grid facilitates orientation and navigation by creating a simple and intuitive movement logic.

Lastly, the interconnected configuration is the most complex solution, requiring different systems to overlap at various levels. This solution is mainly found in vastly expanded metropolises where the flow of people is so high that parallel paths connected at other levels are required. We are primarily talking about solutions that have developed over time, requiring a continuous adaptation of the underground space to the surface space and, in some cases, modifying the initial rigor with solutions capable of extending the underground route to the entire urban fabric.

There is then the topological configuration which can be divided into three subcategories.

The nested spatial arrangement describes how underground spaces fit into each other, creating layers of depth and connection. The hierarchy envisages central bodies as centres of activity and hubs from which pathways, in turn, branch off to other central cores. The result is a highly dynamic and quickly developed structure of nodes and axes that concentrate urban sprawl in the poles that become social, economic, housing, and resource catalysts for the entire city.

The ramified network system represents a diffuse net of connections where all the central stations have the principal role. The configuration has an inward-looking development; the historical centre is the most preserved and connected area. This solution results from a historical city that wants to maintain the city centre from extended metropolises and guarantee a strong identity in each neighbourhood.

The decentralised distributed system is the opposite solution before described. It represents a diffuse net of connections where all the stations assume the same hierarchy. The configuration has an outward-looking development and guarantees a quick reach of peripherical areas still well connected to the historical centre. This solution usually needs both a superficial and underground development and results from an extended metropolis that guarantees a strong identity in each neighbourhood.

Network Configuration
The network structure of underground environments can be analysed in various ways, starting with the concept of hierarchies, which is essential. When planning a network, it's crucial to establish a hierarchy to ensure an organized layout throughout the city. Typically, the lines are categorized into primary, secondary, tertiary, etc., which allows for quick connections between areas, while less critical lines intersect with these to reach different parts of the city.

This categorization serves multiple purposes. Firstly, it helps facilitate smoother navigation through the city, reducing congestion in high-traffic areas where a fast flow is necessary. Additionally, different levels of connectivity can highlight various characteristics of the network. Underground connections often link to surface networks, varying depths affecting how elements connect and what (or who) they transport.

Another important aspect of this hierarchy is accessibility. Not all underground areas are available to everyone due to their natural layout or urban needs. As a result, spaces are typically divided into public, semi-public, and private zones. Public zones like the metropolitan line are open for general use, allowing people to move freely across the city. Semi-public zones are accessible only to particular groups, like companies or institutions with limited access. Private zones are restricted to a select few who own or have permission to enter those areas.

Lastly, networks can also be divided based on security levels for military considerations. For example, in Moscow, the metropolitan line is categorized into first-grade and second-grade lines, indicating which can withstand bomb attacks and which cannot (Toson, 2024).

Another possible classification of the network can be done from a geometric point of view, considering the disposition of the spaces and how they are disposed of in the space. Considering this perspective, we can talk about horizontal systems that are the subject of the underground landscape and represent all the networks, lines, and pipes we can find underground. Then, vertical systems connect between the above-ground level and the underground realm. Lastly, the nodal connections represent the junction between different levels in the subterranean realm and help move from one horizontal system to another or reach the vertical exit/entrance.

The underground landscape "is defined by a world usually described as cylindric, cones, cube-piped, connected, or overlapped," as Christian Toson defines in his book Memorie del sottosuolo. La metropolitana di Mosca (2024).

From a horizontal perspective, tunnels play a crucial role in the city's management and operations by facilitating the underground movement of people, goods, and services. They can be categorized based on their purpose and construction, and each type serves a specific function contributing to the city's efficiency and safety. They include the following types. Firstly, there are the transportation Tunnels. These are essential for public mobility, such as subway lines connecting different city parts. Another type is the Service Tunnel, which houses utilities like electrical systems, sewage lines, and telecommunication networks. Finally, the escape tunnels are designed to allow rapid emergency evacuation.

The list should also include the Transit platform located in elevated areas within the station, facilitating passengers' movement along the line. Occasionally, service personnel utilize these spaces to maintain the lines. The English engineers who designed the first underground line in 1863 implemented a solution that involved placing trains in a central area, supported by platforms on both sides, to effectively manage passenger flow.

Additionally, different technologies were adopted by Moscow stations based on the expected passenger volume. Stations designed with shorter depths that featured columns, a floor slab, and a central platform, allowing trains to operate on either side, hosted a small flow of people. In contrast, deeper stations were designed to accommodate larger crowds, with three interconnected tunnels and various entry points (Toson, 2024).

The passage between the surface and the subsurface should not be perceived as a simple line but as a thick object, a receptacle of the transition between these two parts of the city and the vehicle for moving vertically (Berlanda, 2014; Frampton, Solomon & Wong, 2012): what is going to be called the transition strata. The descent into the underground realm represents a vertical travel between urban time and space (Graham, 2016). Access to the subterranean landscape can be categorised into four primary types: standard entrances typically marked by staircases, entrances enhancing accessibility for individuals or linking to additional stations, entries from public spaces, and entries from private properties.

•*Standard Transitions.* Stairs are the usual way to access the subway, while ladder stairs provide a straightforward way to access the unseen underground, symbolising an immediate shift from the surface to a mysterious, hidden world (Manaugh, 2012). Descending a ladder is viewed as a transformative action, shifting from the familiar and routine to the unexplored and concealed. This movement requires effort and can foster a sense of vulnerability and reflection. These accesses are usually used for maintenance and access to critical infrastructure such as sewer systems and underground power lines (Graham, 2016).
•*Transitions Enhancing Accessibility or Linking to Stations.* The issue of accessibility is crucial when it comes to vertical movement. In 2018, just 25% of New York's subway stations were accessible to people with disabilities who could not use stairs to move between levels. The situation has improved with enhancements such as elevators, access ramps, handrails, tactile indicators on ramps and stairs, and accessible service entry gates[5]. Similarly, in Hong Kong, the Island Line constructed in 2014 features high-speed elevators with high capacity, ensuring easy movement around the city and providing access for people with disabilities, guaranteeing benefits in the use of underground utilities (Chan, Lai-Chi, Mansoor & Chen, 2022). Furthermore, the introduction of the PATH signage program in the 1980s in Toronto by Paul Arthur facilitated orientation below ground level and, more generally, in public spaces in other metropolises (Bélanger, 2007).
•*Transitions from Public Spaces.* The entrance to the subway is designed to facilitate access from the local area to the underground realm. Therefore, the design of Hector Guimard's projected metropolitan accesses in Paris serves an aesthetic purpose and guarantees better orientation, facilitating pedestrian flow (Reynolds, 2020).

•*Transitions from Private Properties.* In Hong Kong, some skyscrapers offer direct access to subway stations, seamlessly integrating public transportation with commercial buildings and enhancing the efficiency of daily commutes. These private spaces are strictly regulated, prohibiting noisy activities, smoking, or animal walking (Frampton, Solomon & Wong, 2018). An opposite example is the structure of Toronto's underground landscape:

5 Inclusive City Makers (last access 30/07/2024)
Source from: https://www.inclusivecitymaker.com/innovation-accessibility-new-york-city-subway/

its logical axes-nodes structure ensures a direct connection to more than fifty buildings, six hotels, two department stores, and 20 underground parking lots. Those underground tunnels guarantee better climate conditions yearly (Bélanger, 2007) and such a straightforward structure facilitates the movement of pedestrians and their orientation below ground level.

Finally, the nodal connection represents an architectonical system complex where different space typologies converge in a unique fulcrum where all different characteristics must be combined. Two leading solutions can be considered, and one is the evolution of the other. The design plays a fundamental role in all these solutions, and all the possible issues need to be addressed to avoid segregation situations.

Firstly, there are the transfer zones, complex areas where different forms of movement intersect and interact. Designing these spaces requires careful consideration of their functionality and dimensions and how individuals perceive and experience them. These zones must accommodate various movement types, including pedestrians, vehicles, and public transit systems. The primary objective is to create a hub as a crossing point and a social and economic activity centre.

Transfer zones must seamlessly link different transportation systems, such as trains, metro lines, and other vehicles, to effectively manage the simultaneous and varying traffic flows. A clear and easy-to-navigate layout enhances efficiency, allowing these areas to handle different speeds and absorb peak traffic volumes effectively. Designing transfer zones necessitates a multidimensional approach. It's not enough to focus solely on functional connections; the movement through these spaces should also be engaging and inviting. Elements such as lighting, materials, spatial configurations, and wayfinding strategies are essential for guiding individuals and creating a sense of continuity as they navigate different levels and areas.

Additionally, these spaces must be adaptable to change, with designs that anticipate future developments. A flexible, implementable, and regenerative layout accommodates ongoing transformations over time.

The other typology is represented by the Central Hubs, zones of transfer that are big catalysers of people and are defined not only by the movement of people (infrastructural spaces) but also by place of being (architectural spaces). They developed and increased their connecting role until becoming a destination point where activities and social interactions happen. Here, movement and permanence coexist. Together with the characteristics of the transfer zones, they also need to offer complementary services, create a social environment, and dispose of the flows of movement directed to another point of the city (Admiraal et al., 2018).

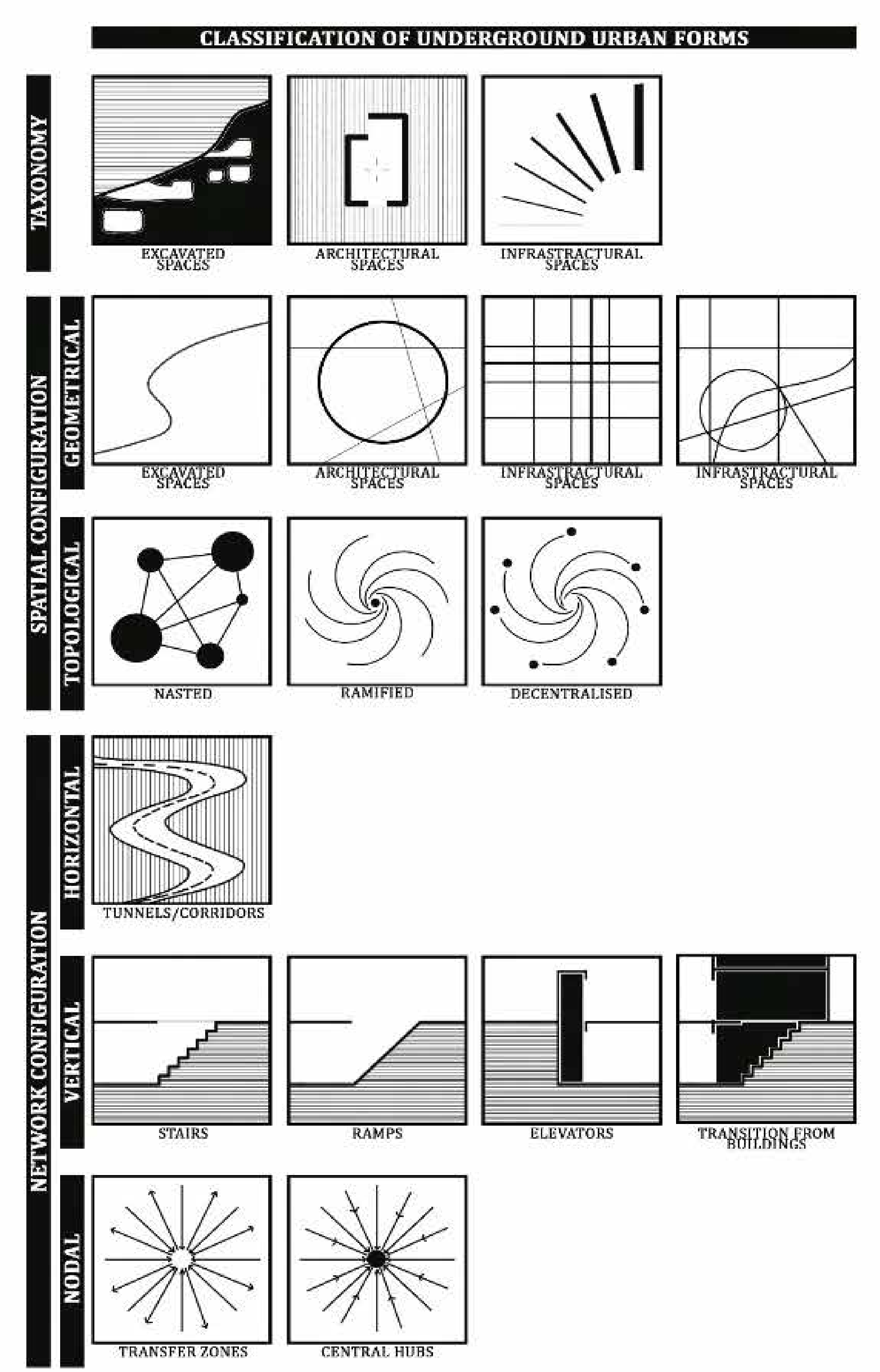

Figure 7 – Classification of underground urban taxonomy

Conclusion

This study has explored the urban underground landscape by proposing a typological and morphological framework capable of interpreting its complexity and overcoming the traditional separation between surface and subsurface realms. Through stratigraphic analysis, the classification of spatial configurations, and the examination of connective networks, a theoretical model has been outlined that recognizes the underground landscape as both an autonomous entity and a deeply interconnected component of urban metabolism. This research highlights the need to develop specific analytical and design tools for the subterranean environment, fostering a three-dimensional vision of the city. However, in order for the underground landscape to be fully integrated into contemporary urban practices, it will be essential to advance interdisciplinary studies that also address the social, technological, and ecological dimensions of subterranean spaces, consolidating their role as an active and strategic part of urban morphology.

References

Admiraal, Han, Cornaro, Antonia (2018) Underground Spaces Unveiled. London: ICE Publishing.

Augé, Marc (1992) Non-places: introduction to an anthropology of supermodernity, Le Seuil: Verso.

Ashford, David (2013) London Underground. A cultural Geography. Liverpool: Liverpool University Press.

Bèlanger, Pierre (2007) Underground landscape: The urbanism and infrastructure of Toronto's downtown pedestrian network, Tunnelling and Underground Space Technology, 22 (3), pp. 272-292.

Bèlanger, Pierre, Rosalind, Williams (2016) Landscape as Infrastructure: A Base Primer. New York: Routledge.

Berlanda, Tomà (2014) Architectural Topographies. A graphic lexicon of how buildings touch the ground. New York: Routledge.

Bobrick, Benson (1986) Labyrinths of Iron: Subway in History, Myth, Art, Technology, and War. New York: Quill.

Burwood, L, Brady, C. (1982) London Transport Maps: a concise catalogue. London: Surrey, pp. 55-84.

Degani, Asaf (2016) A Tale of Two Maps: Analysis of the London Underground "Diagram", Ergonomics in Design, 21 (3), pp. 7–16.

Chan, Ho-Tin, Ip, Lai-Chi, Manoor, Umer, Chen, Anthony (2022) Pedestrian route choice with respect to new lift-only entrances to underground space: Case study of a metro station area in hilly terrain in Hong Kong, Tunnelling and Underground Space Technology, 129.

Erdem, A. (2008) Subterranean space use in Cappadocia: The Uchisar example, Tunnelling and Underground Space Technology, 23 (5), pp. 492-499.

Frampton, Adam, Solomon, Jonathan D, Wong Clara (2012) Cities Without Ground. A Hong Kong Guidebook. San Francisco (USA): ORO Editions.

Garland, Ken (1994) Mr. Beck's Underground Map. Middlesex: Capital Transport Publishing.

Graham, Stephen (2016) Vertical. The City from Satellites to Bunkers. Brooklyn: Verso.

Kim, Annette M. (2016) The extreme primacy of location: Beijing's underground rental housing market, Cities, 52, Pp. 148-158.

Manaugh, Geoff (2012) THE BLDGBLOG BOOK. Architectural conjecture. Urban speculation. Landscape futures. San Francisco: Chronicle Books.

Parisi, Ottavia (2015) La realtà oltre l'utopia. La dimensione sotterranea nello scenario urbano. Celid Dialoghi di Architettura: Torino.

Parriaux, A., Tacher, L., Joliquin, P. (2004). The hidden side of the cities, Energy and Buildings, 36 (4), pp. 335–341.

Pike, David Lawrence (1963) Subterranean Cities: The World Beneath Paris and London. 1800–1945. New York: Cornell University Press.

Reynolds, Elizabeth (2020) Underground Urbanism. New York: Routledge.

Ruming, Kristian, McGuirk, Pauline, Mee, Kathleen (2011) What lies beneath? The material agency and politics of the underground in urban regeneration, Geoforum, 126, pp. 159-170.

Toson, Christian (2024) Memorie del sottosuolo. La metropolitana di Mosca. Siracusa: LetteraVentidue Edizioni.