Sub terra : is only the visible viable?

SUB TERRA

Is Only the Visible Viable?

Antonia Cornaro

We live in an odd yet intriguing world. We produce, generate, consume, and utilize; we design, construct, live, and work; we bustle about, struggle, strive, and entertain ourselves. But in this amazing world, do we take our living environments for granted? Indeed, who has designed and constructed all the buildings around us? Who is in charge of their upkeep? Who builds our streets, sidewalks, sewers, water lines, and power supply? Who maintains them? And who manages the delivery of fresh food and produce from all over the world, which is artfully displayed in storefronts and exquisite boutiques? Which parts of these buildings, facilities, and infrastructure are private, and which are public? And which ones are hidden underground as opposed to visibly on the surface?

Let us for instance consider how food gets delivered into the Jelmoli department store in Zurich: when we look at the delivery of goods and food there, all we see are discreet entrance and exit ramps. What we do not see is that these discreet ramps lead into an underground labyrinth of roadways, storage, and logistic areas. On the city map they are not shown; they are invisible. But is only the visible viable? Surely not, as here high-end consumer goods are being delivered for consumption by a sophisticated urban population. As Joel Zimmerli put it in his contribution to the topology course:

The Jelmoli case study is representative of a development which seems to be occurring in the entire city of Zurich over the last decades. The constant expansion below, into the underground as a solution to managing the existing density of the city center. This expansion is often hardly visible, the entire extension barely noticeable. Manhole covers, garage doors, ventilation pipes and stairs refer to a world beneath ground, a world that is deliberately being hidden, even though it is essential as the machine of the city. The department store is exemplary for this polarity between the facade, the shop window, and the underground world of goods and energy flow.

In densely populated urban areas, it is noticeable that we are expanding buildings both in width and in height, following the growing

Fig.19 ETH Zurich Hönggerberg campus, 2020.
Underground anergy system, intersection.
By Markus Peinter, Leo Müller

trend of urbanization. But it is worth pausing to think about how we have built and keep building our urban environment. Do we want eternally growing urban areas with peripheral residential, shopping, commercial, and industrial areas? Or do we want compact urban environments with good accessibility and first-rate aesthetic and architectural spatial qualities? What influence does increasing urbanization have on our cities and, above all, on future land requirements and use? How do we enable centrality of our daily activities and needs as well as sustainability in our urban living space? What role does underground space play in the creation of new living spaces in cities and urban areas of the future?[1]

A recent exhibition titled "Sub Terra – New Roots for Underground Urbanism" explored the opportunities of building and living underground in Amsterdam and beyond. The exhibition at the Architecture Centre of Amsterdam (ARCAM) was conceived to deepen our knowledge of the use of the subsurface through the ages. It also displayed future visions on overcoming the challenges of housing short-age, biodiversity, and climate change via the use of the subsurface. It is through exhibitions like these that we start a new discourse of our living environment and what will be important in the future.

Our fascination with underground space lies in the stark contrasts it delivers, from the raw, dark utilitarian uses of 19th-century Paris sewer systems designed by Haussmann to the modern architecture of Perrault, manipulating the soil and welding surface and underground together in poetic forms of stunning beauty that enhance the urban fabric and create loveable public spaces. It is the task of the urban planner to unveil these invisible spaces. By unveiling them and making these spaces visible, they will contribute to our cities of the future.[2]

Just as the exhibit in Amsterdam evoked people's thoughts on the subject, the work conducted at the Chair of Landscape Architecture at ETH Zurich makes architecture students think about their built environment in ways they probably never or rarely have before. How did

1 Antonia Cornaro, "Deep Insights: Underground Planning and Construction as Alternative to Continuous Surface and Highrise Development," *Public Sector Review* 45, 2 (2019), 67–8.

2 Han Admiraal and Antonia Cornaro, *Underground Spaces Unveiled: Planning and Creating the Cities of the Future* (London: ICE Publishing, 2018), xi.

the underground in Zurich get developed over time? What uses are hidden and waiting to be unveiled?

Ever since the existence of the city, people have been building downwards. Cellars were dug in order to expand one's house, to store food, to secure one's wealth. Then parts of the urban infrastructure were moved underground, first the sewage system, then the fresh water supply, later the power supply, and finally the analogue and digital communication. When traffic threatened to suffocate the city, trains, cars and even pedestrians were channeled underground. And when urban space became even scarcer, people began to heal, archive, create culture and spend leisure time underground.[3]

Through its research in point cloud modeling techniques, the Chair has found that this technology is particularly well suited for modeling underground structures. The point cloud model and audiovisual project of Zurich's main railway station shows this incredibly lively and heavily frequented structure in a completely new light, transcending into all levels and uses.

How bizarre it is that a parallel world exists underneath our city grids, a layer of a sub terra that was once confined to sewers and rats? Our critical infrastructure situated in the underground includes power, gas, water, and data, as well as fiber-optic cables. We are also delivering high-priced goods into our consumer temples like Jelmoli situated on top and above ground. We safeguard huge stacks of gold in our central bank's underground vaults, a stone's throw away from Bahnhofstrasse.

As Joan Clos, former Under Secretary General, UN Habitat, writes:

A growing interest in underground space is clearly driven by the need and opportunities for the location of services and waste management, as well as energy-related infrastructure for production and distribution. In addition, locating other functions underground (such as transportation, cinemas and shopping facilities, as well as museums and cultural spaces) will create more space above ground for recreation.[4]

In Zurich, recent examples of underground urbanism incorporating art and recreation include the subterranean extension of the Rietberg

3 Marc Valance and Michael T. Ganz, Zürich Untergrund: Die Stadt unter der Stadt (Zürich: Hier und Jetzt, 2015).

4 Joan Clos, foreword to Admiraal and Cornaro, Underground Spaces Unveiled, ix.

Museum and the newly created extension of the Kunsthaus by David Chipperfield, which passes under the busy high street at Heimplatz and connects the two museum buildings underground. For the newly planned Hochschulgebiet Zürich Zentrum, however, the planning of the subsurface has so far not been a central focus. This is despite the fact that other cities have successfully expanded their university campuses into the underground space, housing not only archives and sports facilities but also classrooms below ground. Examples include the Ewha Womans University in Seoul by DPA Architecture, the Artez Academy of Dance in Arnhem, the expansion of the Singapore University campus, and the archives at the University of Minnesota, to name a few.

Furthermore, the construction of the new underground section of the Zurich main station, with incorporated shopping and seating facilities, provides faster and better transport links as well as spaces for circulation and recreation for the close to half a million passengers who use the station on a daily basis.[5] A real gem will be the new bicycle tunnel that was recently voted through in the city of Zurich: a tunnel, which was initially planned as a motorway passing under the main station and lying dormant for thirty years or so will be converted into a bicycle tunnel. This will allow thousands of cyclists to have a more direct and safer connection when passing below this busy train station.

While these examples show that there are some interesting and useful facilities housed underneath Zurich, they are still individual spaces or places not linked through an underground urbanism for major pedestrian, bicycle, or other human-centered needs. So why don't developers and planners see the potential of combining the sub terra into our existing urban fabric, to create synergies and harness energy?

To achieve a new urban underground tissue and the integration between the surface and the subsurface, policy building, and urban planning need to acknowledge the existence of underground space and plan its use in conjunction with the development of the subsurface.[6]

5 "Durchmesserlinie," ZVV, https://www.zvv.ch/zvv/de/ueber-uns/projekte/in-betrieb/durchmesserlinie.html (accessed June 5, 2022).

6 Admiraal and Cornaro, *Underground Spaces Unveiled*.

Fig.20 ETH Zurich Hönggerberg campus, 2020. Underground anergy system. By Yang Bing, Jourdan Rémi

Home to over half of the global population in 2020, cities are increasingly being challenged by the limited availability of land above ground. Decision-makers at all levels of governance are struggling to strike a balance between sustainable development and public space availability on the surface, between livability and price control, between energy efficiency and compact development. Select cities with limited space on the surface and harsh weather conditions – such as Montreal and Helsinki – are expanding the scale and scope of underground space for shopping malls, underground or subterranean parks, churches, art museums, and a lot more.

Traditionally, cities around the world have used underground spaces to lay down service and sewer lines – for water, sanitation, electricity – or for parking and transport. However, the multifaceted value of underground spaces is largely overlooked in traditional planning processes focusing on the horizontal and vertical expansion of urban areas above the surface. This neglect of underground spaces is linked to a limited understanding of their value and of the importance of spatial planning to effectively utilize these spaces. Even cities that are exploring the subsurface for public spaces, entertainment, commerce, and pedestrian connectivity are constrained by challenges of unknown conditions, geology, geochemistry, government regulations, and legal barriers. Moreover, without a coherent city-level vision or appropriate legal, fiscal, and planning instruments, the use of underground spaces for a sustainable, livable, inclusive, and resilient future will remain fragmented and chaotic.[7] There is a real need to document, survey, and study underground spaces as integral systems of cities to become aware of these opportunities and of what an asset the subsurface presents for our cities. In that sense, the scanning and surveying and modeling work of the students at the Chair of Landscape Architecture provides deep insights into forgotten or unknown underground spaces and shows how vital they are for our infrastructure and for the functioning of our city in terms of circulation and connectivity.

The Hönggerberg campus of ETH Zurich, with its underground infrastructure, parking, and logistics systems is a really interesting

7 Mahak Agrawal, Antonia Cornaro, Han Admiraal, Chrysothemis Paraskevopoulou, Marilu Melo Zurita, "Underground Urbanism: Re-imagining the Role of Underground Spaces for India's Urban Future" (National Institute of Disaster Management, Government of India, 2022).

example. ETH Zurich was awarded the Swiss Watt d'Or Energy Prize for its underground storage system at the Hönggerberg campus:

Until 10 years ago, heat for the campus, frequented by 12,000 students and staff, was generated almost entirely from natural gas. In 2013, ETH Zurich began operating its Anergy Grid with an underground storage system to heat and cool the buildings at the Hönggerberg campus energy-efficiently and sustainably, as well as to reduce CO_2 emissions. Both these aspects are an important part of the puzzle for meeting ETH Zurich's goal of reducing CO_2 emissions at Hönggerberg by at least 80% by 2040 compared to 2006 levels. This would be equivalent to cutting around 8,000 tons of CO_2 annually. For 2020, the reduction target is 50% or 5,000 tons of CO_2 annually.[8]

This example demonstrates the potential of using the subsurface in economizing on energy usage, which can be equally applied to smart city grids at a larger scale. There are several ways in which the value of underground spaces and the subsurface can be determined. The subsurface acts as the foundation of life on which cities are built. It is also used for food production and storage, extraction of fuel, and several other resources that power industries and almost all aspects of human life. Essentially, the value of any underground space is linked to its utility. This value – plus human needs – guides the planning, use, and management of the subsurface. If underground realms are to be integrated and activated within urban ecosystems, there is an opportunity and a necessity for the use of alternate representational and surveying methods. Laser scanning and 3D point cloud models have become a powerful medium to reconstruct and integrate existing sub-infrastructure. For this reason, the students' work at the Chair of Landscape Architecture is powerful and beneficial to drive this development further.

Subsurface as a resource is limited in supply and regenerates slowly. The use of underground spaces thus calls for planning for uses and regulations to conserve ecosystem services or to prevent disturbances to these services. Sustaining this balance between exploitation and conservation requires analysis of the use of subsurface, frameworks to

8 Bianca Gasser and Florian Meyer, "ETH Zurich receives Swiss Energy Prize," ETH Zurich, January 9, 2020, https://ethz.ch/en/news-and-events/eth-news/news/2020/01/eth-zurich-receives-swiss-energy-prize.html (accessed June 6, 2022).

guide its use, as well as good knowledge of the composition of the subsurface, the ecosystem services it delivers – such as infiltrated rainwater that the subsurface purifies – and processes that assure delivery of these services. The value of underground spaces is also linked to their utility in relieving surface congestion, connecting people and neighborhoods, protecting residents from pollution and climate risks, increasing land supply in space-constrained cities, and environmental protection.

Returning to the underground flows of goods, food delivery to luxury shopping temples, and the invisible and complex underground logistics and delivery system in Zurich, we need to ask ourselves the following: Instead of delivering food underground, why not also grow it and use the subsurface facilities for food production and energy storage? Recent examples from Growing Underground (London) and the Seoul Metro Farm suggest that we have an ideal climate to do so underground. The ETH spin-off Yasai[9] has started with vertical farming and growing indoors in former warehouses. Their produce is now sold in Jelmoli. Would it not be amazing if it was grown underneath, in the over-dimensioned driveways? Nothing speaks against doing this in underground spaces. As is evident from the documentary *Platzmangel: Die Zukunft liegt im Untergrund*, mushrooms can be successfully grown in underground caverns, for example in tunnels lying dormant near Stansstad that were created for the construction of the Gotthard Base tunnel.[10] Also, the newly conceived project Cargo Sous Terrain[11] foresees parcel and logistic systems including food transport in automated vehicles in a dedicated underground corridor between Zurich and Härkingen. Eventually, the system is to span the entire country and reduce truck traffic on the busy motorways as well as noise and pollution. Meticulous attention is also being paid to the final mile delivery, avoiding single trucks delivering single parcels.

An underground space without natural light has long been used for food storage, but it seems an unlikely place to harvest crops. Yet, investments for food production in underground spaces are increasing in certain parts of the world. In London, for instance, the underground farm Growing Underground is cultivating micro greens and

9 "The Future is Vertical: Grow More with Less," https://www.yasai.earth (accessed July 29, 2022).

10 SRF Schweizer Radio und Fernsehen, *Einstein*. Platzmangel: Die Zukunft liegt im Untergrund, February 16, 2017.

11 https://www.cst.ch (accessed July 29, 2022).

salad leaves for the city using hydroponic technology and LED lighting powered by renewable energy. Situated 33 meters below London, this farm uses less space and 70 percent less water than a conventional farm on the surface. This farm has been developed in one of the eight British government bomb shelters – situated below the streets of Clapham in southwest London – built during the Second World War.[12]

Initiated in 2015 by the Zero Carbon Farms company, Growing Underground is spread over a hectare of underground space and uses a soil-free and pesticide-free approach – plus a team of engineers and data scientists to optimize energy use and crop performance – to produce up to sixty harvests a year. Instead of soil, micro herbs and salad leaves are grown on recycled carpets and supplied to food retailers, local people, and businesses.[13] Growing Underground aims to produce over sixty tons of produce annually by 2022 from 528 square meters of space.[14]

Since 2019, tech start-up Farm8 has been using the operational underground Sangdo Station in Seoul, South Korea for urban organic farming. Using hydroponic trays for growing leafy shoots, sprouts, and microgreens and automated technology systems to regulate temperature, humidity, and carbon dioxide levels, this underground farm produces approximately thirty to forty kilograms of vegetables per day.[15] The harvest is sold to adjacent cafes, and any remaining produce is sold to restaurants.[16] Under the name Metro Farms, Farm8 is collaborating with Seoul Metro and Seoul Metropolitan Government to explore and expand innovative methods of food production in other subway stations of Seoul by using locations away from ticket gates that

12 Douglas Broom, "This WW2 Bunker is Growing Sustainable Salad Leaves Deep Underground. Here's How," World Economic Forum, April 22, 2021, https://www.weforum.org/agenda/2021/04/underground-vegetable-garden-sustainable-farming/ (accessed July 29, 2022).

13 "Salad from Where the Sun Doesn't Shine," Zero Carbon Farms, https://www.growing-underground.com/about/ (accessed July 29, 2022).

14 Louise Walsh, "Growing Underground," University of Cambridge, March 29, 2021, https://www.cam.ac.uk/stories/growing underground.

15 Kotaro Hosokawa, "Underground Farms Sprout in Seoul's Subway Stations," Nikkei Asia, January 14, 2020, https://asia.nikkei.com/Business/Startups/Underground-farms-sprout-in-Seoul-s-subway-stations (accessed July 29, 2022).

16 Kwon Moon, "Is Underground Farming the Future of food?" BBC Travel, July 24, 2020, https://www.bbc.com/travel/article/20200723-is-underground-farming-the-future-of-food (accessed July 29, 2022).

are often not taken up by retailers.[17] In Switzerland, the Swiss Center of Applied Underground Technologies (SCAUT) is also testing underground green farming methods using aquaponic systems, wherein water from fishponds is fed to a hydroponic system and recirculated back to the aquaculture system.[18] The SCAUT pilot focuses on the growth of greens and an inspiration arena for reflection on sustainable development goals, circular systems, and food security. This is being tested and researched at the Hagerbach test gallery,[19] a five-kilometer-long network of galleries and tunnels created to work on research and development in tunneling and innovative uses of underground space. The pilot has successfully demonstrated that this can be implemented anywhere underground. Adjustments of lighting, humidity, crops, and water have to be made depending on the topographic and climatic conditions the space is located in. In essence, investing in underground spaces for food production is an idea that can be replicated in several parts of the world as a new way of providing food security and nutrition. Even though these farms may not be able to produce staple crops of wheat, rice, maize, or animal protein, their utility in addressing burgeoning urban food demand while using 70 to 90 percent less water than traditional farming methods cannot be ignored. These underground farms exhibit an opportunity to transform agriculture and improve food security against a backdrop of increasing food demand and decreasing arable land.

Another interesting aspect of the SCAUT pilot project is the coupling with an underground data center where the excess heat produced is used to power the underground farm, providing a true circularity approach. The consumption of energy and space used by data centers is enormous and continuously growing. Here we have huge potential to go underground in order to save land and reduce energy demand. As stated by Edge Computing Underground, another pilot project in the Hagerbach Test Gallery:

17 Kim, Hae-yeon, "Future of Agriculture Grows Under Seoul's Subway Stations," Korea Herald, January 4, 2021, http://www.koreaherald.com/view.php?ud=20210104001032 (accessed June 5, 2022).

18 "Concept Studies: Underground Green Farming," SCAUT, .https://www.scaut-association.com/en/Concept-Studies/Category/Concept-Studies/Underground-Green-Farming (accessed June 5, 2022).

19 https://hagerbach.ch (accessed June 5, 2022).

Our world is becoming increasingly digital, interlinked and intelligent. IoT, automation, 5G, robotics and artificial intelligence are opening up many new applications and business models. The volume of data produced will continue to grow exponentially. These data volumes have to be processed close to their source (edge computing – due to, among other factors, efficiency and latency times. A lot of mini and micro data centers are needed to do this. In tomorrow's ever more densely populated "smart cities" this development will lead to space problems. The underground concept of "Edge Computing – Underground!" provides a space-saving, cost-efficient, secure and resource-conserving alternative.[20]

In Stockholm, an underground space situated beneath a twenty-six-floor office tower has been given a new lease of life. Once used as an archive for newspapers, it is now used for urban farming where farmers will not have to pay rent; rather, their farm pays for itself in heat. Known as Plantagon City Farm, this underground farm began production in 2018 and grows food in vertical towers under LED lights. The heat from these lights is sent by farm operators to a heat storage system for the office building and used to keep the offices warm during the winter while saving 700,000 kilowatt-hours of energy a year. The cost of the latter is estimated to be three times the rent the previous tenant of the basement was paying. A third of the food produced in this space is sold to people working in the offices above ground and two restaurants in the building. Another third of the produce is sold to nearby grocery stores and the final third is sold in an on-site store in the high-rise office building.[21]

The planning, design, and architecture for use of underground spaces are closely linked to scale. The scale and purpose of use – in addition to policies and regulations incentivizing or adding barriers to the use – differ across geographies and guide priority challenges and opportunities that need to be addressed. These examples highlight only a few of the many options by which investing in underground space can help free up space on the ground and help cities move toward a sustainable, resilient, inclusive, and livable future.[22]

20 https://edge-computing-underground.com (accessed June 5, 2022).

21 Adele Peters, "This Underground Urban Farm Also Heats the Building Above It," Fast Company, December 6, 2017, https://www.fastcompany.com/40503488/this-underground-urban-farm-also-heats-the-building-above-it.

22 Mahak Agrawal, Antonia Cornaro, and Han Admiraal, "The Next Level Up is Down: Exploring the Subsurface for Our Common Future," in *Resilient and Sustainable Cities: Research, Policy and Practice*, Zaheer Allam, Didier Chabaud, Catherine Gall, Florent Pratlong, Carlos Moreno, eds. (Elsevier, forthcoming, 2022).

The book *Underground Spaces Unveiled: Planning and Creating the Cities of the Future*, which I co-authored with Han Admiraal, deals with the future of humanity and our cities. We recommend exploring the underground in the way we explore space. The motives are the same; the difference is that we do not have to leave this planet to do it – and we can take advantage of underground space much earlier. Our message is aimed at urban and transport planners, urban developers, architects, designers, real-estate developers, landscape designers, environmental planners, engineers, lawyers, decision-makers, and really anyone concerned with the built environment. The sustainable future of our cities depends in part on comprehensive planning for the use of underground space. Only then can we be sure that, wherever possible, the greatest contribution will be made to our cities. At the same time, planning makes it possible to secure and safeguard valuable ecosystem services and avoid the negative impact of human interventions on the subsurface. This is also being taught in my class "Planning of Underground Space"[23] at the Department of Civil, Environmental and Geomatic Engineering at ETH Zurich, which caters to civil engineers, spatial planners, and architects to create a mindset that understands the value of underground spaces and their potential. One of the lectures focuses on mapping and visualizing our underground spaces and infrastructure. The work of the Chair of Landscape Architecture in digitalizing and visualizing landscapes in the subsurface and above ground provides a strong addition to this lecture. It is truly beneficial for the students to see and visualize the underground spaces of Zurich and to understand the potential of laser scanning and 3D point cloud modeling to facilitate this process not only as a surveying tool, but also as a novel representational tool.

An urban future in harmony with the underground space offers untapped potential. Underground space is vital to life, providing heat for energy and storage for water. It offers protection and the opportunity to create new connections for telecommunications, transport, goods, and logistics. In addition, under the ground we can avoid obstacles that

23 https://tunnel.ethz.ch/lehre/vorlesungen/planning_of_underground_space0.html (accessed June 6, 2022).

we have created on the surface. As such, it enables us to create efficient, straightforward networks, thus minimizing distances and maximizing connectivity. Implementation requires ingenuity, creativity, innovation, visualization, as well as adaptation of legal conditions and building regulations and possibly more advanced and faster technologies. I am convinced that the thoughtful and holistic use of the underground space will be as successful as it will be challenging.