Changing World - Major Challenges: the Need for Underground Space Planning

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1. Introduction

1.1 Ever changing world

The world today is facing major challenges, one of which is rapid urbanisation. More than half of the world's population is living in cities today, namely 3,5 billion. By 2050 the world's cities will need to accommodate 6 billion people. (or 70% of the world's estimated population at that time. This fact alone poses a major challenge for urban planners. Imagine the world's current population, all living in cities. This is what the figure of 70% in 2050 equates to (Admiraal, 2012). Global climate change and natural disasters are other major challenges facing our planet. The effects of climate change, notable as increasingly extreme weather patterns, are a recurring global phenomenon. This has an enormous impact on large urban conglomerations. Earthquakes, tsunamis, major storms and flooding on a massive scale, are threatening large urban populations and are causing massive disruption. Most large urban conglomerations are in coastal areas and are particularly affected. Cities need to learn to cope with this challenge and become more resilient to such events.

Urban, social and economic structures are constantly and dynamically changing and impacting the way we use the space in our cities and urbanizing regions. There is a need to become more flexible in our planning of cities to cope with the challenges of these ever changing and hyper-dynamic environments. Cities are moving fast forward, driven by social, economic and environmental factors and challenges. The question is how to respond to these challenges?

1.2 How is the world meeting these challenges

The challenges described above have been identified by the United Nations as major issues that require policies and action at a global level. UN Habitat is running the World Urban Campaign which has the theme 'Better City, Better Life'. The basis of this program is not only to raise awareness but it is also a true call for action. It requires engaging the public at large, the civil society, the business sector, the research community and governments in a global movement. The campaign includes a vision of what sustainable urban development requires. As the Executive Director of UN-Habitat Juan Clos (World Urban Campaign, 2012) puts it: *"We need to demonstrate that change is possible through the genius, creativity and audacity of people and decision-makers to make the wisest choices for our urban future. This is the essence of the World Urban Campaign."*

Sustainable urban development calls for resilient cities. This is one of the program objectives of UNISDR, the International Strategy for Disaster Reduction. It asks cities to consider and prepare for natural disasters and to plan for these events. As cities face the task of climate change adaptation, creative thinking is required. Contemporary solutions no longer provide the answers. Margareta Wahlström (UNISDR, 2012), Special Representative of the UN Secretary-General for Disaster Risk Reduction says: *"Unless we act now, we will see more and more disasters due to unplanned urbanization and environmental degradation. And weather-related disasters are sure to rise in the future, due to factors that include climate change."*

These calls for action are not new and are further underlined in the outcome document of the Rio+20 conference (UNCSD, 2012): *"We recognize that, if well planned and developed including through integrated planning and management approaches, cities can promote economically, socially and environmentally sustainable societies."* It's the authors' belief that integrated planning and management efforts must include incorporating underground space.

2. Can underground space use contribute to these challenges?

During the ITA[2] Global Perspective Open Session 2011 in Helsinki, the Deputy Director of UNISDR, Helena Molin-Valdes, pointed out the virtues of the SMART (Storm water Management and Road Tunnel) concept in Kuala Lumpur, Malaysia (ITACUS, 2012). This tunnel was primarily designed to prevent the city from flooding. It helps to drain the water the city has to cope with during major rainfall. But it also partially includes a double deck road traffic tunnel. This eight km long tunnel is a prime example of how an underground solution can both contribute to city resilience and alleviate the effects of rapid urbanization by channeling the road traffic underground.

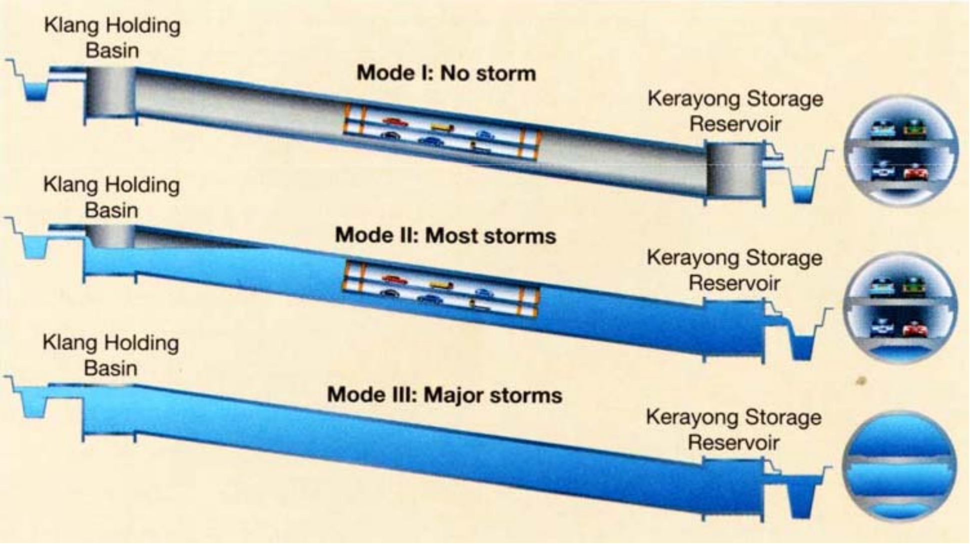

Figure 1: SMART Tunnel showing its three possible modes of operation

Underground structures are way less susceptible to the effects of earthquakes than surface structures. A special report made during the same session by Professor Tetsuya Hanamura on the effects of the Japan earthquake and tsunami of 2011 clearly illustrated this point (ITACUS, 2012): *"Although a very large magnitude nine event, earthquake damage was small compared to the wreckage of the tsunami. Most loss of life was due to drowning and while many surface buildings were swept away by a wall of water, with run-up heights of 10m and 15m at the highest, there was little or no structural damage to underground infrastructure."* Hanamura further reported that although liquefaction had caused damage to the Sendai sewage treatment plant, the damage to underground utility tunnels was minimal. Water supply and sewerage systems were either unaffected or restored quickly. Electricity and shallow gas supply lines were damaged badly, but the underground LNG (Liquefied Natural Gas) storage facilities in the area remained safe (ITACUS, 2012).

The report made by Hanamura clearly shows one of the advantages of the use of underground space: shelter. Underground space can provide shelter from outside influences. This not only applies to people but also for the many infrastructures our modern hyper-dynamic city environments depend on. Modern cities have become vulnerable to natural disasters and effects of climate change. It is the reason cities are called on to invest in becoming more resilient. Helena Molin-Valdes challenged those present during the session to join a mission to influence the design and development of modern cities in such a way that these cities become more resilient and can withstand the consequences of climate change and natural disasters (ITACUS, 2012).

3. Using underground space to enhance urban life

3.1 Underground space as additional spatial and service layer

When looking at finding solutions for the major challenges the world is facing and how underground space use can contribute, it makes sense to look at underground space as an additional spatial and service layer for our modern cities. This layer contains transportation and utility infrastructure (such as metro, road and waste water tunnels). In placing this infrastructure underground we are freeing up surface space: the space above ground can be used more efficiently and effectively to create more livable cities.

Two cases that illustrate this approach are given below. The first is the M30 Motorway project in Madrid, Spain. This major inner city highway was placed into underground tunnels for 56 km of its 99 km length. As a direct result it not only freed the city of major traffic by placing it underground, reducing noise and exhaust emissions, it also created 1 million m^2 of new green space for the city enhancing the quality of life significantly for residents and visitors in Madrid (figure 2).

Figure 2: Surface space freed up by placing the M30 motorway underground in Madrid ©Municipality of Madrid

The second case is an underground Waste Water Treatment Plant in the city of Rotterdam, the Netherlands (the 'Dokhaven'). It shows how a former inner city dock can be re-used and be converted from a former industrial site to contain an underground waste water treatment plant. It is now covered by soil with a beautiful park placed on top for citizens to enjoy the water front and open views. (figure 3).

Figure 3: Dokhaven Waste Water Treatment Plant during construction (left) and after completion (right). Courtesy: City of Rotterdam

In this example urban development can now take place along the river bank on a site which would never have been developed if the plant had been situated on the surface.

So physically using underground space as an additional service and spatial layer is compelling in basically banning noise, pollution and visual blights underground, winning valuable land on the surface for other more compatible uses and enhancing the overall livability of our cities. But does it fully exploit the subsurface as an additional asset for hyper-dynamic cities which require much more integrated functions and holistic approaches to urban planning and design?

3.2 Making underground space visible

The most innovative, creative, audacious underground space projects, are those projects that think about how to use underground space by literally opening up the underground space for all to see. In doing so the underground spatial layer is integrated into the above ground city fabric and becomes an integral part of it.

The Paris Transport Authority, RATP, organized a competition named 'Osmose', to design the metro station of the future (RATP, 2012). One of those designs was made by Foreign Office Architects. The Open Air Metro concept is in a sense about doing away with the ground level as the hard boundary layer between surface and underground space. It is about creating a dramatic entrance to underground space in such a way that it becomes integrated with surface life. The resulting program is not only a metro entrance but provides space for recreation, shopping and dining (see figure 4).

Figure 4: Open Air Metro Project. Courtesy: Foreign Office Architects.

Imagine a city with many historic buildings that are protected and cannot be demolished. A city with height regulations, not allowing new buildings above eight floors. A city in desperate need for new public transport infrastructure, offices, retail and living space. It could be any city, but in this case it is Mexico City. Two young architects came up with a daring plan to build a 65 story (or 300m) deep so called “Earthscraper” beneath the central city’s main historic square (figure 5) . The innovative plan was made as part of an architectural competition. The building would filter in natural light and be beautified with natural greenery. it would house offices, apartments, and entertainment and cultural spaces. The architects have come up with a totally new concept, in a way the antithesis to the skyscraper. Is it feasible? Will it ever be built? In the authors’ opinion the relevance of this case lies in the conceptual solution that it provides. It demonstrates that cities can use underground space in totally new ways by integrating it into the city fabric. Livability needs to be achieved on the surface. That is what cities are for. Underground space can contribute to this, but this concept shows that creating livability underground is also feasible.

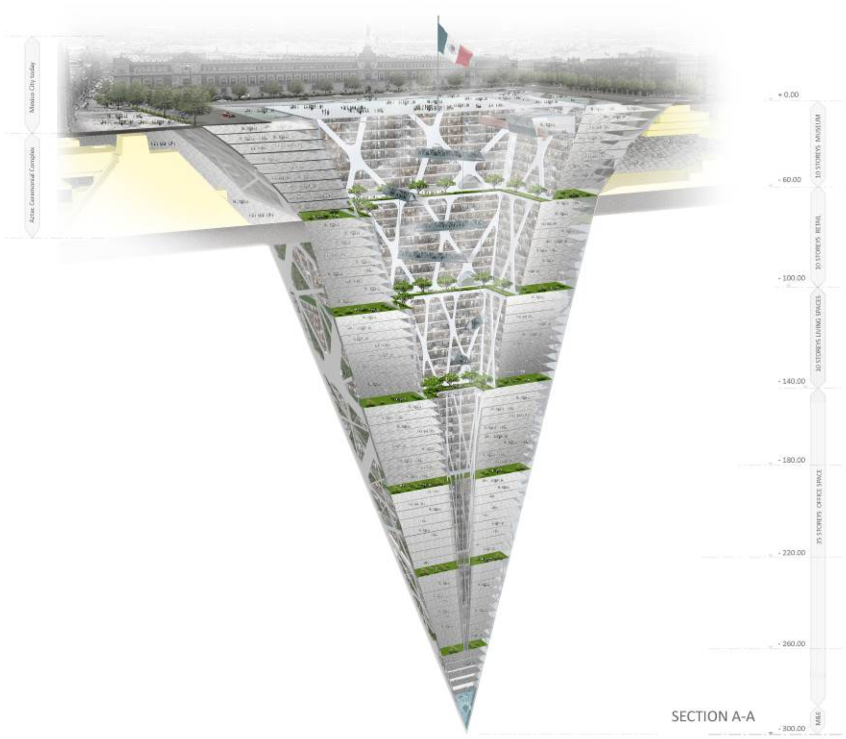

Figure 5: The Earthscraper Project. Courtesy: BNKR Arquitectura.

Just as the earthscraper is the antithesis to the skyscraper, the “Lowline” project is the antithesis to the highly popular “High Line” in New York City. The High Line project is a very successful example of inner city revitalization through transforming a former elevated railway into a linear city park providing much needed new green space to the city. Green and open public spaces are vital for cities: not only are they the lungs of the city, they provide spaces for people to meet and to relax. In the words of the American urban designer and planner, William H. Whyte, who dedicated his life to the analysis and design of central city public spaces: *“(…) in praise of small spaces: The multiplier effect is tremendous. It is not just the number of people using them, but the larger number who pass by and enjoy them vicariously, or even the larger number who feel better about the city center for knowledge of them. For a city, such places are priceless, whatever the cost*” (Project for Public Spaces, 2012). The High Line is a prime example of what Whyte implies. The Lowline, or Delancey Underground project, is aiming at achieving the same goal by re-using a former underground trolley terminal in New York City below Delancey Street. The artist impressions of how this underground space could be transformed into an underground parkscape again demonstrate how powerful the use of underground space can be when opened up from the surface and making it visible for all to see and enjoy (Delanceyunderground.org, 2011).

Figure 6: Transforming a former underground trolley terminal. Courtesy: RAAD Studios.

4. Using underground space – planning challenges and opportunities

4.1 Do we need to plan?

The first question that needs to be asked is: why do we need underground space planning? The answer to this question can be found in many cities where metro systems have almost organically evolved over decades. Finding space for new alignments becomes a major problem and is often solved by going deeper. But also utilities below the surface, cables and pipes, are posing a formidable barrier in accessing the underground in the first place. Added to this we are now finding that energy systems are being developed. Where the former uses where all more or less in the horizontal plane, energy applications call for development in the vertical plane. If we are to develop the use of underground space in a sustainable way, planning and managing it is imperative.

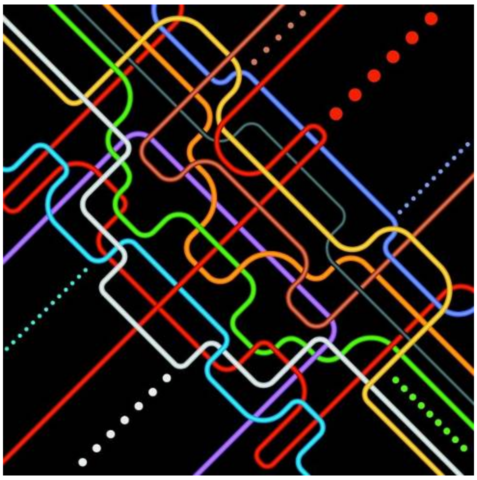

Figure 7: Conceptual scheme of an urban network

Not doing so would leave the use of underground space open to the 'first come, first served' principle. This in turn increases the possibility of a later "underground chaos", severely limiting the use potential for future generations. In the authors' opinion this is non-sustainable. Therefore sustainable use of urban underground space calls for urban planning and management.

4.2 Planning challenges

In an article in the New York Times published on the advent of the Rio+20 Conference, the UN Secretary-General, Ban Ki Moon expresses how the world is slowly realizing that it is entering a new era. *"Some even call it a new geological epoch, where human activity is fundamentally altering the Earth's dynamics"* (Ban, 2012). In this simple statement lies the first challenge the planning profession faces when considering the use of underground space. Can we permit ourselves to intervene in the underground given that we might be interfering with natural processes which occur at vastly different time scales than life on the surface? This question might not make sense when looking at underground space consisting mainly of bedrock. In, for example, more Deltaic regions consisting mainly of soft soils this does make a lot of sense. The underground space in these regions literally supports the life on the surface. Fertile lands were the main reasons why people settled in these regions. There could be underground water aquifers and streams. Will human activity in underground space influence these systems? Ecology and bio-diversity need to be considered when looking at using underground space. But are we only looking at creating new spatial programs below the surface? Do we need to consider other activities as well?

Parriaux, Tacher and Joliquen (2004) first proposed a conceptual model of underground space. This model takes the underground space to consist of four resources: space, water, energy and geo-materials. It proposes that all human activity in underground space will be due to exploitation of one or more of these resources. This model illustrates the second challenge which planners face which is the question: how to plan the use of underground space in such a way that the exploitation of these resources is complimentary rather than being competing. This can easily be illustrated by the above example of autonomous development of metro systems. When now looking at exploitation of underground space for energy purposes: i.e. geothermal systems or ground source heating and cooling systems, this could be severely hindered or even be impossible because of the presence of these metro systems. Even more to the point: how can city planners choose between using underground space for transport solutions or energy applications? Part of the answer lies in the need to understanding the importance to plan underground space.

4.3 The need for a deeper understanding of underground space

Planning on the surface has one major advantage over planning below the surface. The area to be planned can be seen. It can be seen by literally walking around, it can be viewed from the air, and it can be analyzed by images taken by satellites that give unique insights into the topography and settlement patterns. The ability to visualize surface planning in the context of the surface is the main difference between planning on the surface and planning below the surface. The challenge for planners is therefore to understand underground space in such a way that it is possible to use it to its full extent and without influencing or intervening in the Earth's dynamics. Using it to its full extent in this sense means, using it for a multitude of purposes that are complementary to each other rather than competing or preventing future uses. Understanding underground space from a planning perspective calls for new approaches, methods and models to be able to do this.

To further illustrate this point consider the case of the Earthscraper described above (para 3.2). As antithesis to the skyscraper there is one major difference. Where the skyscraper concept is more or less universal in its application, the earthscraper concept can be severely restricted due to the geophysical constraints of underground space. In deltaic regions with characteristic high groundwater tables, the depth at which physical underground space use can take place is often constrained by the water pressure. In the Netherlands the deepest tunnel lies at 60m below mean sea level. This means withstanding 6 bar outside pressure on the construction. A 65 story deep earthscraper would be a technical challenge from this perspective. In other areas the existence of hard bedrock provides enormous opportunities for underground space use. But the actual composition, layering and presence of the underground geology, determine where physical underground space use can take place. The presence of underground water aquifers, for instance, would automatically limit the physical use of underground space. Before any planning activity can take place a deep understanding of the underground space is required.

4.4 The spatial dialogue

Getting a deep understanding of underground space, does not resolve some of the issues that have been highlighted. It is however a first step of the planning process, analyzing the underground space to get a better understanding. A second step is to create a vision on how to use underground space. This vision could look at the future requirements, functions that can be placed underground but also on how to integrate the underground with the above ground urban context. Are we developing a new urban tissue or are we enlarging current space? The vision should also be part of a process of a spatial dialogue with all involved stakeholders. This dialogue not only aims at creating the vision but also at finding solutions for competing functions. In the earlier case of metro systems competing with energy applications, a vision on underground space use could call on future metro systems to be designed as energy systems. In this way multi-functional use can be made of underground space across the four resources: space, water, energy and geo-materials. The third step would be to combine both vision and the outcome of the spatial dialogue into developing an Underground Master plan for the city.

In addition to what has been described above the advantage of developing an underground master plan also lies in the ability to plan ahead. Current use of underground space in many cities teaches us that it only comes about when no more surface land is available. It also teaches us that from a technology point of view this is the most difficult way in which to create physical spaces below the surface. Planning ahead, integrating the use of underground space into the development or redevelopment of cities has one major advantage: underground space use can be created before surface development takes place. A second advantage of planning the use of underground space is that due consideration can be given to the creation of public spaces. Where public spaces on the surface are formed by the occupation patterns created, the same doesn't hold true for underground space. Often physical spaces are created without any thought given to connecting these spaces. So the public often has to leave an underground car park and exit to the surface only to go down again in the cinema next door to enjoy a movie. The logic of creating an underground passage between the two objects was not seen as both were independently developed at different times. Planners should consider this and be aware that underground public spaces will only exist if they are planned and constructed.

5. Examples of Underground Master planning

The cities of Helsinki (Finland) and Arnhem (the Netherlands) have been master planning the underground of their cities. Both of these cities reserve strategic underground areas for future uses.

Helsinki was the first city in the world to adopt an Underground Master plan as part of its urban development policy. This is facilitated by the fact that 60% of land in the city is owned by the local government and that the city is built on solid granite which is highly favorable for excavating cost-effective under- ground facilities. The Underground Master Plan of Helsinki reserves designated space for public utilities and important private utilities in various underground areas over the long term. The Master Plan also provides the framework for managing and controlling the city's underground construction work, and allows suitable locations to be allocated for underground facilities (ITACUS, 2010).

> Since the 1960s, the City of Helsinki has been adept at widely utilizing the opportunities for underground construction. More than 400 premises and over 200 kilometers of tunnels have already been built underground. Furthermore, there are more than 200 new reservations in the register for long-term underground projects. Demand for underground facilities in central Helsinki has grown considerably and, at the same time, the need to control construction work has increased substantially (…)

As the city's structure becomes more dense, more and more facilities suited for different purposes are being built underground. There is also a growing need to connect underground premises to each other to form coherent and interrelated complexes. When planning and carrying out new building projects, it is important to make sure that space reservations for public long-term projects, such as tunnels and ducts for traffic and technical maintenance, are retained for future construction. The growth in underground construction and planning and the need to coordinate different projects led to the need to prepare an Underground Master Plan for Helsinki. Having legal status, the Master Plan also reinforces the systematic nature and quality of underground construction and the exchange of information related to it (…)

Underground reservations and existing facilities/tunnels have been divided into the following categories on the basis of their main purpose:

1. Community technical systems;
2. Traffic and parking;
3. Maintenance and storage;
4. Services and administration;
5. Unnamed rock resource (does not yet have a designated purpose) (…)

The reservations in the Master Plan are divided into the following four planning levels:

- Project plan;
- Needs specification;
- Provisional space requirement;
- Space requirement (…)

The Master Plan shows the most important underground facilities and plans with which the space requirements for confirmed or planned public and private projects can be secured over the longer term. Since the Underground Master Plan has legal status, landowners and authorities are obligated to adhere to it. The Underground Master Plan has some of the same features as a strategic land preservation plan. It shows land reservations for key projects that are considered important to society at large. The Underground Master Plan shows both existing and future underground facilities and tunnels (Vähäaho, 2012).

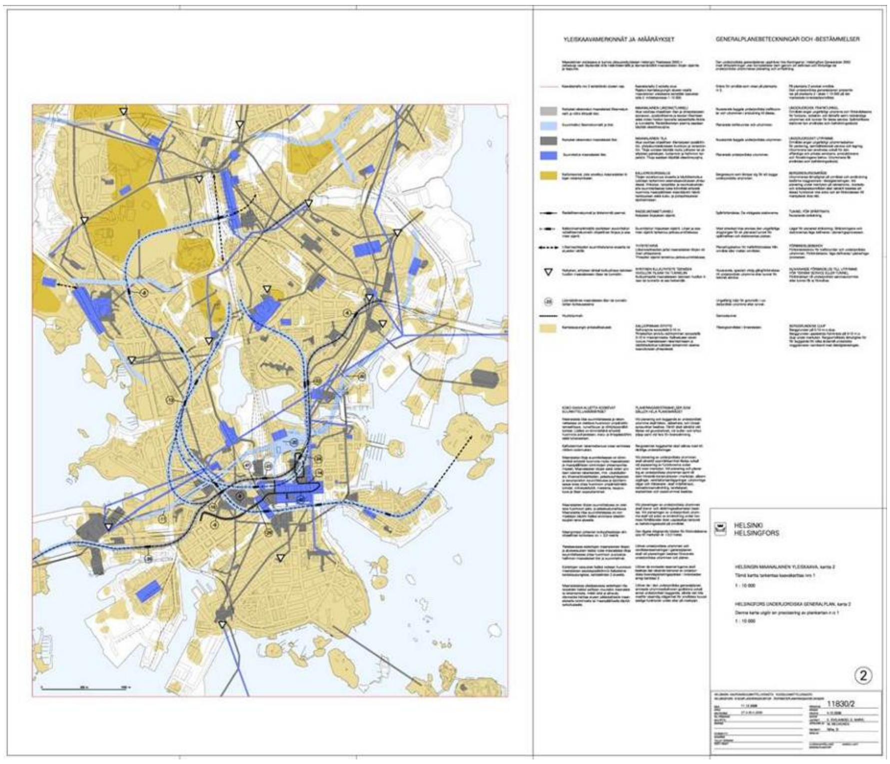

Figure 7: Helsinki Inner City Underground Master plan map. Courtesy: City of Helsinki.

In the Netherlands an integrated planning approach and the identification of underground space as an important component of planning has encouraged the inclusion of the underground in city planning. For example, in the City of Arnhem, the use of underground space has been supported and promoted by the City Council due to the shortage of overall space for development and, at the same time, the need to maintain and enlarge the spatial qualities of the city. All parties involved in the process of city planning in Arnhem, both public and private, now need to specifically consider underground space use in their planning.

The cities of Hong Kong and Singapore are also increasing their underground master planning activities at a strategic level. The main reason being that they have limited surface land area available and want to use their existing space wisely and efficiently. The Singapore Government has initiated a study to be conducted on utilizing the island nation's underground space- a quality approach in optimizing its scarce land area. The study under the Ministry of Development is looking forward to come up with an 'Underground Master Plan', subterranean land right and valuation framework. In a report from the Singapore Economic Strategies Committee the Senior Minister of State for National Development, Ms. Grace Fu is quoted (ITACUS, 2010): *"We would like to develop an underground master plan to ensure that underground and above ground spaces are synergized and optimized so that we have more space for Singaporeans and give the sense of space to Singaporeans."*

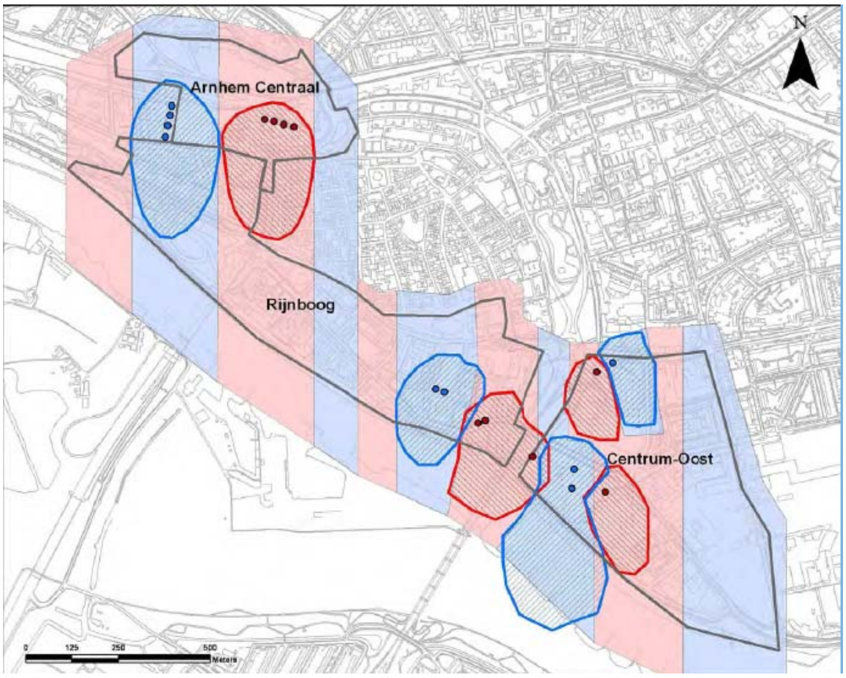

Figure 8: Extract from Arnhem Underground Master plan map showing zoning for ground source heating and cooling in the third water layer. Courtesy: City of Arnhem.

The City of Shanghai in China provides an example of how a city can run into problems if no planning regulations exist. The use of underground space in Shanghai, as in many other Chinese cities, has been growing rapidly in the last two decades but conflicts with prior uses can cause major difficulties. For example, city planners have been forced to divert the alignments of planned metro lines because of recently constructed building foundations, extending deeper than the expected 16 meters below grade. In Shanghai and in Beijing, local regulations have now been put in practice to coordinate the use of underground space and to prevent spatial conflicts by regulating, notably regarding parking and commercial uses, the amount of underground space property developers can use under high-rises.

Nearly 20 cities in China now have plans compiled for the use of their underground space. The plans show the size, layout, function, development depth and timescale for planned projects.

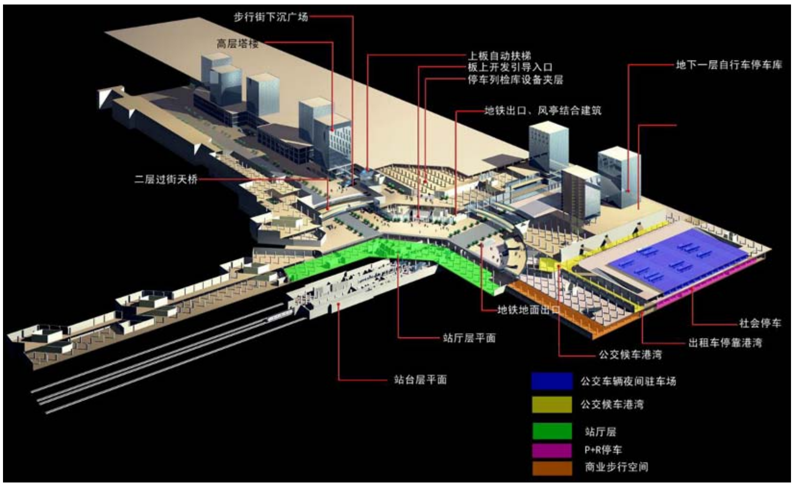

Figure 9: Underground space integrated design and use - Guogongzhuang Station of Metro Line 9, Beijing China – comprising 200,000 m2 of underground space (Courtesy X.D. Shi)

6. Discussion

The authors have shown that the use of underground space can contribute and indeed already contributes to helping cities evolve within a hyper-dynamic context. They have also shown that it is imperative that the use of underground space is planned and managed if sustainable development is to be achieved. In terms of developing Underground Master plans, evidence shows that this is not (yet) a worldwide practice. In this sense the authors feel that the international planning professions needs to further discuss and develop this specific part of planning. Given the specifics of underground space planning as discussed above, they feel however that a larger co-operation between planners, architects, engineers and decision-makers is required to fully comprehend the potential of this societal and spatial asset. This co-operation could be similar to the spatial dialogue proposed as part of the approach to underground space planning.

7. Conclusions

Urban underground space can play a vital role in creating cities that are able to evolve within the hyper-dynamic context of modern times. It can contribute to making cities more resilient and cope with rapid urbanization. In order to use underground space in a responsible, effective and sustainable way, it is vital that underground space planning and management are seen as an integral part of planning practice.

Planning underground space poses new challenges to planning professionals but also provides them with new opportunities. New approaches must be explored as planning underground space is not a simple inverse of surface planning methodologies.

A multi-disciplinary approach is required at all levels to further enhance our understanding of underground space and to make it possible to use it in such a way that it will be part of the future we want and the future that coming generations will want.

8. Acknowledgements

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[1] ITA Committee on Underground Space

[2] ITA-AITES - International Tunnelling and Underground Space Association