**An Integrated Planning Concept for the Emerging Underground Urbanism: Deep City Method Part 1 Concept, process and application**

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**Abstract:**

Four underground resources have been seen as having a long-term potential to support sustainable urban development: underground space, groundwater, geomaterials and geothermal energy. Utilization of these resources proposes a new paradigm of economic development: underground urbanism. The new management approach named “Deep City Method” is put forward to aid decision-makers to integrate global potential of the urban underground into city-scale strategic planning. The research output will be presented in form of two papers each with a different focus. Part 1 aims to introduce the concept, process and initial application in Switzerland; Part 2 is devoted to show methodological insight for a new zoning policy in China and investment scenarios for project cost viability.

This Part 1 paper will begin by presenting the fundamental concept of the Deep City Method, followed by a proposition for a trans-institutional planning process. The application is firstly based on a rating system to identify cities having a potential for underground development. The city of Geneva is selected for conceptual application and strategic level study. Further operational steps are required in order to generalize the concept to other cities around the world.

**Keywords:**
Underground urbanism, Deep City Method, Integrated Planning, Management process, Geneva city

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## 1. Context of the emerging underground urbanism and purpose of the research

In 2007, the urban population around the world surpassed 50% of total habitants, among which nearly 20% live in metropolitan areas (urban areas with more than one million people)[1].This emerging trend of rapid urbanization and concentration requires smarter solutions for adapting to growing needs of living space, construction land, water access, energy production and material provision. While decision makers are facing challenges to seek additional resources to meet urban demand, some emerging resources are becoming more and more attractive.

Land, as the main production factor of cities, is limited, nonrenewable and scarce. Cities are transforming from agricultural traders to industrial manufacturers to service providers. Their land use planning agenda is changing from industrial land oriented planning to commercial land oriented planning to residential land oriented planning, even to mixed use planning (Kivell 1993; O'Sullivan 2009). In a context of sustainable urban development, innovative spatial planning attempts to maximize land use value by mixing urban activities, linking urban mobilities, and compacting the urban fabric. While more space is needed but more land leasing is frozen, space hunting is going to a three-dimensional trend. Density generates space, but over-densification is always restricted by planning regulations. Another dimension is being stated by civil engineers, claiming that by going underground we can acquire more possibilities for construction. Emerging uses became attractive such as subway tunnels, road tunnels, buried utility lines, subterranean parking, deep storage, pedestrian pass, and large basement buildings (Magnus Bergman 1986). Technological advancement makes these uses even more competitive (Goel, Singh et al. 2012), because going underground can mitigate surface constraints on land acquisition, from building height limits and from landscape control (Carmody and Sterling 1993; Golany and Ojima 1996). Relocating space volume underground helps to equilibrate densification and revitalization. This is the first resource being used to shape underground urbanism: *underground space*.

Water, is another critical production factor for agriculture, industry and urbanization. The use of groundwater exceeds 70% of the total water consumption in most European countries, especially for domestic drinking water use (Zektser and Everett 2004). In the post-industrial era, quality of life dominates our residential location choice. An abundant source of drinking water has a competitive advantage for sustaining urban growth. This is the second resource offered by underground urbanism: *groundwater*.

Energy provisioning is a challenge to modern societies. Transport and building count for more than half of the total energy demand, which is being intensified by rapid urbanization. Energy efficiency can be gained from technological innovation in transport systems and building structures. A subway, as a transport system of high efficiency, speeds up urban mobility and shortens travel time. The building sector is also undergoing continuous progress to save energy use. The ground source heat pump (GSHP) market is expanding around the world (Navigant Consulting 2009; IEA 2010), making this hidden resource the third element in underground urbanism: *geothermal energy (Parriaux, Tacher et al. 2004)*.

Availability of materials is one of the main factors influencing construction industry, a mainstay sector in the urban economy. As mining areas become limited, provision of material is becoming more difficult. A recyclable material source from construction excavation sites could relieve material provision deficiency (Rochat, Erkman et al. 2006). Excavation provides raw materials that may be able to aid in meeting higher demand. This is the fourth emerging resource: *geomaterial*.

This article will present an appraisal system of these four underground resources (Figure 1) as a starting point for investigating a deeper dimension of urban sustainability. Underground Urbanism can be defined as an innovative concept for urban restructuring and transformational construction practice (Utudjian 1972; Barles and Guillerme 1995; Bélanger 2007), aiming to increase mixed uses in urban centers by relocating space underground in order to release surface land, while safeguarding valuable groundwater, geothermal energy and geomaterial resources. This new concept is named “Deep City method” (Figure 1), an interdisciplinary project based in Switzerland since 2009 (Parriaux, Blunier et al. 2010).

[1] Data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS

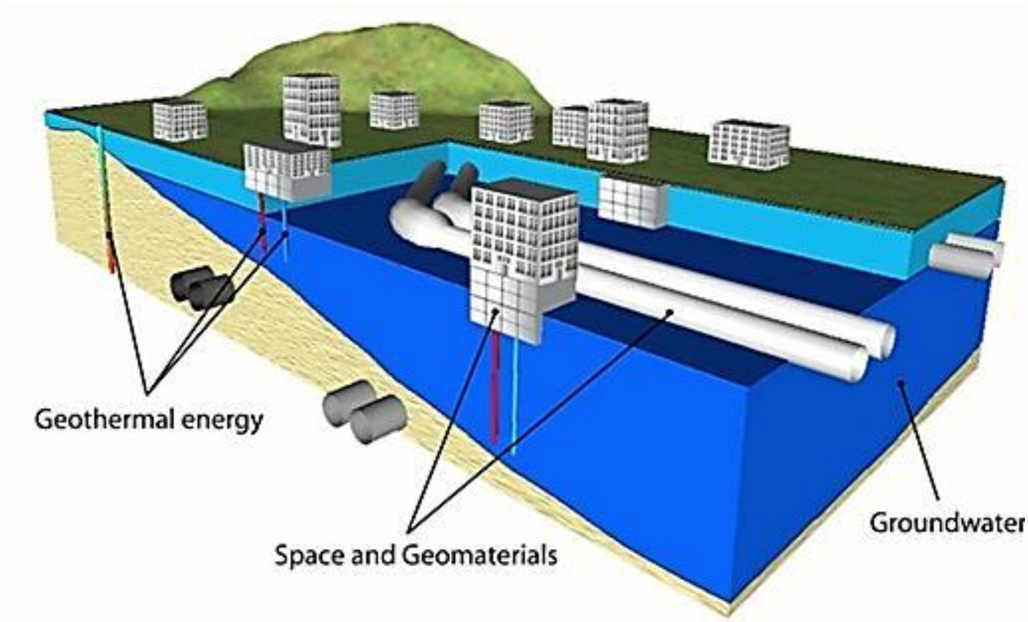


Figure 1 Deep City Method: a holistic management concept for underground resources

After a holistic investigation of supply capacity of these four emerging resources, the main research contribution of the study will be founded on economic and institutional feasibility of underground space development, proving that the underground will become a strategic resource for urban growth. An integrated management process is created for strategic thinking and operational planning practices, combining understandings on supply and demand schemes of underground resources. A new economic index is introduced (in the Part 2 paper) in order to comprehensively assess underground projects, taking into account divergences of land quality, project scope, land price and building configuration.

Section 2 will present the integrated planning process, followed by the first–step critical success factor framing in Section 3. Two groups of cities are evaluated in Section 4 to select applicable cities, which are further studied through remaining steps based on the integrated management process.

## 2. Methodology: trans-institutional planning process for underground urbanism

Current development of underground space in cities is facing coordination dilemmas: on one side, public infrastructures are growing fast and going deep, congestion and disorder hinder future development (Sterling 2005; Sterling, Admiraal et al. 2010); on the other side, private developers are playing a major role in property development but lack of cognition of subsurface potential and comprehensive decision-making.

The 6-step process proposed below (Figure 2) is a facilitating procedure to frame a comprehensive decision platform, linking public and private sectors into new subsurface urbanism plans. It is also a value chain of underground development by linking multi-disciplinary capitals to create long-term growth, aiming to meet urban demand while optimize the use of underground space in the city.

Table 1 points out new responsibilities to the related municipal institutions and actors in this facilitating process:

Table 1 Institutional capacity building proposition

| | | |
|---|---|---|
| **Economic planning institution** | | |
| Strategic level | Step 1: | Accumulate critical success factors from best practices around the world, select critical success factors of sustainable underground development for urban economy. |
| **Land use institution** | | |
| Operational level | Step 2: | Collect local urban data for problem diagnostic in underground exploitation, study feasible solutions. |
| **Urban planning institution** | | |
| Operational level | Step 3: | Map the city with different levels of potential, based on comprehensive but simple indicators for public use. |
| **Urban construction institution** | | |
| Operational level | Step 4: | Assess project typologies, introduce new economic indicators for project evaluation. |
| **Real estate promoters and infrastructure builders** | | |
| Operational level | Step 5: | Lever the scenarios based on potential indicators and economic indicators, to guide project implementation. |
| **Legislative institution** | | |
| Strategic level | Step 6: | Propose new institutional tools or legal instruments to improve public management process. |

This new strategic and operational process dedicated to urban underground development, is based on the classical theory of rational model for policy implementation (Patton and Sawicki 1993). The continuous improvement loop showed in Figure 2 helps to develop a long-term vision and planning methodology for sustainable subsurface use in urban centers. Implication for innovative underground management is an "integrated planning" linking multiple spatial scales (international, national, municipal, local, parcel), linking multiple institutional levels (political, strategic, scientific, economic, private) and linking specific analytic methods to the whole framework. This paper will focus on strategic level study while another paper (Part 2) will focus on operational level study.

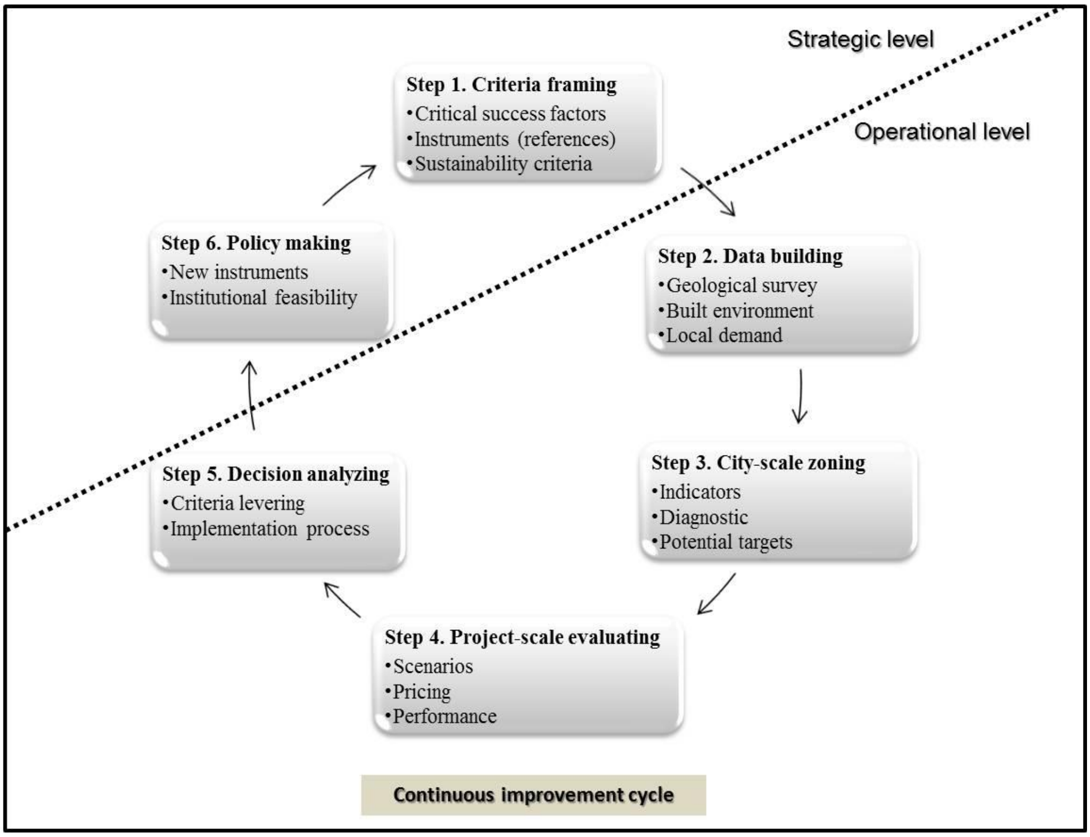


Figure 1 Integrated planning process of Deep City Method (by the authors)

## 3. Strategic benchmarking: Critical success factors for urban underground governance

Intensification in metropolitan areas is one of the driving forces for underground space use in forms of infrastructures and buildings. The authors have investigated five leading cities (Montreal, Helsinki, Tokyo, Paris, Amsterdam) on policy implementation of underground space planning, relating to their major development plans, policy streams and milestones, representative large underground projects, capacity building within institutions, and specific planning instruments (Table 2) (Li, Parriaux et al. 2012).

Table 2 Catalogue of successful policy references in underground space development

| City | Strategic plans | Milestones in Policy History | Capacity building with Collaboration bodies | Instruments and Methods |
|---|---|---|---|---|
| Amsterdam | *AMFORA* (Alternative Multifunctional Underground Space Amsterdam) (Rein 2009) | • 1998 policy initiation for assessing “underground development” possibility(Monnikhof, Edelenbos et al. 1998)<br>• 1999 policy application on Great Randstad spatial planning revision(Monnikhof, Edelenbos et al. 1999)<br>• 2008 mainstream into Amsterdam Action Plan Healthy City | • COB (Netherlands Knowledge Center for Underground Space and Construction)<br>• TUD (Delft University of Technology)<br>• RPD (National Physical Planning Service)<br>• Ministry of Housing, Spatial Planning and Environment(Edelenbos, Monnikhof et al. 1998) | • Layered land planning and Area-scale mapping<br>• Multi-criteria decision making process(Monnikhof and Bots 2000)<br>• Economic valuation for resources(Weytingh and Roovers 2007) |
| Montreal | Indoor City Master plan (Boisvert 2004) | • 1960s conception and initiation<br>• 1970s network expansion (RESO)<br>• 1980s maturity with functions (commerce, mobility, institution, office, culture)(El-Geneidy, Kastelberger et al. 2011)<br>• 1992 adoption of Master Plan<br>• 2002 revision of Master Plan | • OVI (L’Observatoire de la Ville Intérieure)<br>• University of Montreal<br>• City Council of Montreal<br>• Association of owners (ARQIM)<br>• CNR (Canadian National Railway)<br>• STM (Société de Transport)(Besner 1997) | • Public-private partnership(Boisvert 2007)<br>• Land use rights and incentives(Besner 2007)<br>• Layered planning and inventory<br>(Boivin 1989; Boivin 1990) |
| Tokyo | Deep Space Utilization Law (Nishioka, Tannaka et al. 2007) | • 1955 construction of large volumes of underground shopping arcades<br>• 1965 “Golden age”<br>• 1980 regulation restriction<br>• 1988 promotion of effective land use with subsurface<br>• 2000 new legal system(Japan Tunnelling, Takasaki et al. 2000) | • USJ (Urban Underground Space center of Japan)<br>• JTA(Japan Tunneling Association)<br>• Investigation Committee for Deep Underground Space use<br>• (MITI) Ministry of International Trade and Industry(Tetsuya 1990)<br>• Urban Development Department<br>• National Land Policy Institute | • Legalization of deep space (-40m public domain)<br>• Planning method for zoning(Barles and Jardel 2005)<br>• Numbers of building investigations and social surveys<br>(Nishi, Kamo et al. 1990; Nishida and Uchiyama 1993; Nishida, Fabillah et al. 2007; Okuyama 2007) |

| | | | | |
|---|---|---|---|---|
| **Helsinki** | Underground Master Plan (VÄHÄAHO 2009) | • 1955 database building (Real Estate Department and Geotechnical Division 2005)<br>• 1996 initiation of feasibility study for underground space(Rönkä, Ritola et al. 1998)<br>• 2006 working group on 3D property cadastral system<br>• 2009 adoption of rock space Master Plan | • Helsinki City Real Estate Department<br>• Geotechnical division<br>• Ministry of Environment<br>• Land use department<br>• Ministry of Agriculture and Forestry (3D cadaster) | • Detail mapping of existing & planned facilities and potential geo-space(Chow, Paul et al. 2002; Paul, Chow et al. 2002)<br>• Public acquisition of land<br>• Legalization of underground (rock) space utilization |
| **Paris** | Development Program (*Ville 10D*) (Labbé 2011) | • 1972 initiation study for underground urbanism(Utudjian 1972)<br>• 1995 feasibility research for underground urbanism(Barles and Guillerme 1995)<br>• 2006 policy initiation for sustainable subsurface use<br>• 2010 action plan of “Ville 10D” | • Underground Space Committee (AFTES-COMES)<br>• Regional Economic and Social Council<br>• Ministry of Ecology, Energy and Sustainable Development<br>• IREX (Institut de la Recherche appliquée et l’Expérimentation en génie civil) | • Economic valuation for subsurface use right(Barles 2000)<br>• Integration with existing planning instruments(Barles 1999)<br>• Sustainability indicators (M. Deffayet and d’Aloïa-Schwartzentruber 2011) |

Critical success factors of their underground urbanisms can be concluded as seven aspects: (Table 3)

Table 3 General critical success factors (CSF) of underground governance

| **CSF 1** | **CSF 2** | **CSF 3** | **CSF 4** | **CSF 5** | **CSF 6** | **CSF 7** |
|---|---|---|---|---|---|---|
| **Strategic Thinking** | **Information Building** | **Functional Reinforcement** | **Knowledge Cluster** | **Private Involvement** | **Economic Feasibility** | **Social Acceptance** |
| Identification of priority urban zones | Interpretation of resources to potential | Transformation of land to space system | Assemblage of expertise& technologies | Creation of joint value chain | Disclosure of overall benefits | Securing public welfare |
| **Scaling** | **Informing** | **Converging** | **Progressing** | **Associating** | **Reasoning** | **Adapting** |

These five cities with respective characteristics in the routes to manage underground urbanization are selected as experience learning for worldwide underground space development. Their governance models can be referred by future cities having similar contexts, to personalize processes and strategies in the establishment of underground urbanism policies.

## 4. Selection of pilot cities by “Deep City Applicability Score”

For the purpose of this joint research between Switzerland and China, numbers of candidate pilot cities in the two countries are examined with general criteria of geography, geology and population. Finally four representative cities in each country are selected according to their significant population size and diversity of geo-resources. The comparison by rating in this section serves to identify a particular city which deserves an imminent management of the urban underground.

The economic importance of underground resources is determined by combining the value of resources and the macro-economy, which in turn aids in defining the applicability of underground urbanism for a particular city. The “Deep City Applicability Score” is the potentiality of the urban underground to provide reliable building space, good-quality drinking water, safe geothermal energy and usable construction material, in response to urbanization demand. It is supposed that, the level of potentiality can reveal to decision-makers the urgency of the city to manage its underground resources. Table 4 shows the criteria structure used in developing the score. Capacity of resources (A1) addresses the global potential of natural underground resources by qualifying geological characteristics. The macroeconomic context (A2) determines the quantitative demand scheme of using these resources along with urbanization, which induces increasing need in living space, water, energy and material supply.

Distribution of importance to the three level criteria is formulated by following arguments:

- First level criteria: supply and demand (A)

We considered equal importance between geo-resources' supply capacity and urban demand in macro-economic growth, meaning urban underground's sustainability can't be achieved by overexploiting available geo-resources.

- Second level criteria: supply potentials and demand driving forces (B)

According to (Dobbs, Oppenheim et al. 2011), emerging opportunities in land, energy, water and material should be captured to support rapid urbanization by expanding alternative supply source and increasing resource productivity. At the developing stage of the urban underground, opportunities and potentials of exploiting these four subsurface resources define a supply capacity of underground urbanism. This is the reason of choosing sub-criteria from 1.1 to 1.4, representing potential types for underground resource supply.

Among the four criteria of supply, groundwater especially for drinking use is considered as the most concerned sub-criteria for the supply criteria, due to the increasing deficiency of drinking water supply in urban areas (Zektser and Everett 2004). Since location of protected aquifer is considered as a spatial expansion limit for subsurface construction and geothermal drilling in the Swiss environmental regulations, subsurface construction potential zoning has to be compatible with aquifer protection zoning.

Urban population and living density as driving forces for underground development has been recognized by (Golany and Ojima 1996; Bobylev 2009). An empirical study showed both population density and Per capita GDP have positive correlations to the future demand of underground space (He, Song et al. 2012). Therefore, three driving forces are included into demand sub-criteria from 2.1 to 2.3. Densification demand is weighted as the most important sub-criteria for demand side.

- Third level criteria: quantitative and qualitative standard (C)

Information about the status of four resources and three driving forces was collected for cities selected below, from municipal geological department website and economic statistics website. Quantitative and qualitative data is treated and classified on three standards (from most preferable to least preferable) for each sub-criteria. Classification of geological resources is based on previous research results on geo-resource potential evaluation by Deep City team (Blunier 2009).

- Final weighting and grading for selected cities

Weights of sub-criteria are evaluated by authors based on facts mentioned above, using pairwise comparison with Expert Choice Comparison Suite. Final score for each city is calculated as:

$$Deep\ City\ Applicability\ Score = A1 \sum_{1.4}^{i=1.1} (Bi \times C) + A2 \sum_{2.3}^{i=2.1} (Bi \times C)$$

Two groups of cities are placed in the Table 4 according to their local context. For example, the final score for Beijing city is calculated as:

$$0.5 \times (0.30 \times 0.69 + 0.45 \times 0.80 + 0.15 \times 0.21 + 0.10 \times 0.25) + 0.5 \times (0.22 \times 0.64 + 0.41 \times 0.65 + 0.37 \times 0.07) = 0.535.$$

Table 4 Criteria structure of Deep City applicability score and attributed weights

| | A | Bi | C | China | Switzerland |
|---|---|---|---|---|---|
| Applicability criteria | **A1.** Capacity of resources – criteria of supply (0.50) | **1.1** Subsurface geotechnical quality (0.30) | - favorable condition (0.69) | Beijing, Suzhou | Bern, Lausanne |
| | | | - unfavorable condition (0.23) | Shanghai | Zurich, Geneva |
| | | | - presence of special risks (0.08) | Nanjing | |
| | | **1.2** Groundwater quality and quantity (0.45) | - drinking water aquifer (0.80) | Beijing, Nanjing, Suzhou | Zurich, Geneva |
| | | | - low quality aquifer (0.12) | Shanghai | Bern |
| | | | - no aquifer under city (0.08) | | Lausanne |
| | | **1.3** Geothermal energy quality (0.15) | - high quality reserve (0.70) | Shanghai | Bern, Lausanne |
| | | | - conditional exploitation (0.21) | Beijing, Nanjing, Suzhou | Zurich, Geneva |
| | | | - restricted exploitation (0.09) | | |
| | | **1.4** Geomaterial quality (0.10) | - valuable mines (0.68) | Shanghai, Suzhou | Bern, Lausanne |
| | | | - reusable material (0.25) | Beijing, Nanjing | Zurich, Geneva |
| | | | - material needed treatment (0.07) | | |
| | **A2.** Macroeconomic context – criteria of demand (0.50) | **2.1** Urban population (0.22) | - over 5 million (0.64) | Beijing, Shanghai, Nanjing | |
| | | | - between 1 and 5 million (0.27) | Suzhou | Zurich |
| | | | - below 1 million (0.09) | | Geneva, Bern, Lausanne |
| | | **2.2** Living density (0.41) | - over 5000 per/km$^2$ (0.65) | Beijing, Shanghai, Nanjing, Suzhou | Geneva |
| | | | - 2000 to 5000 per/km$^2$ (0.22) | | Zurich, Bern, Lausanne |
| | | | - below 2000 per/km$^2$ (0.13) | | |
| | | **2.3** GDP per capita (0.37) | - over 50K USD (0.74) | | Zurich, Geneva, Lausanne |
| | | | - between 20K to 50K USD (0.19) | Suzhou | Bern |
| | | | - below 20K USD (0.07) | Beijing, Shanghai, Nanjing | |

According to the World Urbanization Prospects from the United Nation Population Division (2007), the Swiss urban population will rise from 73.6% in 2010 to 83.4% in 2050, with a population growth of 1.5 million in the cities. The Chinese urban population will rise from 44.9% in 2010 to 72.9% in 2050, with a population growth of more than 400 million in the cities. The number of Chinese megacities with a population of more than 1 million will reach 141 in 2025, and four huge urban agglomerations will house more than 10 million people. While Chinese cities are undergoing a critical transition to urbanization, Swiss cities are tackling the challenge of intensification in urban agglomeration. Both cases present contemporary urban planning challenges.

The rating method enables a first insight into cities' urban underground diversity and current economic development level. The final choice for applicability test can be the highest-scored cities; more considerations can also be taken such as significance of emergence and outstanding economic achievement. The contextual analysis of four Swiss cities is shown in Table 5 and Figure 3: Highest scores are given to the city of Geneva, with a high degree of underground resource diversity and a high urban development demand. The city of Geneva was chosen for further evaluation.

Table 5 Rating the Deep City Applicability Scores for four Swiss cities

| Criteria | Zurich | Geneva | Bern | Lausanne |
|---|---|---|---|---|
| 1.1 subsurface geotechnical quality | 0.04 | 0.04 | 0.11 | 0.11 |
| 1.2 groundwater quality | 0.18 | 0.18 | 0.03 | 0.02 |
| 1.3 geothermal energy | 0.02 | 0.02 | 0.06 | 0.06 |
| 1.4 geomaterial quality | 0.02 | 0.02 | 0.04 | 0.04 |
| 2.1 urban population | 0.03 | 0.01 | 0.01 | 0.01 |
| 2.2 living density | 0.05 | 0.14 | 0.05 | 0.05 |
| 2.3 GDP per capita | 0.14 | 0.14 | 0.04 | 0.14 |
| **Final scores** | **0.46** | **0.53** | **0.31** | **0.41** |

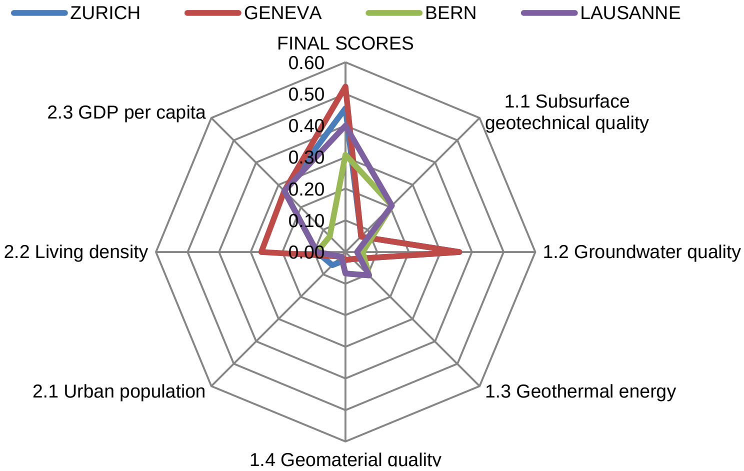


Figure 3 Deep City Applicability Scores of Swiss large cities

The contextual analysis of four Chinese cities is shown in Table 6 and Figure 4: Beijing and Suzhou are rated the highest applicability level, with high geo-resource capacity and a very high population demand. In China, the city of Suzhou is the earliest prefectural level city equipped with metro system, its distinct economic achievement (highest per capita GDP) allows us to use it as a case study city for underground urbanism. The city of Suzhou also represents one of the new megacities coming up in China in the near future.

Table 6 Rating the Deep City Applicability Scores for four Chinese cities

| Criteria | Beijing | Shanghai | Nanjing | Suzhou |
|---|---|---|---|---|
| 1.1 subsurface geotechnical quality | 0.11 | 0.04 | 0.01 | 0.11 |
| 1.2 groundwater quality | 0.18 | 0.03 | 0.18 | 0.18 |
| 1.3 geothermal energy | 0.02 | 0.06 | 0.02 | 0.02 |
| 1.4 geomaterial quality | 0.02 | 0.04 | 0.02 | 0.04 |
| 2.1 urban population | 0.07 | 0.07 | 0.07 | 0.03 |
| 2.2 living density | 0.14 | 0.14 | 0.14 | 0.14 |
| 2.3 GDP per capita | 0.02 | 0.02 | 0.02 | 0.04 |
| **Final scores** | **0.54** | **0.37** | **0.44** | **0.54** |

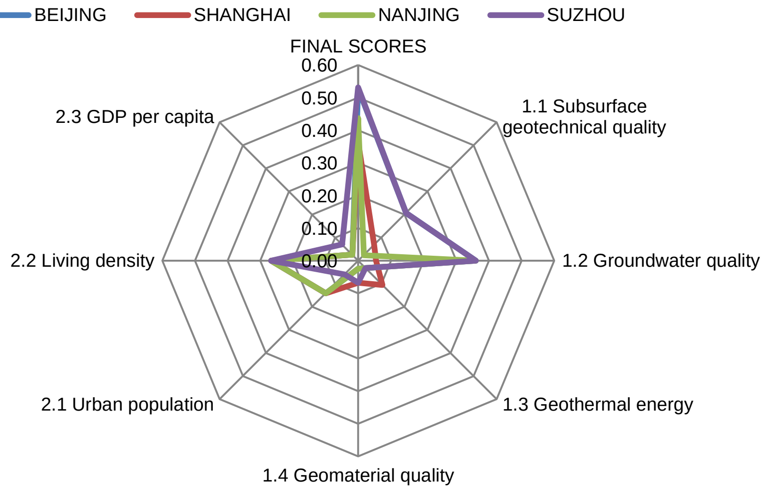


Figure 4 Deep City Applicability Scores of Chinese large cities

## 5. Conceptual application in the city of Geneva

After a four-year research program focusing on the city of Geneva (Deep City project 2005-2009) (Blunier 2009; Parriaux, Blunier et al. 2010; Maire 2011), a general planning process for the urban underground was formulated, based on the research outputs on geo-resources exploitation and socio-economic evaluation. Three operational steps are performed at three urban scales:

- Urban scale: choose three districts for underground potential evaluation based on existing data
- Land parcel scale: compare construction costs of underground building with different land qualities
- Project scale: calculate underground building life-cycle costs for commercial space use

Knowledge of Deep City Method is transferred from academic level to political level, with two motions submitted to federal department in favor of integrating underground resources management into urban planning system[2]. At the local level, a policy proposal was issued by the Cantonal office of Geneva in 2010[3], aiming to encourage a sustainable underground urbanism to aid in urban densification and revitalization, as well as to raise the consciousness of resources' multiple use potential. Instruments are to be implemented in order to target priority zones, improve general perception on the richness of underground resources, and create a joint value chain between the public and private sectors.

While collecting the related instruments launched by the city of Geneva, a validation of the critical success factors mentioned in Section 3 was observed in terms of adapting public instruments to the sustainable use of urban subsurface. Components of this policy instrument framework, classified according to the general critical success factors (CSF) mentioned in section 3, are as follows:

Table 7 Geneva city's Deep City policy instruments

| Critical Success Factors (strategic step 1) | Policy instruments (strategic step 6) | Examples |
|---|---|---|
| **1. Strategic thinking (CSF1 Scaling)** | Integrate underground solutions into "Major Project Area" schemes | PAV renewal project enables an opportunity of forward thinking to use subsurface |
| **2. Information building (CSF2 Informing)** | Enrich geo-resources database and create mixed land use planning tool | Open source: GeoAgglo, a mapping application with open database |

[2] The Swiss Parliament: Motion 09.4291 http://www.parlament.ch/f/Suche/Pages/geschaefte.aspx?gesch_id=20094291 and Motion 09.4067 http://www.parlament.ch/f/suche/Pages/geschaefte.aspx?gesch_id=20094067
[3] http://etat.geneve.ch/dt/geologie/a_votre_service-mieux_gerer_ressources_sous_sol_urbain_cle_developpement_durable-3988.html

| | | |
|---|---|---|
| **3. Functional convergence (CSF3 Converging)** | Promote underground infrastructure projects to revitalize urban surface | Subway tunnel CEVA, parking, museum, geothermal energy system, utility lines |
| **4. Knowledge cluster (CSF4 Progressing)** | Assemble academic research and professional practice | Joint research, Seminars, public consultations, Websites |
| **5. Private involvement (CSF5 Associating)** | Mobilize enterprises to join initiative public private partnership | ECOMAT$^{ge}$ program (partnership for material valorization) |
| **6. Economic feasibility disclosure (CSF6 Reasoning)** | Bring together economists, jurists, civil engineers, energy engineers and architects into project appraisal | Life cycle cost model of an underground commercial center |
| **7. Adaptation to social acceptance (CSF7 Adapting)** | Improve architectural quality of subterranean space, release public green space on the surface | Atrium-style underground station design for CEVA subway |

The proposed instruments in the Canton of Geneva are being examined at the federal level, where a territorial planning law revision project is taking place and serves as an ideal opportunity of formulating comprehensive three-dimensional land use planning regulations. The dense central area of Geneva city (15.89 km$^2$ surface area with density of 12,081 habitants per km$^2$) is looking for multilayer solutions for transport and parking infrastructures, commercial and cultural services. Along with urban intensification in the agglomeration, population growth in the city generates urban sprawl into nearby suburban zones, such as Lancy (2.7 km$^2$) and Carouge (4.77 km$^2$) near central Geneva. The subway tunnel project CEVA is being built to connect these suburban districts to the center (Figure 6).

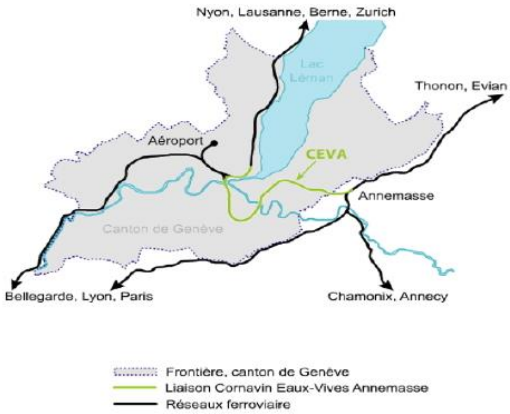


Figure 6 Subway tunnel of CEVA in Geneva city http://www.ceva.ch/geneve

While housing policy is on the main agenda of maintaining urban growth, the provision of related amenities and services is essential to ensure quality of life for citizens. As the city has a high "Deep City Applicability Score" on the potential for underground urbanism, its global potential of the four resources is taken into account for district-level land use planning. A suitability study in three urban zones identified land parcels with high potential for synergetic underground development (optimization of underground construction condition, synergetic use between geothermal system and geomaterial, conflict prevention from groundwater protection) (Blunier 2009; Piguet and Blunier 2009).

The renewal area PAV[4] zone is one of the key study areas, covering 2.3 km$^2$ and undergoing post-industrial regeneration. High potential land parcels for multilayer underground urbanism are shown in Figure 7:

[4] PAV district: Praille-Acacias-Vernets (http://etat.geneve.ch/pav)

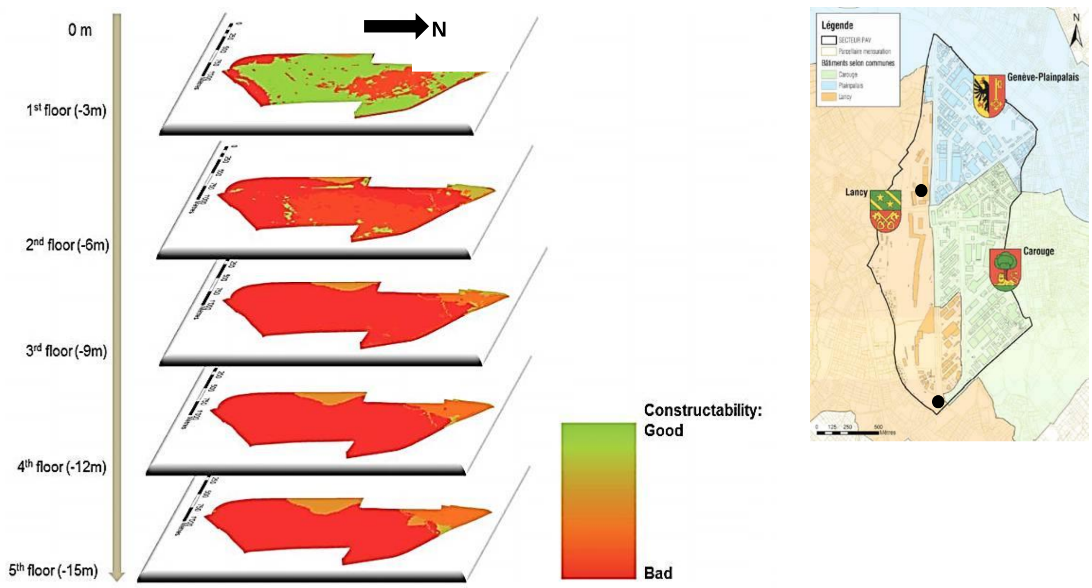


Figure 7 Underground Space Construction Capacity mapping for PAV district
(Left: Subsurface geotechnical quality,
Right: Administrative divisions of PAV district, black points are locations of CEVA stations)

Lower than 30 meters, a subway tunnel CEVA[5] will be built, with two subterranean stations (black points) serving the district. A large underground building with more than two levels below-grade should choose good quality parcels in north-west part, with good subsurface land quality, high geothermal energy reserve and lower impact on aquifer. It is estimated that 10% of land is suitable for shallow underground construction (0-15m). An exploitable gravel material zone near river bank also has potential for additional uses. Underground urbanism helps this development zone (building height limit to 24 m) to balance urban density and landscape liberty. Possible land saving in building footprint extension can reach 19% (Table 8), which could serve to create more public recreational spaces.

Table 8 Inventory of underground space supply (0-15m depth) in PAV district

| Indicators | Planning reference (PAV) | Space and land (PAV) |
|---|---|---|
| Housing sector | 9,550 housing units | [6]764,000 $m^2$ |
| Commercial sector | 45,200 jobs | [7]1,356,000 $m^2$ |
| Built-up area | 1.35 $km^2$ | |
| Green space | 35% in built-up area | 472,500 $m^2$ (0.47 $km^2$) |
| Building footprint | 50% in built-up area | 675,000 $m^2$ (0.68 $km^2$) |
| **Densification demand** | Floor area ratio | 3.14 |
| **Underground resources supply forecast:** | | |
| **1. Underground space** | | |
| Underground space supply | 10% of built-up area (3 floors) | 405,000 $m^2$ |
| Densification input | Underground space rate | 0.19 |
| Building footprint release | Underground space / density | 128,950 $m^2$ (0.13 $km^2$, 19%) |
| **2. groundwater** | | |
| Three groundwater wells nearby, providing about 5 million $m^3$ of clean drinking water per year | | |
| **3. geomaterial** | | |
| a gravel material reserve zone in the area, excavated soil can be revalorized in the construction site | | |
| **4. geothermal energy** | | |
| Northern part of the area is identified as high potential for geothermal drilling, potential map can be found in (Piguet, Blunier et al. 2009) | | |

[5] Rail network of Cornavin-Eaux-Vives-Annemasse (http://www.ceva.ch/geneve )
[6] Assuming that household size is 2 persons with Swiss average level, housing space per person is 40 $m^2$.
[7] Assuming that per employee working space is 30 $m^2$.

In order to test the robustness of our results obtained in the Swiss case study, the methodology is further applied in the case of Suzhou city in China. The case, described in Part 2 of the paper, provides a more comprehensive study conducted on a much larger urban scale (built-up area 324 $km^2$) involving four underground layers (15m, 30m, 50m, 100m) and illustrates a quantitative forecast for development potential.

## 6. Conclusion

The paper has introduced an overview of the Deep City Method and it has demonstrated an integrated planning tool for underground urbanism. Two innovative principals for urbanization strategy have been introduced in the paper:

1. Resource-based management:

While the use of underground space is not a recent discovery, managing underground resources as a whole system including space, groundwater, geomaterial and geothermal energy has been ignored in the history of urbanization, this paper provides a first demonstration of the importance of managing four geo-resources in the developing stage of underground urbanization. By proposing an "Applicability score", cities are examined through a general diagnostic, which helps to qualify and prioritize pilot cities for underground urbanism. Since data on geo-resources is usually fragmented or sometimes missing, a sound resource management is based on a foundation of existing knowledge and information.

2. Institution-based management:

Success models of governing underground urbanization are summarized in section 3. This benchmarking study helped to extract critical success factors to be referred by applicable cities. An integrated management process involved by different levels of institutions is proposed, to ensure that international experiences on strategic thinking are transferred to city level and adapted to local operational schemes.

To illustrate a combination of the above-mentioned principals, a conceptual case study is demonstrated at the end. The city of Geneva is the first municipality to experience a restructuring with underground urbanism, its performance of adapting public instruments is based on the existing territorial information platform for knowledge sharing, as well as interactive coordination with existing urban planning process. These two advantages are usually not evident in those emerging growing cities.

When more cities are imminent to manage the urban underground, building a comprehensive management model and planning process become critical for decision-makers in operational levels. More operational steps are required for generalizing the method to other cities around the world; this is further studied in the Part 2 paper at three scales:

- Urban scale: identify key issues of underground construction and resources exploitation by academic research, digitize parameters into territorial information platform to aid urban planning and classify land qualities for land administration.
- Land scale: renew land asset management based on supply capacity and demand level, by coordinating regulatory guidelines from land administrators (legal rights of land parcel) and urban planners (building codes of land parcel).
- Project scale: indicate investment choices according to different uses and cost efficiency levels.

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