Urban underground space resources: assessment of the environmental potential for a rational use

Nikolai Bobylev,
Saint Petersburg State University

Wolfgang Wende,
Technische Universität Dresden & Leibniz Institut für ökologische Raumentwicklung

E-mails: n.bobylev@spbu.ru, W.Wende@ioer.de
Overview

-The Driving Factors – Why are we using and need to use more the Urban Underground Space (UUS)?

-Urban Infrastructure Futures – Innovations & spatial transformations

-Urban Underground Space use statistics

-Examples & discussion on environmentally friendly solutions (smart, resilient, carbon neutral, energy recovery, sound proof, liveable)

-Policy recommendations - Three-Dimensional Planning

UN Millennium Development Goals

Goal 7: Ensure environmental sustainability
Target 9: Integrate the principles of sustainable development into country policies and programs and reverse the loss of environmental resources

Post-2015 Development Agenda

New Goal: Address Global Environmental Change
New Goal: Ensure sustainable Urbanization

A Target: Create liveable human settlements
A Target: Preserve natural landscapes and ecosystems (as much as possible)
Underlying drivers for contemporary UUS growth (urbanization, density, environment),

**Facts = Land cover change!**

Global average annual increase in urban area, %

- **years 1970-2000**
  - OECD/developed countries: 1.3
  - non-OECD/developing countries: 4.6

- **years 2000-2030**
  - OECD/developed countries: 4.4
  - non-OECD/developing countries: 7.6


Data: Goldewijk K. and Van Drecht G., 2006; OECD 2008, Angel et al, 2005

*tolerances: built-up area equals urban area; OECD countries equals developed equals industrialised countries.*
Underlying drivers for contemporary UUS growth (urbanization, density, environment)

Policy = Urban sprawl? A Compact city?

Average annual indicator change rates in countries, %

<table>
<thead>
<tr>
<th></th>
<th>Urban population</th>
<th>Built-up area</th>
<th>Population density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrialised</td>
<td>0.6</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>1.2</td>
<td>6.9</td>
<td></td>
</tr>
<tr>
<td>Developing</td>
<td>2.2</td>
<td>7.6</td>
<td></td>
</tr>
</tbody>
</table>


Calculated using data from: China Urban Development Report, 2010; He et al, 2012; UN-Habitat, 2011; Angel et al, 2005; UN-Habitat, 2013. *tolerances: built-up area equals urban area, excluding major green areas and water bodies; OECD countries equals to (1) developed (2) industrialised countries; data for China is for the years 2000 - 2009, data for the urban population is for the years 2010 - 2020, data for urban population density is for the years 1990 – 2000, the rest data is for 2000-2030.
Underlying drivers for contemporary UUS growth (urbanization, density, environment)

Facts = Land cover change!

Source: Dr. Ling Xue, Towards sustainability: ‘new’ urbanization, new planning. Spring Campus, April 11-15, 2016

Source: HoukaiWei, Contrast between Population and constructed area in China
A sequence of different land-use regimes that may be experienced within a given region over time: from presettlement natural vegetation to frontier clearing, then to subsistence agriculture and small-scale farms, and finally to intensive agriculture, urban areas, and protected recreational lands.
Underlying drivers for contemporary UUS growth (urbanization, density, environment),

Urban Underground Space (UUS) use transitions

Soil - vegetation

Groundwater aquifer

Utility lines

Groundwater aquifer

Motor-rail transport

Groundwater aquifer

Brown fields-contaminated soils

Groundwater aquifer

Soil-vegetation, paved surface

Utility lines

Utility lines

Utility lines

City

Urban agglomeration

Pre-settlement

Village & town

Bobylev & Jefferson, 2014
Urban Physical Infrastructure: adaptation, transformation, transitions?

Housing support infrastructure development trends (from Bobylev, upcoming)
UUS services and resources

**UUS resources** (after Parriaux, Bobylev, Sterling)


- Physical space
- Geomechanical properties of disturbed ground
- Geoenvironmental properties and underground flora/fauna
- Geothermal - high extraction rate
- Excavated or extracted materials
- Cultural heritage

Urban Underground Space Services / Resources

- Potentially Renewable
  - Groundwater
    - Drinking water supply
    - Irrigation
    - Surface water exchange
  - Geothermal energy
    - Geothermal - seasonally balanced

- Non-renewable
UUS statistics

UUS statistics

UUS statistics

<table>
<thead>
<tr>
<th>City</th>
<th>Population density, person/km² (thousands)</th>
<th>Urban Underground Space use density m³/m², (shown in centimetres)</th>
<th>Urban Underground Space volume per person m³/person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helsinki</td>
<td>2.4</td>
<td>1.2</td>
<td>5.4</td>
</tr>
<tr>
<td>Beijing</td>
<td>3.3</td>
<td>2.5</td>
<td>7.9</td>
</tr>
<tr>
<td>Paris</td>
<td>3.8</td>
<td>3.3</td>
<td>8.9</td>
</tr>
<tr>
<td>Stockholm</td>
<td>3.8</td>
<td>2.9</td>
<td>8.8</td>
</tr>
<tr>
<td>Shanghai</td>
<td>6.2</td>
<td>3.4</td>
<td>7.2</td>
</tr>
</tbody>
</table>

UUS statistics

<table>
<thead>
<tr>
<th>Population density, person/km² (thousands)</th>
<th>Urban Underground Space use density m³/m², (shown in centimetres)</th>
<th>Urban Underground Space volume per person m³/person</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4</td>
<td>1.2</td>
<td>5.4</td>
</tr>
<tr>
<td>2.8</td>
<td>4.6</td>
<td>16.6</td>
</tr>
</tbody>
</table>

1998  2013

UUS statistics

<table>
<thead>
<tr>
<th>Population density, person/km² (thousands)</th>
<th>Urban Underground Space use density m³/m², (shown in centimetres)</th>
<th>Urban Underground Space volume per person m³/person</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3</td>
<td>2.5</td>
<td>18.8</td>
</tr>
<tr>
<td>4.1</td>
<td>7.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.9</td>
<td></td>
</tr>
</tbody>
</table>

UUS statistics

Analytical estimation of urban underground space use by function (Berlin, Alexanderplatz)

UUI state-of-the-art: Berlin

Quantification & statistics on UUI

UUI state-of-the-art: Berlin

Correlation between dwelling units density and UUI public transport infrastructure

UUI in Berlin districts. Relation between BVG (public metro train operator) density and dwelling units density

Source: Bobylev, 2009, upcoming
Berlin, Potzdamer Platz & Sony Centre; Tokyo, Shiodome
Photo: Nikolai Bobylev
An example: Addressing vulnerabilities to climate change
A problem of urban water runoff after heavy rain (incl. flash floods)

• Flooding and inundation
• Untreated water discharge into surface water bodies;
• Infrastructure damage;
• Disruption if critical (vital) urban services

Conventional solutions:
• Reduce runoff (trees, green zones);
• Increase capacity of drainage infrastructure.

Smart city solutions:
• Manage runoff between city areas (valves, barriers, automated water management (smart grids)).
• Inform citizens to temporary cut domestic water use (e.g. for one-two hours).
Contemporary agenda for UPI planning - Energy

Max-Schmeling Halle, Berlin

Photo: Sebastian Greuber – Max-Schmeling Halle, Berlin
Contemporary agenda for UPI planning - Energy

Max-Schmeling Halle, Berlin

*Drawing*: Jörg Joppien
Contemporary agenda for UPI planning - Noise

The Landtunnel Utrecht at Leidsche Rijn, Utrecht

Policy Summary

Cities: addressing Sustainability, Resilience

Cities: addressing Global Environmental Change (and climate change)

Cities: Overarching goal: Quality of Life?

Cities: green, sustainable, liveable, smart, climate-neutral, resilient

Key policies:
- urban density and efficiency
- master planning, 3D planning, democratic, expert-based, political, coherent with other policies
Urban Futures:
3D city – active use of underground space
3-Dimensional Planning is required!

Photo: Nikolai Bobylev - Tokyo
A concept of contemporary UUS development agenda addressing the transitions in UUS
Tunnelling and Underground Space Technology Technology incorporating Trenchless Technology Research
Editor-in-Chief: Jian Zhao
5-Year Impact Factor: 1.833

http://www.journals.elsevier.com/tunnelling-and-underground-space-technology/

Special Issues

The Emergence of Underground Space Use Planning and Design Virtual Special Issue from Underground Space (1976—1985)

Improvements in Underground Space Utilization and Planning Virtual Special Issue (1986 – 2014)

Main themes 2016


Sustainability, Resilience, Livability, Urbanization, Futures, Urban development concepts

Resources use, energy, land use, user competition, conflicts of interest

City planning, master plans, zoning, functional use, city case studies

Social sciences perspective: governance, administration, management, institutions, stakeholders, professionals, education, disciplines, policy and legal

Data, analysis, and tools: statistics, quantification, valuation, 3-dimensional mapping, GIS, decision analysis, economics

Human perspective: Architecture, interior design, health, ergonomics, psychology

Special and distinct issues: civil defense, disaster reduction, renewal, rehabilitation, redevelopment, environmental protection
Urban Underground Space Research & Development Agenda

A scope of key questions that UUS professionals should be considering can be identified as:

1. How can we describe highly developed cities now and in the future? (e.g. quality of life, environment, public amenities, and secure provisioning of ecosystem services);
2. How will UUS look like in the future in highly developed cities? What are the pathways to those futures?
3. What urban functions should/will be located predominantly underground?
4. What could be a target indicators for UUS in highly developed cities now and in the future? (e.g. functions, services, densities, asset value and the role in urban life);
5. Are there any universal UUS development trends? Which UUS development trends are local, i.e. depend on geographic location of a city, characterized by e.g. geology, climate, population; and which are global?
6. What is the best way in which UUS can address global environmental change factors (e.g. urban sprawl, energy consumption, climate change mitigation/urban adaptation)?
7. How much land can be saved by intensive use of UUS?
8. What actions can we take now to ensure the best outcome in urban and UUS development?
9. What will be the transitions to a high density UUS? (e.g. integrated urban district redevelopment?) Where are opportunities for optimization? How can be transitions to high density UUS be managed/governed?
10. What is the most rational use of UUS to provide maximum benefit to society? What should be a UUS use policy?
Projects:
Bobylev & Parriaux: SNSF Scientific &Technological Cooperation Programme Switzerland-Russia, Ecole polytechnique fédérale de Lausanne, 2011.

Publications:

Photo credits:
Nikolai Bobylev;
Berliner Wasserbetriebe and Berlin Institute of Technology;
G-Cans, Tokyo (http://www.g-cans.jp/).
Thank you for your attention!

E-mail: nikolaibobylev@gmail.com