John Fernandez Keynote
Urban Metabolism and Sustainability Transitions

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Socio-metabolic regime change*: urban growth**

Materials use (DMC = DE) by material types, 1990-2005

* Krausmann, 2008 and 2009  ** Fernandez 2007
Urban Metabolism

Urban metabolism is the study of the physical flows required to serve the urban economy.

Figure 1 - The urban metabolism of Brussels, Belgium in the early 1970s. Source: Duvigneaud and Denaeyer-De Smet 1977.

From Kennedy (2007)
Urban metabolism is the study of the physical flows required to serve the urban economy.

From Ferrao and Fernandez (2014)
Caral, Peru
Total neolithic* human material consumption

Breath

$\text{Solid waste}$

$\text{Excreta}$

Unit: tonnes/cap-yr
Total modern* human material consumption

Unit: tonnes/cap-yr
Urban metabolism projects

Caracas
Caral
Lima
Ica
Santiago
Talca
Figure 5: Causal loop diagram of reinforcing behavior in Caral society

Figure 6: Causal loop diagram of balancing behavior in Caral society

3 We use organizational structure here to describe both the government and religious system.

<table>
<thead>
<tr>
<th>Loop</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>As the population grows, the birth rate increases as a function of the number of people.</td>
</tr>
<tr>
<td>R2</td>
<td>Due to improved agricultural techniques there is increased food available which enables the population to grow.</td>
</tr>
<tr>
<td>R3</td>
<td>The organizational and religious structure is strengthened by temple construction.</td>
</tr>
<tr>
<td>B1</td>
<td>As the population grows, the death rate increases as a function of the number of people.</td>
</tr>
<tr>
<td>B2</td>
<td>Due to increased population and temple construction their is increased environmental vulnerability.</td>
</tr>
</tbody>
</table>

Observations
agrarian urban economy (pre-fossil fuel): 1 ton per capita/annum
fossil fuel urban economy: 20 – 50 tons per capita/annum
Lisbon, Portugal
Lisbon, Portugal

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Biomass</td>
<td>3.67</td>
<td>4.23</td>
</tr>
<tr>
<td>Fossil fuels</td>
<td>2.13</td>
<td>2.24</td>
</tr>
<tr>
<td>Metallic minerals</td>
<td>0.78</td>
<td>9.19</td>
</tr>
<tr>
<td>Nonmetallic minerals</td>
<td>12.99</td>
<td></td>
</tr>
<tr>
<td>Nonspecified</td>
<td>0.52</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>20.08</strong></td>
<td><strong>15.66</strong></td>
</tr>
</tbody>
</table>

Note: t/cap = tonnes per capita; DMC = domestic material consumption.
Singapore, Republic of Singapore
Urban Metabolism of FM

Urban Activity 1
Mobility

Urban Activity 2
Built Environment

1960 1975 1990 2005

1960 1975 1990 2005
Urban Metabolism of Singapore

DMC_{mobility}
DMC_{built environment}
DMC_{goods and services}
DMC_{total}
Singapore city-wide data

DMC (MT/cap.)

Electricity (kWh/cap.)

Water (m³/cap.)
Boston, Back Bay
Urban metabolism of the Back Bay
Back Bay Filling Progression

Image Source: Seasholes, Gaining Ground
Overall Building Weight Per Floor Area
Brownstones / Brick Structures Only
Building Weights Over Time
Including Demolished Houses
Cumulative Building Weights Over Time
Houses of the Back Bay
Understanding the Resource Intensity of Cities
Interactive Visualization and Measurement of Urban Areas
March, 2012

About the Neighborhood Visualizer

How do we assess the materials and energy used to create our cities?

Urban planning has focused on identifying many important questions about the formation and functioning of our cities. But there is a shortage of knowledge in understanding the spatial pattern of material and energy use in our cities.

This work attempts to address this knowledge gap. Several cities have been analyzed in detail, and measurements gathered of material and energy use patterns.

To make this work as useful as possible, we are interested in examining whether the information is presented in such a way that it builds intuition about the function of cities. One of the objectives is to assess whether an **intensity** measure is intuitive, and if this tool facilitates learning.

There are a series of short questions to explore this approach.

Figure 1: Understanding the spatial distribution of resource intensities.

How can we assess the materials and energy used in our cities?
Urban information query record

(a) Location of the first 3,000 users.

1
2
3

4
5
6

Query Count

Area of Query (km²)

(a) All queries.
(b) Boston
(c) New York.
(d) San Francisco
(e) Los Angeles
(f) Chicago
City Typology
Global City Typology: *Purpose*

1. Appropriate and effective ‘green’ city policies
2. Regional and international cooperation
3. Reasoned transition pathways to green infrastructure and consumption
4. Scientific consideration of socioeconomic constraints and opportunities (HDI, population density)
Global City Typology

• Consumption
• Statistical analysis
• Case study affirmation

A typology based on urban resource consumption is partly discovered and partly constructed from available data and recent findings.
Typology of Urban Resource Consumption
Transitions thought experiment

Kolkata, Islamabad, Phnom Pehn, Dhaka
Lagos, Mumbai, Nairobi, Quito
Manila, San Salvador, Panama City, Cali
Casablanca, Tunis, Lima, Rabat

Beijing, Shenzhen, Bangkok, Istanbul, Mexico City
Belgrade, Tripoli, Sarajevo, Tehran, Budapest, Lisbon, Buenos Aires

Delhi, Cairo, Ho Chi Minh, Hyderabad, Bangalore
Japanese Cities: Nagoya, Osaka, Yokohama, Tokyo

Johannesburg, Cape Town, Guangzhou, Shanghai, Tashkent, Tel Aviv
Jerusalem, Hamburg, Copenhagen, Moscow, Seattle, Singapore

Kiev, Vladivostok, Santiago, Warsaw, Dublin, Athens, Prague, Berlin

London, Milan, Caracas, Barcelona, Madrid, Kuala Lumpur, Rome

Boston, Phoenix, Denver, Detroit, Vancouver, Melbourne, Sydney
Burkina Faso, Burundi, Cape Verde, Democratic Republic of Congo
Angola, Botswana, Congo-Brazzaville, Gabon, Namibia, Sudan
Recent Publications

CITY-LEVEL DECOUPLING
Urban resource flows and the governance of infrastructure transitions

SUSTAINABLE URBAN METABOLISM
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