Causal links in urban metabolism: a case study in the Metropolitan City of Milan

Gabriela Fernandez
Ph.D. Urban Planning, Design and Policy
Department of Architecture and Urban Studies
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The Problem

Considering ongoing, rapid urbanization and the vast resource consumption of metropolitan areas around the world, it is important to integrate urban resource management with the design of our future cities. But how can resource management become an integral part of planning and designing urban landscapes?
Cities as material systems
Natural Resource degradation is essentially a net result of a chain reaction

Population Explosion
Industrialization
Urbanization
Transmigration from villages and rural areas
Wasteful use of available resources
Over exploitation of the natural resources (overharvesting/overconsumption)
Urban Metabolism

**Figure 1:** The metabolism of cities

**Figure 2:** Circular city
Figure 4: The Metabolism of Cities. Abel Wolman, 1965
Understanding urban systems by means of Urban Metabolism

industrial ecology, urban ecology, sociology, ecological economics, political ecology, architectural design, natural resource management, waste management, political geography, engineering…

Figure 3: Cities are animals. Nelson, 2010
Urban Metabolism Methodologies

- Concept and theory
- Accounting
- Simulation
- Regulation and Optimization

Figure 5: Research methodologies used to study urban metabolic systems. Zhang, 2013
Material Flow Analysis

Figure 6: Typology of urban metabolic profiles (b) (Saldivar-Sali, 2010)
### Indicators

Table 1: General indicator scheme for economy-wide MFA, (Eurostat, 2001)

<table>
<thead>
<tr>
<th>Category of indicators</th>
<th>The main analytical indicators</th>
<th>Calculation formula</th>
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<td>Material input indicators</td>
<td>Direct Material Input (DMI)</td>
<td>Regional extracted materials + import</td>
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<td></td>
<td>Total Material Input (TMI)</td>
<td>DMI + hidden flow within the region</td>
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<td>Total Material Requirement (TMR)</td>
<td>TMI + hidden flow outside the region</td>
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<td>Material output indicators</td>
<td>Direct Material Output (DMO)</td>
<td>RMO + export</td>
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<tr>
<td></td>
<td>Total Regional Material Output (DMO)</td>
<td>Regional material output + regional hidden flow</td>
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<tr>
<td></td>
<td>Total Material Output (TMO)</td>
<td>TRMO + export</td>
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<tr>
<td>Material consumption indicators</td>
<td>Regional Material consumption (RMC)</td>
<td>DMI - import</td>
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<tr>
<td></td>
<td>Total Material Consumption (TMC)</td>
<td>TMR - export and relevant hidden flow</td>
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<td>Balance indicators</td>
<td>Net Addition to Stock (NAS)</td>
<td>Net addition to the materials in stock</td>
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<td>Physical Trade Balance (PTB)</td>
<td>Import - export</td>
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<td>Intensity and efficiency indicators</td>
<td>Material Consumption Intensity (MCI)</td>
<td>TMC /population (or GDP)</td>
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<td>Material Productivity (MP)</td>
<td>GDP /RMC</td>
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<td>Waste Rate (WR)</td>
<td>The amount of waste generated/GDP</td>
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Social and material independent indicators

- Population
- Population Density
- GDP Per capita
- Climate
- Area
- Country GDP
- Input
- Output
- Economy

Figure 7: General scheme for economy-wide MFA, (Eurostat, 2001)
Interactive web mapping tool to explore U.S. cities

Figure 8: Interactive web mapping tool to explore major U.S. cities (Visualizing cities’ energy usage, population density and material intensity. (Quinn, 2012)
Material and Energy Flow Data Collection Sources

Figure 9: MFA Tools. www.mfatools.org

Figure 10: Italian Statistical Agency (ISTAT)

Figure 11: Social Ecology Vienna

Figure 12: World Research Institute. Italy material extraction and consumption
LA Energy Atlas

A first of its kind interactive website built with the largest set of publicly available disaggregated energy data in the nation.
The multi stakeholder collaboration is still in preliminary stages and is currently recruiting interested members. The idea is to collaborate with different university professors from all around the world and discuss and share new urban metabolism challenges, processes and data. The goal of this collaboration is through the lens of urban metabolism, to: generally rethink the contemporary urbanization processes (i.e. material flow analysis, footprint analysis, etc...) in cities; untangle the transformation of spatial forms and structures and; explore the agency of design in confronting these challenges; urban planning and policy.

Website Link: Urban Metabolism of Milan
Energy consumption in the Metropolitan City of Milan as part of the energy metabolism

Figure 13: Metropolitan City of Milan total energy consumption (ISTAT, 2010)  
(Sector: residential, tertiary, urban transport, agriculture and industry)
Energy consumption in the Metropolitan City of Milan as part of the energy metabolism

Figure 14: Metropolitan City of Milan total energy consumption (ISTAT, 2005-2010) 
(Sector: residential, tertiary, urban transport, agriculture and industry)
Summary Points

• Understanding urban systems by means of urban metabolism.

• Urban metabolism for planning and designing sustainable cities.

• Measuring the intensity and efficiency of material use of economic activities, and the urban area’s dependence on externally sourced materials;

• Calculating environmental pressure indicators, such as the ecological footprint or greenhouse gas emissions;

• Uncovering the infrastructure needs for waste management and the potential for establishing a circular economy; and

• Benchmarking urban areas and defining urban typologies.

• Studying urban metabolism in a particular city boundary
Conclusion

There is an importance to the considerations associated with city level measurements, and the trade-offs associated with compactness in urban form. While there is significant variation within different parts of each city, there are common patterns across all cities (Bettencourt et al. 2007). Focusing on the physical characteristics of the built environment and socio-economic measurements is crucial in identifying the social behavioural, cultural and economic drivers in a city.

However, when considering the resource intensity of a city, it is important to consider the overall urban system in a regional context, rather than just focusing on historical political boundaries. As policy makers gain a better understanding of how cities metabolize and address behavioural and economic trends through drivers resource consumption measures will become a more accepted metric for assessing the sustainability of cities globally.
References


Thank you for your attention.