Ecologies of Construction: Urban Metabolism 02

Urban metabolism

State of research addressing the global impact of cities.

- The role of large urban centers in the global biosphere remains a relatively neglected area of environmental research.

- Most studies of anthropogenic metabolism and its environmental effects are at the national scale and don't explicitly target the city as a metabolizing entity.

- Studies involving cities focus primarily on either human health or environmental pollution specifically.

- Yet, emerging studies have begun to place cities within the larger global context of material and energy consumption and waste production.The reasons for this include the growth of megacities (10m+, by 2010) and the continuing widespread urbanization of global populations.

anthroposphere

M_i
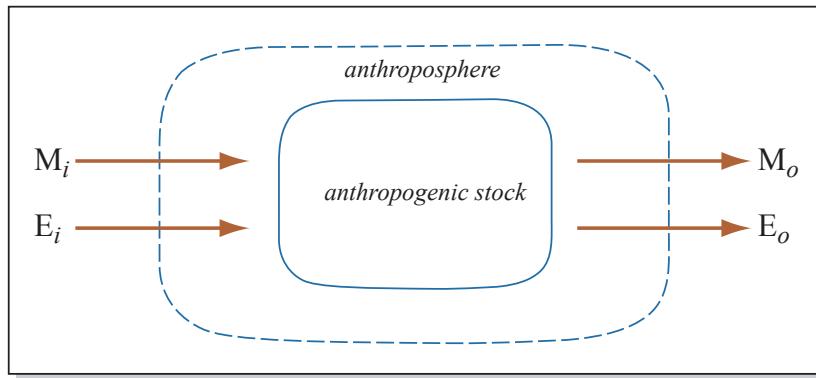
E_i

anthropogenic stock

M_o

E_o

Figure by MIT OCW.

source: Fernandez, J. (2005) The metabolism of buildings: the unique spatial, temporal and physical attributes of contemporary construction. Working paper.

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Material and Energy Flows

- Urban Context
- Inputs
- Outputs
- Models of Urban Metabolism
- Research and knowledge gaps

Urban Context

- Most of the largest cities are found in mid latitude zones.

- Many (but not all) of the largest cities are situated very close to large bodies of water – within 100 km of a coast. Many of these cities originated as ports and continue to operate large port facilities.

- Exceptions include Moscow and Dehli (river towns) and Mexico City and Tehran are not near large bodies of water.

- Mean elevation of megacities is 121 m (above sea level).

- Topography and climate vary greatly.

- Because the majority of urban populations are located north of the equator, the vast bulk of atmospheric and waterborne effluent originates from this hemisphere.

source: Decker, E.H., Elliot, S., Smith, F.A., Blake, D.R., Rowland, F.S. 2000. Energy and material flow through the urban ecosystem. Aanu. Rev. Environ., 25:685-740

Demographic and Economic attributes

- Again, like climate and topography, there is great diversity in the demographic and economic attributes of large urban centers.

- Megacities, while fueled by active national economies, are not limited to the largest countries by population or land mass.

- Consider Tokyo and Buenos Aires:

  - Buenos Aires: Argentina national population of about 37 million. Small country. Buenos Aires is the 12th largest city in the world with a population of 11 million.

  - Tokyo is the world's largest city at 30 million.

  - Approximately 30% of the national populations of both Argentina and Japan are located in one or more megacities.

Demographic and Economic attributes (continued)

- GDP and other economic measures vary widely among megacities.

- For example:

    - GDP per capita in Bangladesh = 286USD

    - GDP per capita Japan = 33,265USD

- Currently, it is not clear whether residents of megacities are more or less privileged than national averages (again, an indication of the lack of data regarding megacity attributes).

- Socioeconomic data is typically only available for national or regional entities.

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Inputs and Outputs

Inputs

- Inputs include both active and passive elements:

  - Active: construction materials brought within municipal boundaries.

  - Passive: rain, wind, water from rivers, pollution from outside of the city, solar radiation.

- Active input can end up being stored or transformed:

  - Stored: stone, wood in a building, concrete for bridges, etc. Also materials in landfills.

  - Transformed: water, black and grey, treated and removed from urban center (dissipation into the larger environment). Also, all fuel materials are transformed.

- The largest input, by far, for any city large or small is water.

Inputs and Outputs

Inputs

- Stored inputs

    - Excluding water, fuel and food, nearly 75% of all remaining materials consumed in the US are aggregates (stone, sand, gravel) used in construction.

    - Of the remaining 25%, other construction materials like gypsum and cement and plastics still tend to dominate.

- As previously noted, and apart from landfills, the built environment is thus the location of much of the stored inputs of cities.

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Inputs and Outputs

Inputs

- For example:

  - Shanghai built 20 million square meters of floor space between 1990 and 1993. On average, 450 kg of material are required for every square meter of floor space. This resulted in:

    i. About 9.27 million tons of material (or 119.5 petajoules, *peta: 10^{15}*) being added to Shanghai.

    ii. Furthermore, as more is built, higher density and taller buildings are required. These buildings are even more resource-intensive per square meter.

Inputs and Outputs

Inputs

- Stored inputs

    - Landfills are the other major component of "stored" materials that are a result of active inputs.

    - In many cities, it seems about 30-40% can be attributed to food wastes and 20-30% to construction debris.

    - The remainder consists of paper, plastic, glass, various kinds household refuse (like lawn trimmings), industrial effluent and an array of smaller waste streams

    - In rapidly expanding megacities, illegal dumping can be rampant. In Mexico City, over 29% of solid waste ends up in illegal dumps.

    - In established megacities, waste removal and discard is well organized. Los Angeles recycles 10%, Tokyo 60%!

Inputs and Outputs

Inputs

- Stored inputs

  - Globally, landfills are a major source of the greenhouse gas methane, a primary driver for the alteration of planetary-scale photochemistry.

  - Therefore, landfills should be considered a major biogeochemical reservoir. What we do with these "reservoirs" is an open question.

Inputs and Outputs

Inputs

- Energy

  - A typical megacity will consume from 100 – 1000 petajoules of energy per year to operate its transportation, electrical, and climate control infrastructures.

  - Though these cities are expanding more rapidly in developing regions than developed, per capita rates of consumption in the developed world are very much higher.

Inputs and Outputs

Inputs

- Finally, in most megacities, it has been estimated that less than 10% of material outputs are exported as goods (to be consumed elsewhere).

Therefore, cities are net resource sinks for most materials.

Inputs and Outputs

Inputs

- Transformed inputs

  - Water, food and fuel are the three primary "transformed" resources actively imported into cities.

  - With regard to food and fuel, anthropogenic use of these resources makes a significant impact on the global and regional carbon and nitrogen cycles.

Inputs and Outputs

Inputs

- Transformed inputs

  - Food

    - Data is lacking here. It is generally not clear how much food is imported into cities and also how much is discarded.

    - One exception is New York City: imports 20,000 tons of food each day. Roughly half is lost to spoilage or simply not eaten and eventually sent to the landfill.

Inputs and Outputs

Inputs

- Transformed inputs

    - Fuel

        - While volumes of consumption are hard to pin down, the types of fuel used has been well-documented.

        - Because of substantial volumes, fuel types are closely associated with the regional resources, except in wealthier nations that can import a diversity of fuels. Therefore, oil-intensive urban centers include Jakarta and Manila;natural gas-intensive include Bangkok, Bombay, London, Mexico City and Moscow. Coal is used extensively in Beijing, Shanghai, Calcutta and Soeul; hydroelectric in Los Angeles and Sao Paolo.

        - The increase in transportation, especially automotive, presents a real challenge.

Inputs and Outputs

Inputs

- Transformed inputs

  - Water

    - The ultimate solvent: used as potable and waste medium.

    - Great variation in the provision of water to large parts of megacities: for example, Mexico City serves 45% of its citizens in the inner urban core, while only 27% in the formal city perimeter are served, while close to zero is actively provided in the vast squatter and slum settlements.

    - Water is the largest single material flux in urban centers, by far!

    - For example, a typical city may consume 1,000kt of water per day, while consuming 20-30 kt of fuel.

Inputs and Outputs

Outputs

- Best data concerns itself with atmospheric outputs.

- Driven primarily by concerns for human health and well-being.

- These atmospheric effluents can be considered as the output of "transformed" passive inputs from the atmosphere.

- Other outputs include water, exports (small in comparison to inputs), and biological agents.

Models (physical flux)

Municipal flux

- Not well-established because, as mentioned previously, most material and energy flux models concern themselves with national flows.

- For example, carbon cycles are within larger regional and national spatial scales.

- Exceptions include transportation studies and some socioeconomic issues such as demographics (but still rarely).

- Urban biogeochemical flux is rarely modeled.

Not only a concern for physical accounting;

- Also, economic cycles are typically refined at a national scale.

Models (physical flux)

So, if there is little data, and not well-refined models of physical flux, how does one develop ideas of a sustainable city (or a city that behaves in a sustainable way within a global context)?

- Urban metabolism

- Metabolic budgets

- Ecological footprint

  - All contemporary cities of some scale run ecological "deficits".

- Urban ecosystems

  - Ecosystem services include filtering air and water and absorbing dissipated wastes and residues.

Pioneering work here: Spirn, A.W. *Granite Garden: Urban Nature and Human Design*. Basic Books, New York.