

Developing the urban metabolism approach into a new urban metabolic model

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Abstract

Considering the city as a peculiar kind of ecosystem, this paper explores the potential of a metabolic approach to urban development interpretation, proposing an enhanced metabolic urban model. This new metabolic model strongly focuses on the influence that institutional activities have on urban sustainability. Such activities – like planning and other decisional processes - are considered as an important feedback of urban dynamics. This last updating aims at connecting the conceptual modelling to urban governance.

1 Introduction

Urban settlements have recently become the most popular choice of life for human kind. More than 50% of the world population already lives in cities [6] and this figure rises to 80% if referred to the European continent [2].

In environmental terms, this approach has a great impact on the identification, description and evaluation of urban processes, being the city simultaneously:

- The place of highest consumption of energy and transformation of material resources;
- The most relevant source of waste and contamination/pollution;
- The most relevant contributor to regional and global environmental threads.

In ecological terms, cities can be seen as a peculiar kind of ecosystem. Such analogy is based on the fact that a city contains, in a limited space, a heterogeneous community of living species, dominated by mankind. Humans have the ability to transform heavily their surroundings to meet their needs. These transformations are caused by internal activities and by a working



mechanism based on the interchange of matter, energy and information with the surrounding environment. This environment can be considered both as a supporting system for the acquisition of resources, which are necessary to maintain the urban processes and as a “sump”, used to dispose exhausted materials. Thus, in a way, some dynamics and laws commonly used to describe the functioning of an ecosystem in terms of flows can be applied to urban research in order to obtain a different insight on the way cities work and develop. The knowledge that rises from an ecosystem approach can be used to find new solutions to improve the environmental performances of urban settlements.

This paper explores the potential of a metabolic approach to urban development interpretation, proposing an enhanced metabolic urban model. This new metabolic model includes in the scheme the influence that institutional activities have on urban sustainability. Such activities – like planning and other decisional processes - are considered as an important regulative mechanism of urban dynamics. This last updating aims at connecting the conceptual modelling to urban governance.

2 Flows in cities

Urban settlements are open systems that need matter and energy to keep functioning their complex structure. Cities have a purely heterotrophic nature, which makes them dependent from energy and materials imported from the supporting system. Internal processes are fuelled by a great amount of exosomatic energy .

Such predominance of the human dimension over the physical and spatial layout of urban areas indicates that the environmental analysis of the city system cannot ignore the integration of classical scientific variables with socioeconomic variables. Otherwise the interpretation would be incomplete.

When considering the system, we need to study in depth the level of interrelation between its components and sectors, in order to establish which urban layouts offer the best guarantee of support of its presence, in terms of management and development.

Lastly, the importance of the supporting system has to be acknowledged: as a matter of fact, its relevancy to urban performances is considerably increasing, especially in the industrialised countries. This is a clear consequence of the dominant economic model– focused on growth and consumerist factors – but also because of the technological development, more and more efficient in the global movement of people and goods.

The study of the streams dynamics of matter and energy in urban areas - and the functioning mechanisms behind them - represents a useful exercise to evaluate the possibilities of optimisation - therefore of sustainability - of the processes taking place in the cities.

An interesting approach to such a problem is the one regarding the study of urban metabolism, based on a transposition that comes from biology. The city can, in its processes, be characterised by two main phases:



- *Anabolism*, or constructive activity, that is the complex of processes of matter and energy revision entering in the city system to satisfy demands and needs expressed by the human population;
- *Catabolism*, or destructive activity, that is the complex of processes related to the production and removal of waste resulting from urban activities.

In its catabolic phase, the city pushes away towards the surroundings (supporting system) the entropy, which could be represented by energy with less information - for example infrared radiation - and waste, according to the principles of evolutionary thermodynamics.

Basically, the city system is seen as a black box, which increases its own internal order at the outer environment's expense. The major environmental problems (with high economic costs) expressed by urban systems relate to the growth of entering streams and to the management of outputs' increase. According to the II principle of thermodynamics, the higher the entropy produced by the black box, the lower the level of the city's sustainability on the surrounding environment.

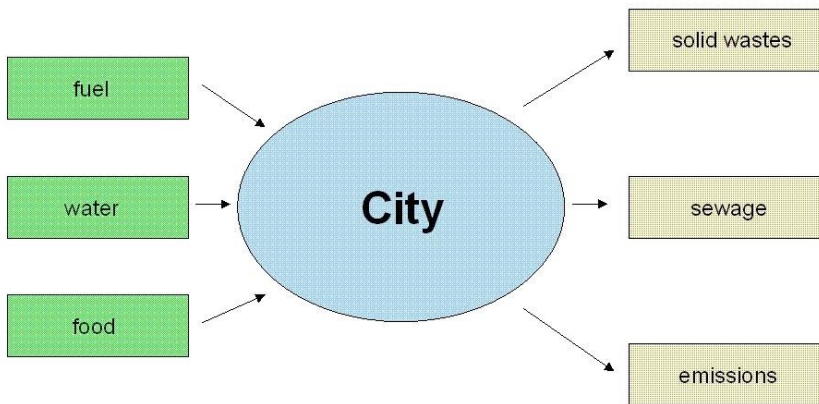


Figure 1: Wolman's metabolic model [7].

Therefore, it is possible to define the goal of urban sustainability as the decrease of both exploitation of natural resources and production of waste, together with the increase in living standards, so that the city object can better cope with the carrying capacity of local, regional, and global ecosystems [3].

3 Evolution of urban metabolic models

Three different versions of the urban metabolic model have been developed so far, beginning with its original formulation in the mid-60's [7] to the so-called extended urban metabolic model (EUMM) at the end of the 90's [4]. In this evolution, the model's conceptual scheme becomes more articulated – as shown

in figures 1, 2, 3 - containing a more analytic list of the categories constituting the input/output sequence. This happens because there is more to city than a processing mechanism of resources and waste production: the city is a place where human opportunities are created [3] and for which the population has hopes and expectations. The city is in reality a dynamic and complex ecosystem.

Through such evolution, the equivalence “city = black box” has been overcome, including in the metabolic scheme the effects of a set of internal dynamics. These dynamics have control over the input’s repartition and transformation (and consequently over the output’s quantity and destination) of human settlements. For each category of dynamics, then, a group of descriptive indicators of urban environmental performances has been elaborated, in order to make the results and the consequences of metabolic streams analysis more easily interpretable.

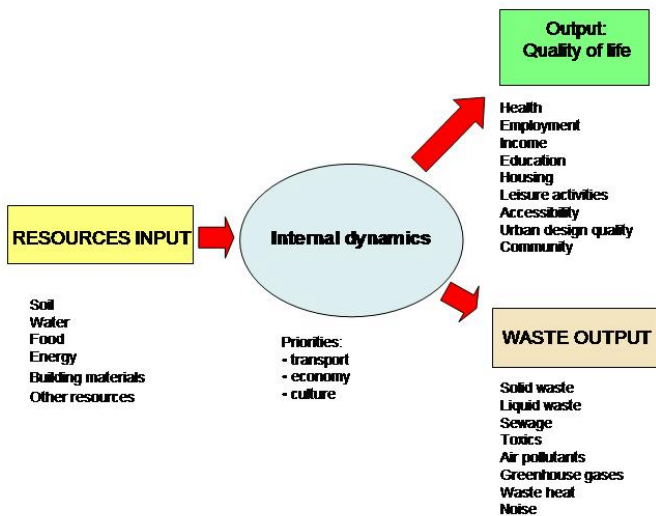


Figure 2: Newman’s Extended Metabolic Model (EMM) [3].

The main features of the urban representation provided by the metabolic model are the following [3]:

- it accepts within itself performance indicators and quantitative goals (standards and benchmarks) that could lead to future analytical approaches;
- it represents a broad spectrum of the urban key sectors (housing, health, transport, employment, consumption, leisure, economic activities, et cetera) and puts forward a systematic vision of the city;
- it allows the representation of causal relationships within the system, following the classical DPSIR sequence (driving force/pressure/state/impact/response);

- it allows an effective representation of those dynamic processes that can be more closely associated with sustainability, following the sequence endowment/processes/output.

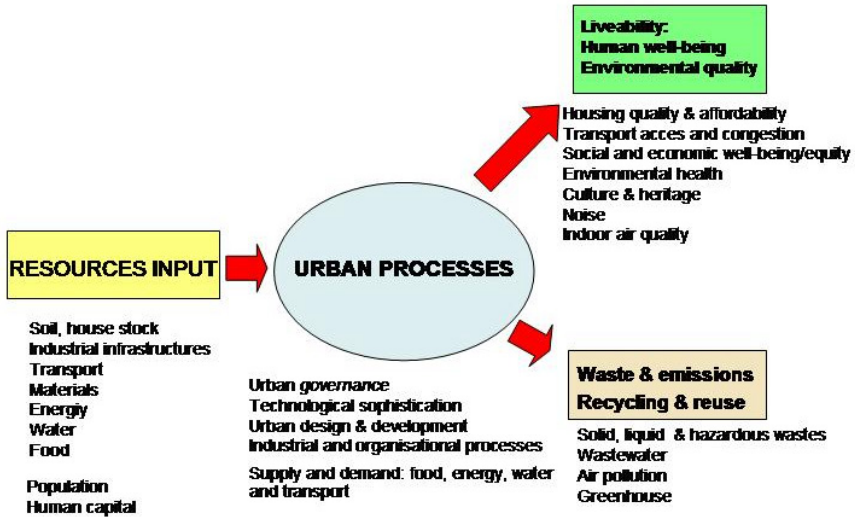


Figure 3: Newton's Extended Urban Metabolic Model (EUMM) [4].

In its last version (EUMM) the metabolic model adopts the four key principles of urban sustainability:

- the analysis of the input of resources, with reference to its reduction through the maximization of their use;
- the increase of urban liveability;
- the reduction of waste and emissions produced by anthropic activities;
- a higher efficiency in urban processes' management.

The metabolic approach is particularly suitable for comparative urban studies. It can be used for the compilation of standardised monitoring procedures and it constitutes an ideal reference scheme through which outline the results of the comparison.

If it is possible to clearly identify boundaries and gates of flow, urban metabolic models can then be applied also to suburban spatial sectors. This task is helped by the existence of intra-urban geographical barriers (like water bodies, transport infrastructures etcetera). The analysis at the suburban spatial scale

constitutes a simplified range of investigation, with respect to the city as a whole. A reduced number of urban actors, of urban dynamics and a general greater ease in the acquisition of the needed data set are the main features of such analysis.

The late metabolic approach can be used to define a checklist of environmental issues, dynamics and factors that are critical to urban development. This checklist could constitute a tool to identify whether there is enough information about a specific topic and to recognize where there is need of tackling problematic conditions.

As a practical application of metabolic urban models, it can be mentioned the use of the EUMM as a reference structure in the exposition of urban environmental problems listed and deepened in the Australian State of the Environment of 2001 [5].

4 The New Urban Metabolic Model

With the intention to better integrate sustainability principles and the role of control mechanisms (feedbacks) within the metabolic scheme, a further development of the metabolic model has been proposed. This scheme takes the name of New Urban Metabolic Model (NUMM).

Following the evolution of the international debate on sustainability that took place during the last decades, the NUMM acknowledges the importance of *institutions* as one of the four pillars of sustainable development, adding this independent factor to the old conceptualisation based on three components (ecology, economy and society). (With the term *institutions* we refer to those organizations that govern collective practices. They can be mainly subdivided into two different categories: managers of the *res publica* and managers of the resources.)

In a heavily anthropic environment, the feedbacks that have a more effective impact in governing urban dynamics and processes are the ones established by humans. In this sense, institutions (administrative, juridical, social, economical, financial, cultural and so on) represent those urban actors that provide the system with rules. This aspect should be internalised into the metabolic scheme, making sure that sustainability principles are admitted as basic principles of institutional activities. Such behaviour should be put in practice especially in the following activities:

- evaluation of urban development proposals and strategic planning;
- urban management activities (day-to-day activity);
- environmental command & control activities.

In the end, institutions act as a “filter” that mediates the relationships that exist among the different components of the urban ecosystem.

A further essential factor related to institutional activities is that urban policies that contain environmental implications are the result of decisional processes participated with citizens. Such a vision entails a governance model based on the synthesis of local groups’ needs and expectations.



Summing up urban sustainability principles developed along the last decades debate, the analysis of the environmental performances of a city may be assessed on the basis of the implementation of the following key factors:

- the “cyclization” of the material flows and the maximizing of energy efficiency in city systems;
- the respect of the carrying capacity of the support system;
- the fostering of a high standard of liveability;

The translation of such key factors into goals of environmental policy determines a list of rules which are generally valid:

- promote the culture of *waste as resource*, via the fostering of the philosophy of the 3R (Reduce, Recycle and Reuse), broadening this approach to soil policies, which has to be seen as a scarce resource (giving priority to the urban regeneration of abandoned areas instead of fostering urban expansion);
- promoting practices of energy efficiency, focusing on energy reuse and the exploitation of renewable energy sources;
- restore the natural capital equilibrium in urban environment, in order to regenerate ecosystem services;
- minimize the emissions produced by anthropic activities;
- minimize the environmental impact of transport systems;
- instigate the sense of belonging to an urban community;
- enhance social equity and the access to urban opportunities;
- develop policies of spatial compatible multi-functionality, with particular reference to the coexistence of housing and business activities;
- promote efficient urban services;
- compacting the density of urban sprawl;
- develop a governance model open to the active participation of citizens in the debate on urban development and transformation.

Combining the remarks referred to the cyclization of flows with the ones on institutions as control mechanisms of the urban environment enables the definition of a new metabolic scheme. This version of the model has been conceived in order to explicitly evaluate how different sectorial environmental



policies take part in the definition of a project for a sustainable urban environment.

Combining the concepts mentioned in this paper the following metabolic model is obtained. The section that refers to the inputs of the system embodies material, energetic and water resources, but also soil and infrastructural equipment (transport, communication, manufacturing and environmental services). Particular attention has to be devoted to capital (natural, economic and human). The flow of inputs has to be conveyed via the intervention of different institutions acting within the city.

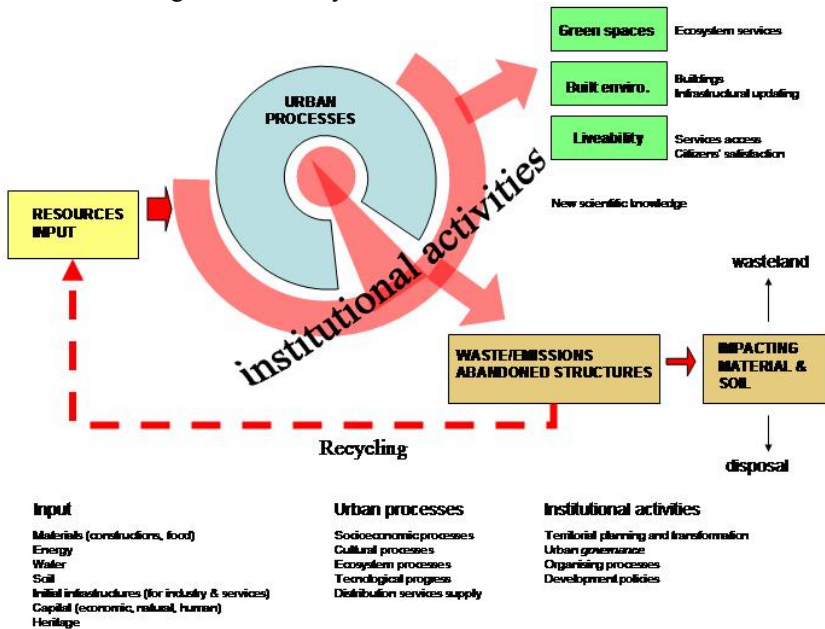


Figure 4: The New Urban Metabolic Model (NUMM).

It is in this area that urban processes are organised and regulated through institutional interaction.

Such a dynamic feeds two areas of output:

- one referred to material and intangible urban production;
- a second one referred to the production of waste/emissions and physical elements (soil and buildings), which are not used any longer and need to be disposed and/or requalified.

The first of these areas of output focuses on three different kinds of urban products: green areas, built environment and other elements that concur to the quality of life (as already stressed in the EMM and EUMM schemes). In addition to these elements, new scientific knowledge must be taken into account as an element that is central to technological progress.



The second area of output focuses on other interesting elements. Thanks to sound environmental policies carried out at institutional level, one fraction of the catabolite flow can be transformed into a positive cycle, hence feeding again the flow of inputs. The more considerable is this fraction of recycle, the more relevant is the degree of closure of the system. At the same time, as a matter of fact, is reduced the fraction that reaches the area of matter that needs to be disposed outside the city system. Again, the effectiveness of closure of the cycle resides largely at governance/institutional level. The latter has to be capable of developing a sphere conducive to the implementation of all the policies listed in the mentioned above paragraph.

The chart of the NUMM is represented in figure 4.

This model is, hence, strongly characterised by a focus on an explicit circularity and on the analysis of the institutional feedbacks within urban processes.

5 Conclusions

As it is conceived, NUMM is a metabolic model which integrates material flows with processes that take place at urban level. At the same time it has a strong focus on sustainable development principles and system feedbacks. Therefore, the NUMM can be a useful tool for the support of the decision making process carried out by the actors/institutions devoted to the development and management of urban areas.

The task of the local policy maker, referring again to the ecological view of the city object, must consist in the management of urban ecosystem that can insure the transformation of the linear flow natural resources/goods/waste into the circular and self regulated flow typical of a mature ecosystem. This practice will contribute to slow down the process of entropic decay of matter and energy. At the same time, such control process should not affect negatively the quality of life, on the contrary it should increase the liveability of the city itself.

The renewed metabolic model was tested on Homebush Bay area, home to the Sydney 2000 Olympic Games. Homebush Bay is located in an area that is well geographically limited (760 hectares), a mix of heterogeneous urban functions, ranging from housing to industrial and tertiary activities, including leisure and sports. It takes place in an area, which went through a very heavy process of functional and environmental retraining. The requalification was only possible thanks to the funding from the Olympic event [1]. The expectations of NSW Government regarding the replanning of the site, which is strategically located at the heart of the metropolitan area, and the amount of social, economic and environmental data gathered during the pre-Olympic and post-Olympic interventions, make Homebush Bay an area particularly suitable for a metabolic analysis.



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