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Case Study

The study of urban metabolism and its role in urban planning

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ABSTRACT: Cities are growing rapidly, 68% of the world population projected to live in urban areas by 2050, this rapid growing leads to rapid and continuous demand in resources as inputs to the urban system which creates an urgent need to deal with it as output as well. This complex, diverse and multi stakeholder's environment the city with conflicts among its ecological, economic and social aspects, is facing a common question which is how to achieve sustainability? New studies on sustainable urban planning call for a more integrated approach to answer this question the concept of urban metabolism (UM) has expanded from its biological under-standing to analyze the interrelations between the natural, human and built environment in cities, and how they interact with their hinterlands at various scales. The notion of urban metabolism has been employed in various disciplines and has recently started to influence urban planning and policy. This paper aims to examine how the UM concept can be integrated into urban planning by recognizing the most used methodology of UM analysis.at the end of research we compared different approaches of UM studies and criterias which were analyzed.

Keywords: Sustainability, urban metabolism, urban planning, UM, UM analysis

RUNNING TITLE: Urban metabolism and urban planning

INTRODUCTION

The time of the expression UM appeared

Urban metabolism started by Wolman (1965) as he used the concept of an "urban metabolism", Wolman regarded the city as analogous to an ecosystem, and defined how materials and energy flowed into the system, same as the path that organisms in an ecosystem consume resources such as sunlight and food. (Zhang, Y., 2013) In the other word, he tried to quantify per capita consumption of food, water, and fuel, and per capita generation of waste and air pollution, nonetheless, the UM concept only focuses on the linear processes of input and output flows in a city without knowing the back box inside. Later in 1990, Girardet revised the concept of Wolman's UM and focused on the cyclic flow without discussing the black box and in 2009, Zhang et al ,integrated the merits of previous concepts and proposed the network UM system to analyze the input, recycling, transformation, and output within a city; in other words, they looked inside the black box to inspect the interaction between components. In addition, the concept of network urban metabolism had already been applied in Beijing to acquire a complete evaluation of the

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city. (Tsenga, w., Chiueha, B., 2015). Then urban metabolism focuses on the sources and consumption of resources, and on their cycling within the system plus the emission, treatment, and recycling of wastes. You can find models of the processes that define urban metabolism in the following: (Zhang, Y., 2013).

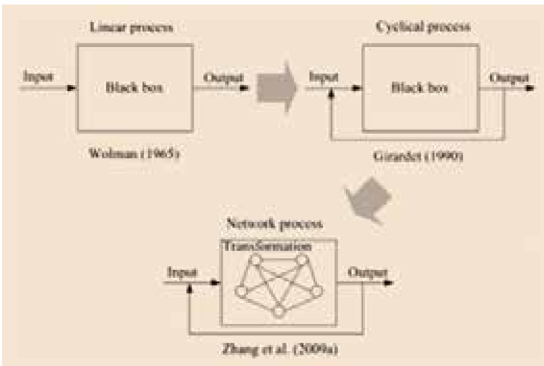

Fig 1: the evolution of models of the processes that define urban metabolism (Zhang, Y., 2013)

Following formative work in the 1970s, disappearance in the 1980s, and reemergence in the 1990s, a chronological review shows that the past decade has witnessed increasing interest in the study of urban metabolism. The concept conceived by Wolman (1965), is fundamental to developing sustainable cities and communities. It may be defined as "the sum total of the technical and socio-economic processes that occur in cities, resulting in growth, production of energy, and elimination of waste". (Kennedy C., et al., 2010)

The reasons of importance of UM:

The city is where important exchanges of resources happen, but where what is received from the environment differs greatly from what is returned to it. Energy, water, materials and food are received, yet other waste energy, wastewater, waste materials and organic waste are returned (Davis, M., et al., 2016). «Urban metabolism analysis has become an important tool for the study of urban ecosystems. The problems of large metabolic throughput, low metabolic efficiency, and disordered metabolic processes are a major cause of unhealthy urban systems. » (Zang, Y., 2013)

Cities are facing serious ecological and environmental problems as a result of being places of intensive human activities and again as a result of the rapid socioeconomic development. And this increase the question whether cities can be designed to simulate natural ecosystems and face their ecological and environmental problems? And we could achieve the goals of "Eco-city" or a "Low-Carbon city"? And if that is feasible, what are the methods used to make that viable? Exploring the urban ecosystem sustainability is becoming a key in global sustainable development. Urban metabolism is an effective analysis tool for the study of urban ecosystem. In continuing, how to evaluate the level of urban sustainable development and identify the key factors that affect urban metabolism is critical. Many studies on urban metabolism have been explored during the past half century, but few concerns about the key factors that affect urban metabolism. (Sun, et al., 2015)

It is necessary to mention that Anthropogenic activities have increased waste volumes dramatically, particularly in urban environments (Tsenga, W.L., Chiueha, P.T., 2015). Urban metabolism is loosely based on an analogy with the metabolism of organisms, although in other respects parallels can also be made between cities and ecosystems. Cities are similar to organisms in that they consume resources from their surroundings and excrete wastes. "Cities transform raw materials, fuel, and water into the built environment, human biomass and waste" (Decker et al., 2000) (Kennedy C., et al., 2010). «Nowadays, urban metabolism (UM) is believed to provide new insights for more sustainable resource management in cities and their hinterlands. UM studies, however, focalize chiefly on quantitative resource input and output (e.g. energy, materials) and tend to neglect the element of space and the qualitative characteristics of the urban landscape. » (Pistoni, R., Bonin S., 2017).

The increasing of urbanization and the concomitant problems of the depletion of fossil fuels, climate change, and increasing pollution in these days, has highlighted the need for more efficient and sustainable resource management. The awareness that the problems that we are facing today cannot be solved solely with technological solutions is becoming increasingly widespread. Meanwhile, the links between sustainable resource management and spatial planning have been recognized, and the fact that the spatial organization of cities and regions and their infrastructures influence resource management practices has been acknowledged. (Pistoni, R., Bonin S., 2017). «The resource challenge associated with anthropogenic forces gained attention in recent years. However, the pathways toward urban sustainability is complicated and depend on local conditions, which need an understanding of the characteristics of urban metabolism. » (CUI X, et al., 2019).

MATERIALS AND METHODS

In this study, we used literature review and library studies and for collecting information and tried to use all the analyzes in the discussion of urban metabolism that were different from the case studies in the analysis of information, especially in the field of different types of analysis methods in urban metabolism.

RESULTS AND DISCUSSION

In the next two decades, large areas will be converted into urban environments, a process that will include many transformations in economic activity, environmental health, and social justice. To tackle these complex problems, scholars use the metaphor of the "urban metabolism," describing an understanding of the interdependencies and dynamics of cities and the ecosystems they rely on. Research on urban metabolism has achieved important methodological advancements, such as descriptive analytical frameworks, decision-making models, and resource flow models. However, these contributions have rarely engaged with the transformational potential of designing sustainability solutions for socio-ecological dynamics (John B, 2019).

Within the next two decades 60% of the global population will live in cities. As a result, large areas will need to be converted to urban environments. Cities, which rely on enormous amounts of energy and resources, are increasingly dependent on surrounding ecosystems. Due to these immense inflows of resources, cities have become "barely sustainable but paradoxically resilient networks" that, in fact, degrade the capacity of Earth's life support system (Grimm et al., 2008; Rockstrom et al., 2009). To cope with these challenges, scholars have described the cities' resource and energy systems with the metaphor of "urban metabolism".(Johna, B.,2019)

«Massive consumption of resources and energy during urban development has put great pressure on the environment. To understand the urban metabolic processes that create this pressure and to identify the relationships among components of this metabolism are the keys to promoting sustainable urban development. » (LI Y., 2019). Cities create large benefits, as they are the main places for human social innovation and wealth creation, but the accelerating process of global urbanization has led to massive problems related to excessive resource consumption and environmental pollution. UN-DESA (2015) reported that the proportion of the world's population living in cities is about 54%, but cities consume around 75% of the world's natural resources and nearly 67% of its energy annually, inspite of occupying only 2–3% of the world's land area;

By analogy with an ecosystem or an organism, urban metabolism research attempts to synthesize all of the natural, technological, and socioeconomic processes that happen within an urban system, since this analysis can reveal disorders in these processes that as a conequence in excessive resource consumption and waste discharge (LI Y., 2019). «UM assessments are key to gearing urban sustainability strategies and policy toward optimized urban resource management » (Kennedyet al., 2011) (Perrotti,D.,2019).

Urban metabolism concerns the evaluation of how much urban ecosystems effect on (produce and consume) resources, this kind of assessment is now a critical perspective in understanding the manner in which city development affects local and regional environment. Research in urban metabolism is a new and ever-evolving area that encompasses a multidisciplinary field and moves toward a combined natural and social science (CUI X, et al., 2019).

What are the methods used to analyze UM?

Based on our analysis 2 methods are using very much comparison with other methods in urban planning subjects namely: Material Flow Analysis and Emergy (energy flow) Analysis. Material flow analysis begins with classification of the different material flows, and includes a balance sheet that accounts for all of these flows. If a sufficient quantity of reliable statistical data is available, the method allows researchers to monitor the flow of materials throughout their entire life cycle within the urban system. The national-wide MFA is a framework that includes material input, output, and stocks, where in data can be easily derived from the Eurostat empirical databases and national statistics. To be in exact the material flows in the urban system and understand the process of UM we have chosen a study (one of the articles) established a model of metabolism based on Material flow analysis.

This model of metabolism enables the systematic calculation of material input, output, and stock by determining flows through each part. In a given type of activities, the input side usually consists of local extraction (biomass, fossil energy, metal ores, and nonmetallic minerals), industrial products, material imports (biomass, fossil energy, metal ores, and non-metallic minerals), balancing items, and hidden flows. The output side is made of products (biomass products, agricultural products, and industrial products), pollutants (air pollutants, water pollutants, and solid pollutants), material exports, balancing items, and hidden flows.

The difference between input and output is the net increase of this part, denoted as system stock. As different parts vary in its material type on the input or output side (CUI X, et al., 2019). For calculation, the Law of Conservation of Mass is adopted as the analytical device: mass change of a system is equal to the difference between the mass output and input of the system. The theorem implies that.

$$\Delta S_t = I_t - O_t,$$

where DSt is the total change in mass of the system in a reference period of one year (denoted as t), It is the total mass input to the system in year t, and Ot is the total mass output from the system in the same year. It enables related material flow calculation. As balancing items always exist between material input and output in empirical analysis, the calculation needs further conversion as follows:

$$\Delta S_t = I_{mt} + D_t - E_{xt} - W_t + P_t,$$

where Imt is import mass from other areas in year t; Dt is biomass extraction mass in the study area in year t; Ext is material exported mass to other areas in year t;Wt is the emission of polluted material mass in year t; and Pt is the accumulation mass of dissipative loss and balance items in year t.

Besides the inner flows within the system, flows exist beyond the boundary, such as the trade (import and export) with other economies and the pollution to the natural environment. Given the rarity of statistics of the material flow between different cities, the location superiority principle is accepted when dealing with the import and export data.

This rule means that material flow is first regarded as being obtained from the local system. If the local extraction cannot satisfy the demand, then material imports are considered. The excess is considered as export when local extraction or industrial production exceeds the consumption and stock (CUI X, et al., 2019).

It is necessary to mention that for The material input in this model (biomass extraction, fossil energy, mineral resources, industrial products, and pollutants) can be directly or indirectly derived from the municipal statistical books. In the following you can find one of the example of material flow analysis that illustrated in Xuezhu CUI article (CUI X, et al., 2019).

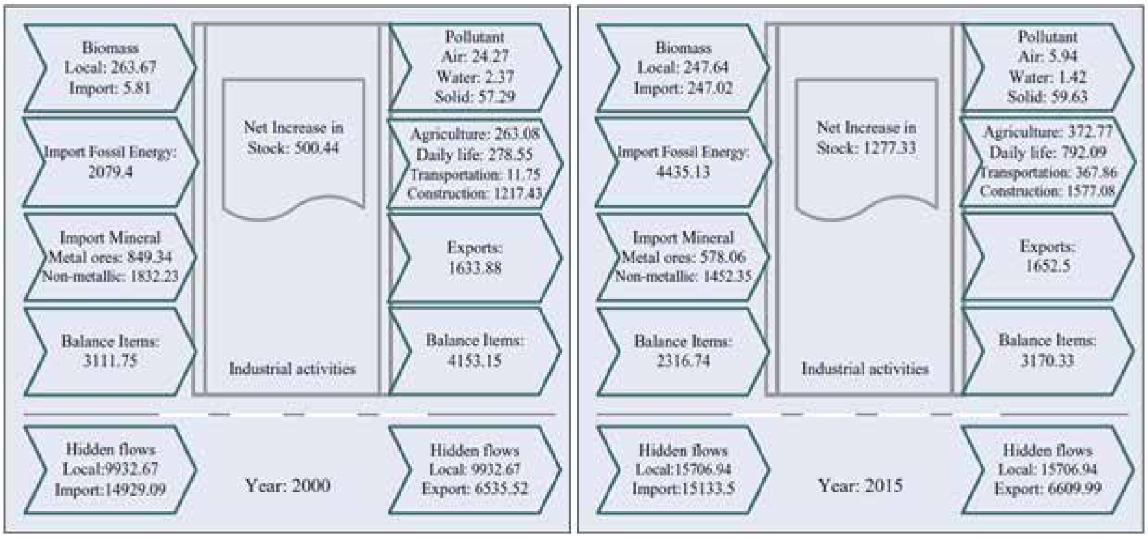

Fig 2: Material flows of industrial activities. Source 2: (CUI X, et al., 2019).

Emergy analysis is a methodology of systems analysis and quantitative assessment, which considers both the economic and ecological (including abiotic and biotic) aspects of a system by converting all inputs, flows, and outputs to the common denominator of solar energy, which is the basic energy behind all the processes of the biosphere. Abiotic sources are often referred to as environmental sources. An important matter in this analysis is that not all forms of energy are equal. The second law of thermodynamics states that all real processes, including processing of energy and storage of materials, imply a dispersion of part of the energy in the form of heat. Real world systems, natural and human alike, are organized in flows of energy of different qualities. The quality measure is the way energy is concentrated, e.g. solar energy is "concentrated" into chemically bound atoms of water, whereas carbon dioxide and nutrients are concentrated in sugar molecules. This concentration process has a cost, which is measured in solar radiation joules turned into heat (dispersed energy) joules. Odum recognized the implications of these different types of energy quality and introduced the concept and term of emergy (initially called 'embodied energy') to quantify the energy of a given type used directly and indirectly to make a product. The type of energy chosen as reference was solar energy, since it is basically the source of all flows in the biosphere.The solar emergy (or simply called emergy) of a product is, therefore, the solar energy needed, directly and indirectly, to make that product. Emergy is thus the counter concept of exergy (sometimes called burnable calories). (Pérez-Soba, M.,2019)

Energy language, energy modelling and hierarchical web to describe the flows of energy and matter in a system, a modelling language has been developed. Systems are made up of forces and energy pathways: the former are causal actions; the latter represent how and where these forces are directed. The symbols used in energy diagrams are summarized in Figure 5. The emergy concept was developed with hierarchical webs in mind (Figure 6). In these webs, the quantity of energy associated with each transformation decreases at each step in the process. Every transformation is accompanied by heat dispersion. In the energy diagram the productive units on the left produce goods and services for those on the right which return materials and control (= work and information, which are energies of high quality) to the left (also called positive or enhancing feedback). Energy is transformed from left to right and in each transformation the output has less energy (burnable calories) but the remaining energy is concentrated in some form (plant biomass, meat) of higher energy quality and controls other units of the system. In conclusion: to create the high-quality energy products on the right side in the diagram, a great amount of low-quality energy is necessary. The diagrams in Figure 6 show an energy hierarchy with step-wise convergence from left to right. (Pérez-Soba, M.,2019)

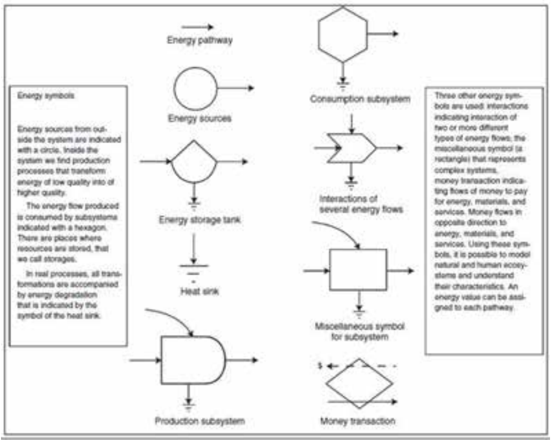

Fig 3: Symbols used in emergy analysis

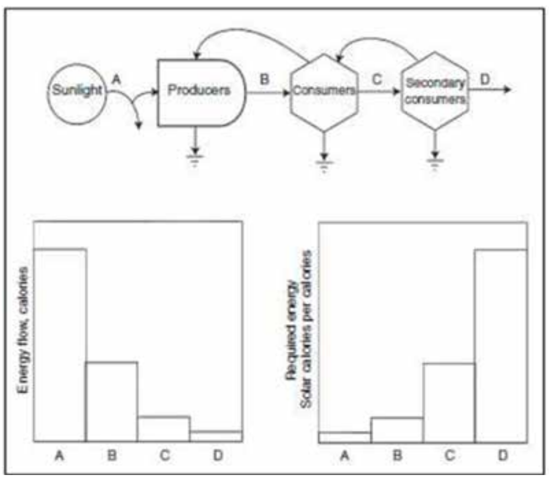

Fig 4: Hierarchical webs and energy flows. Source 4:Ridolfi and Bastianoni (2008).

Emergy analysis is useful to check applications of Herman Daly's first rule of sustainable development, 'the sustainable yield principle', that states that resources should be exploited at a rate compatible with their replacement by nature (Daly, 1990). It can be used to define guidelines for consumption of resources compatible with their formation times. Emergy can therefore be used to define guidelines for consumption of resources compatible with their formation times. Emergy can be used to estimate the solar energy necessary to sustain a system; the greater the total emergy flow necessary for obtaining a product, the greater the consumption of solar energy necessary for its re-formation once it has been used, and thus the greater the past and the present environmental cost to maintain it. The intensive use of the services and products of an ecosystem can degrade its structures and functions, decreasing the capacity of the ecosystem to self-organize efficiently. In order to facilitate the measurement of a system's sustainability, some emergy indicators were introduced. The diagram in Figure shows them. Emergy flows to the system are divided into the main categories as given in the following: ● local renewable resources (R); ● local non-renewable resources (N); ● feedback (F): purchased resources and services from outside system; and ● the total output of the system, called yield (Y) = (F+R+N). (Pérez-Soba, M.,2019).

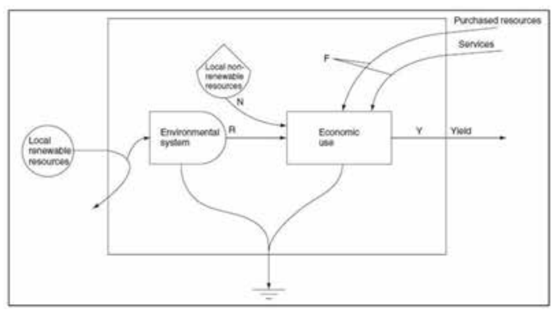

Fig 5: Emergy system diagram of a generic system.. Source 4:Ridolfi and Bastianoni (2008).

These flows can be combined to obtain a set of indicators. The two most common indicators are defined below and will be calculated in this study for the different cropping systems examined in this study. ● Emergy Yield Ratio (EYR) is the ratio of the output of a system (Y) to the external inputs (feedback) from outside (F): EYR = Y/F. Therefore, it is the ratio of total emergy of the yield to the purchased (economic) inputs. Considering that the total emergy is the sum of all local and external emergy inputs, the higher the ratio, the higher is the relative contribution of the local sources of emergy to the system. This index therefore shows the ability of a system to use the available local resources. ● The Emergy Investment Ratio (EIR) is the ratio of external inputs (purchased, feedback) to local resources (renewable and otherwise): EIR = F/(R + N). It measures how much a system depends on the outside rather than on local resources, and how much a system or process uses invested emergy in comparison with alternatives.

In emergy accounting, the largest of all the related environmental or renewable solar based inputs -such as solar energy, rainfall, wind and evaporation- is used in the calculations of the indicators, to avoid double counting, because all the climatological renewable energy flows are by-products of coupled processes. (Pérez-Soba, M.,2019)

How can we apply these methods?

Kennedy et al. (2007) described urban metabolism as the new technology, changing industry and growing population that happens in the city, accompanied by economic growth, material accumulation or storage, energy consumption, and disposal of waste. (CUI X, et al., 2019) other scientist defined Um as a cycle of natural resources and environmental system that you can see in the diagram below and by knowing them and apply these methods world can reach to urban metabolism.

One of the road maps for the evaluation of urban metabolism based on studies:

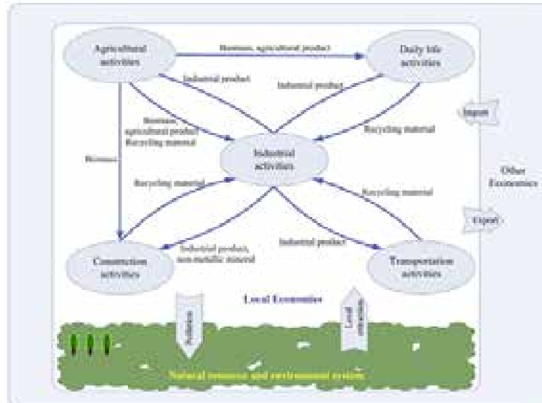

Fig 6: A model of metabolism and its inner material flow. Source 6: (CUI X, et al., 2019)

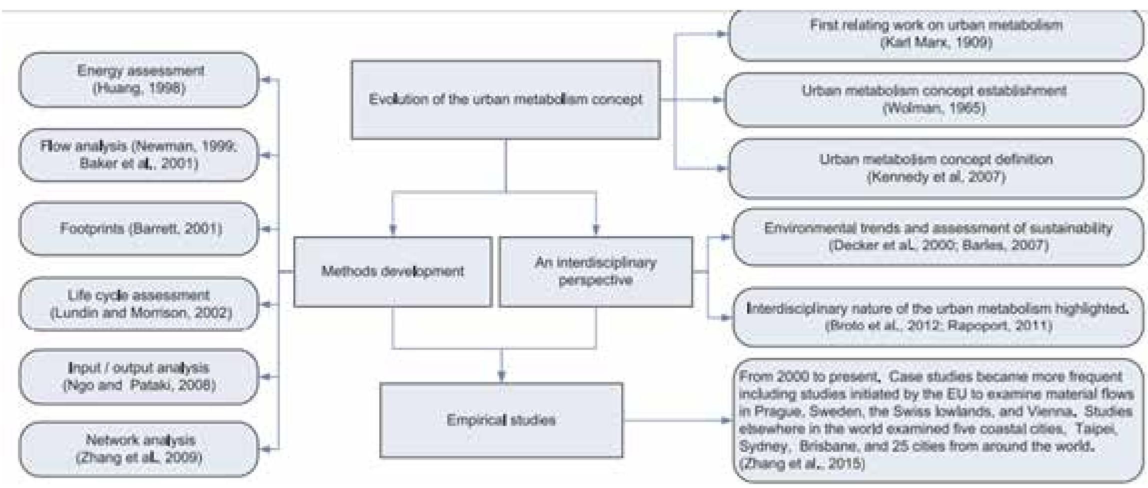

Fig : Roadmap for the evolution of UM studies. Source 7: (CUI X., 2018).

•Accounting and assessment:

Urban metabolism approach has been widely adopted as a framework because it provides an effective way to gain information on energy efficiency, recycling of materials, waste management, and the infrastructure characteristics of an urban system. It is also important to quantify the inputs of water, food, energy as well as outputs and wastes to determine the scale and potential extent of recycling through the urban system.

The most important challenges to material flow analysis and energy flow analysis are that the sustainability of a system cannot be judged, and this sustainability can only be evaluated based on a horizontal comparison of different spatial units and a vertical comparison of different times. Therefore, the inability to judge the degree of sustainability (high or low) and assess the changes (increase or decrease) in sustainability is an important deficiency of material flow analysis and energy flow analysis compared with alternatives such as the ecological footprint method that can be used to evaluate the ecological sustainability of a system. As a comparison the main accounting method as shown in the table:

Table 1
Comparison of the main accounting methods.

Method	Merits	Drawbacks
Material flow analysis	Measuring the inflows and outflows of a city's materials is an effective way to support resource and environmental management. Tracking hidden material flows can be used to improve the description of the pressures on the environment.	Adding the weight of different materials directly increases the substitution of resources, and ignores the quality differences among materials. Ignoring the important role of energy flows is a crucial omission because these flows drive all material flows throughout the urban metabolic process. This approach is unable to judge the degree of sustainability and the changes in sustainability.
Emergy (energy flow) analysis	This method ensures that the energy that underlies the creation and flow of all materials is accounted for along with the materials, and accounts for differences in the quality of the materials and energy.	Appropriate energy transformation rates must be determined for all flows, and the methods of accounting for wastes have not been unified.
Ecological footprint analysis	Combining the socioeconomic development demands with the ecological environment's supply capacity lets researchers determine the ecological deficit or surplus. This can help to reflect the complementary relationship between natural capital and socioeconomic development, and can reveal ecologically unsustainable situations.	The use of a single land function neglects other potentially important functions and the functional diversity of the land (i.e., its ability to provide multiple services). In addition, the selection criteria for the ecological supply area have not been unified, and the method relies on an incomplete description of the resources provided by the natural system and the wastes eliminated by the natural system, thereby underestimating the magnitude of the human impacts.

indicators Study of the urban metabolism is an integral part of State of the Environment (SOE) reporting and provides measures that are indicative of a city's sustainability. The parameters of the urban metabolism generally meet the criteria for good sustainability indicators, they are: scientifically valid (based on principles of conservation of energy and mass), representative, responsive, relevant to urban planners and dwellers, based on data that is comparable over time, understandable and unambiguous. The main objectives of SOE reporting are to analyze and describe environmental conditions and trends of significance and to serve as a precursor to the policymaking process.

•Dynamic mathematical models for policy analysis:

While most researchers have primarily used the urban metabolism as the basis of an accounting framework, others have begun to develop mathematical models of processes within the urban metabolism. Such mathematical models have mainly been developed by the MFA community, usually to study specific substances e metals or nutrients in the urban or regional metabolism. Example model platforms include SIMBOX and STAN, these models include representation of sub-processes, stocks and flows within the metabolism, sometimes linked to economic input/output models. While the models are useful for determining present material stock and flows, they can also be used to simulate future changes to the urban metabolism as a result of technological interventions or policies. The models are particularly useful for identifying solutions to environmental issues beyond "end of pipe" approaches.

•Design tools:

The potential to use the concept of urban metabolism in an urban design context is a relatively new development. Fernandez and students in MIT's School of Architecture have used the perspective of urban metabolism in considering redesign of New Orleans, while students in Civil Engineering at the University of Toronto study the urban metabolism in order to design infrastructure for sustainable cities. (Kennedy, C., 2010)

The impacts of UM:

How does it affect the surroundings and urban planning?

The concept of urban metabolism sees cities as living organisms. It refers to physiological processes producing all substances and energy needed to sustain life, but translating this idea into urban settings. As it happens in nature, cities require resources and products such as food, water and energy to live, in fact, most of the resources on Earth are used for supplying urban areas. Urban metabolism provides a holistic framework for analyzing all inflows and outflows with the surrounding biophysical environment.

Urban Metabolism has many impacts on the urban system in general, whereas the Urban systems have been widely investigated by means of several different economic and biophysical approaches. Which we can notice it by the performance of indicators for cities, regions and nations have been developed, based on well-known assessment methods, sometimes integrated into a specific toolkit: embodied energy, material flow analysis (MFA), life-cycle analysis (LCA), CO2 emissions, cost/benefit and economic returns. These indicators individually or in combination do not necessarily provide a fully adequate characterization of an urban system environmental integrity and resource use. Therefore, it is fundamental to discuss and to deeper understand the complexity of future city development and management, going much beyond the linear and mono-dimensional approach of just measuring a city population or energy consumption or GDP.

Through the notions of flow and circulation, the concept of urban metabolism (as we defined or mentioned) links material flows with ecological and social processes, and the potential for change to sustainable patterns of consumption and production. Therefore, UM should be understood in the context of a (stocks and) flow model. Within this flow perspective on cities, we need to understand the drivers that affect the flows – and vice versa – to better understand the UM.

This starts with the socio-demographics (e.g. gender, age, household type, income, educational level and ethnicity) and their impact on lifestyles which can be expressed in terms of activities and travel patterns, use of ICTs, consumption patterns and residential choices. And affected by the social behavior and individual preferences are deeply affected by competition for available resources, space, opportunities. It is impossible to have an educated next generation without investing into education, impossible to enjoy healthy food without investing resources in cleaner production, impossible to have a stable and happy community without ensuring equitable access to basic resources. As a consequence, appropriate and fair resource management is likely to affect (and be affected by) education, democracy, stability, sense of belonging, balanced interaction with surrounding areas and populations.

This also can be followed by the built environment attributes (e.g. density, diversity and design of urban functions and infrastructures) and interaction with urban microclimates (e.g. urban heat island effect and air quality).

We have to notice the political aspect which is linking urban metabolism to policy strategies it is necessary in order to measure and change urban sustainability performances, developing interdisciplinary practice of urban metabolism.

Finally, socio-cultural drivers (e.g. prevailing views on openness, sharing, equity, responsibility and accountability) are affecting mobility and migration flows, networking, and other (urban) activities. These factors closely connect to macro developments in culture, economy, infrastructure, technology, environment, and climate.

This demonstrates how all factors affecting the UM are connected, and the concept of UM is how it affects the surrounding by it is assessment methods which drives it from the recourses and affected by it is indicators. This is what we need to develop an integrated view and vision to better understand UM and ways to shape UM within sustainable development paths which heading towards 3 basic approaches goals: economic, social, environmental.

Resource use and impacts:

We have two types of resources, it is important to distinguish between direct resource use, which is not assessed on a life cycle basis, and indirect (or embedded or embodied) resource use, which is assessed on a life cycle basis. For both sides the environmental approach or to the health care approach, most of the paper sheets studied the environmental aspect and environmental impacts(direct/indirect). Direct resource use and emissions occur within the geographical boundary of the area under consideration (a city in this case), whereas indirect resource use and associated emissions occur in the supply chain and therefore may arise within the urban area or anywhere else in the world. Although direct resource use (and associated emissions) can be useful when considering urban metabolisms, the life cycle approach gives a more complete picture.

A whole life cycle approach would additionally take into account the direct emissions and resource use. If we take the case study of "social urban metabolism strategies (SUMS) for cities" which consider the organic waste as a direct resource to produce from it the biogas ,and use it as electricity which is a final result or product, so we can consider the transportation that transport the organic waste(solid waste) which is collected from the city to transformation stations then to landfills as indirect resource.

Approaches to assessing resource use and emissions:

According to the consumption perspective, material flows, energy use and the associated emissions are attributed to final consumers, regardless of the location where the emissions arise. In other words, in the consumption perspective we take account of material flows, energy use, and the associated emissions embedded in imports into the city, but exclude those embedded in exports. Conversely, in the production perspective we take account of material flows, energy use, and the associated emissions embedded in exports and exclude those embedded in imports into the city. The consumption perspective is a great deal more complex and requires considerably more data than production accounting.1.3.1.3. Theory for Measuring Urban Material and Energy Flows:

As we mentioned before the 3 approaches that UM tried to affect and manage, we have to notice the amount of this impact by the theory of measuring. This contains a number of urban metabolism frameworks and models to assist with measuring urban-scale material and energy flows. "Baynes and Wiedmann (2012) present a robust set of approaches often used in urban metabolism, such as transboundary foot printing, input-output consumption-based approaches, and complex systems science. One additional approach is a network-oriented method termed "ecological network analysis," or ENA, which presents a set of strong tools for examining structure and function of ecosystem flows." (Elmqvist T, Xuemei Bai X, Niki Frantzeskaki N, 2018) ENA is a variant of economic input-output analysis. ENA has been used to model various metabolic flows, including energy, carbon, water, and others, in a range of cities. The most notable benefit of the network approach is that it can provide information about relationships between urban sectors in a holistic way, in which both direct and indirect (remote) interactions can be captured.

Increasingly, current research has been striving for urban metabolism data that includes both in-boundary activities and out-of-boundary (or life cycle) impacts. Input-output models and life cycle analysis have been utilized to include activities that occur "upstream" and "downstream" of the city in the framework of urban metabolism. With their embodied material and energy inputs for urban growth, they are both capable of assessing the footprints of cities. Recent work integrating input-output and life cycle data with ENA "ecological network analysis," is promising for assessing and regulating urban sectors to mitigate resource overuse and unintended emissions. Novel integrations could assist metabolic understanding of cities.

Future theoretical frameworks can consider integrating multiple metabolic lenses into understanding the complexities of cities. For example, considering the multiple possibilities for parceling cities into territorial, production, and consumption footprints can help us gain a stronger appreciation for the metabolisms of cities and the relevant approaches for maximizing their respective material and energy flows.

Efficient, Sustainable, and Resilient Metabolisms:

Creating efficient, sustainable, and resilient metabolism models, while challenging, is imperative in our rapidly expanding and urbanized world. Resource use is increasing, many production systems are peaking, and the consumption and demand for goods and services are at unprecedented highs. Methods and principles of industrial ecology, such as those mentioned in Section 3.3 (material and energy flow analysis and life cycle foot printing), as well as others (dematerialization, recyclability, urban industrial symbiosis, and so forth), can become the cornerstones for assisting the range of stakeholders who are integrating and implementing three vital characteristics – efficiency, sustainability, and resilience – into community metabolisms. While sometimes perceived as interchangeable, these three attributes are unique in the following ways:

- Efficiency concerns the quantity of inputs to produce an output. Typically, an efficient metabolism is characterized by relatively low levels of material use and energy flows to achieve a standard level of output. Examples of key indicators for measuring and tracking efficiency in community metabolisms are electricity per economic or sector output, energy per sector output, or material inputs per waste generation.

- Sustainability in urban metabolism addresses the impacts associated with the material and energy flows of a particular system. Sustainability can be measured via environmental (such as CO_2 per sector or CO_2 per GDP), economic (such as income, energy use, and energy-use intensity), and social (such as education and public health) indicators.

- Resilience of metabolism relates to the capacity of a particular flow, or to the entire metabolism, for recovery after a disruption. While linkages between metabolism and resilience are ripe for new lines of inquiry, their coupling with disciplinary extensions can yield a practical suite of options for metabolisms to absorb or mitigate against shocks. Industrial ecology – and, specifically, supply-chain analysis – has the potential to reveal key areas of material substitutability, helping inform alternate material uses should system disruptions occur. Example of key indicators of resilience may include metrics for diversity, alternatives among inputs, and measuring impacts from shocks.

What are the issues and limits facing UM?

Urban metabolism has many approaches and different sights, each of them is heading towards a certain direction and has it is own methodology, and therefore it has also it is own issues and limits which depends on the approach and the methodology, most of them goes towards the economic, social, environmental directions. According to the case studies that we studied, we conclude some limits and issues that faced those countries which was applied UM:

•Data Base & the resources

"Resource metabolism affects and is affected by the way urban communities self-organize and make decisions, consume and save, degrade and recycle resources, share community services, design, and use infrastructures" (Sergio Ulgiati1,2 and Amalia Zucaro3). Nevertheless, the community aspect and management of resource metabolism are still poorly explored. The challenges that they faced in data base and resources:

1.The limitation of data availability and the quality and proficiency.

2.More work is needed to accurately quantify the information, accurate information and tracking methods must be developed

3.database and reported official statistic includes two gaps:

•a reliable material flow methodological framework to ensure data availability

•the related inner-flows of the urban system with potential policy implication for sustainable development.

4.differences in the material utilization characteristics.

5. collecting data.

6. Gaps in Knowledge between relative concept to urban metabolism.

7.Commitment to established boundaries -structure of statistical records does not included at a city level.

8.absent of recent data.

Therefore, it is very difficult due to the complicity of assessing the resource metabolism of an urban system, becomes increasingly crucial, not only concerning the relation with the environment as a source or a sink, but also concerning the internal dynamics of resource exchange among city components and sectors as well as competition among cities for scarce resources.

•Practical application

An important topic must be consider that is the way urban systems relate to the surrounding rural areas and wilderness, respect them, help them develop and keep their integrity patterns, this depends on how they using the resources and the availability materials and find the suitable method to be tapped in a good way.

1.The production of biogas from household residual waste does not include all the support services for the operation of the plant, such as:

• Waste collection and sorting services. First point

• Removal distribution and sales of fertilizer by-product.

2.More outputs were obtained with fewer inputs.

•Unplanned growth of the territory due to illegal land occupation

•the lack of legislation that properly includes ecological services into account,

•the focus on palliative solutions instead of long-term planning

•budget limitations.

3.The city is not capable of producing everything it consumes, and does not have the adequate amount of space to dispose its waste.

4. contributions to sustainability is necessary, instead of merely judging whether one specific city is sustainable.

Monitoring resource inflows and outflows and understanding how they relate to population, resource availability, and environmental carrying capacity is crucial for aware and concerned urban sustainability policies and governance. “Reorganizing cities’ structures linking biophysical aspects with social, well-being community aspects, is a priority challenge in policy making worldwide.” (Ulgiaty, 2019).

We have to consider and notice about de-growth of assets, population and consumption, but this was very much limited to quantitative de-growth, without exploring still possible patterns of qualitative growth, in terms of job quality, safety, community interaction, sharing, happiness, fair access to resources at all levels and participatory processes. This is likely the most difficult but also the most crucial aspect of sustainability and stability of cities. An urban integrative governance, through appropriate management and environmental assessment of the benefits and trade-offs with regard to development planning, infrastructure spatial planning as well as corresponding auxiliary intervention, becomes fundamental .Instead of merely addressing urban development and eco-environmental preservation, “city planners should always be conscious of sustainability aspects related to the quality and typology of metabolism” (Ulgiaty, 2019) . The problem is not to maximize or ensure huge energy supply or the largest possible amount and variety of food or the fastest possible transport, but instead to optimize at all levels the access of the entire urban population to services, goods, education, leisure, health services, environmental quality to a sufficient extent to ensure quality of life, stability, fairness, and respect.

To influence urban metabolism, we need to have a better understanding of the relations between societies, environment, mass and energy flows (production and consumption) without underestimating the population growth factor. Well-being, not wealth or affluence, is going to be the keyword for the future of cities, namely an aware and balanced relation of a city population with surrounding environment, resources, other species, in order to promote fair and equitable access to social, cultural, economic, health improvements not necessarily linked to increase per-capita resource consumption.

CONCLUSION.

After we present our case studies that we studied, we conclude by the table below some criteria that is crossed together, and how those criteria affected our overview of the similarities and the differences between the cases by rating or weighting them or putting them as an informative way.

Criteria	Case 1	Case 2	Case 3	Case 4
For how instance did the case apply sustainability?	●●●●●	●●●○○	●●●○○	●●●●●
Did the case study took into account the environment? For how instance?	●●●●●	●●●●●	●●●○○	●●●●●
For how instance did the case study took into account the social aspects ?	●●●●○	●●○○○	●●●●○	●●●○○
For how instance did the case study took into account the economic party?	●●●●○	●●●○○	●●●●●	●●●○○
Was the approach talking about energetic party? For how instance?	●●●○○	●●●●●	●●●●●	●●●●○
Was the case study a top-down method? For how instance?	●●●○○	○○○○●	○○●●●	○●●●●
Was the case study a bottom-up method? For how instance?	●●●●○	●○○○○	●●●●○	●●○○○
Were the objectives of the case study clear?	●●●●○	●○○○○	●●●●●	●●●●●
Was the criteria of the case study's objectives clear?	●●●○○	●○○○○	●●●●●	●●●●●
For how instance did the case study give future scenarios?	●●●●●	●○○○○	●●●○○	●●●●●
For how instance did the case study give alternatives?	●●●○○	●○○○○	●●●●○	●●●●●
Were the policies clear?	●●●●○	●●●○○	●●●○○	●●●●○
Were the practices clear?	●●●●○	●○○○○	●●●●○	●●●●●
How much was the case study comprehensive?	●●●●○	●●○○○	●●●●●	●●●○○
For how much was the case study improving for the knowledge?	●●●●●	●●●●○	●●●●●	●●●○○

Was the case study informative? For how instance?	●●●●○	●●●●○	●●●●○	●●●●●
Was the case study practical? For how instance?	●●●○○	●○○○○	●●●●○	●●●●○
For how much was the case more like an evidence-based design or tool that can be used?	●○○○○	○○●●●	●●●●●	○●●●●
Was the case study improving for the knowledge of decision-makers? For how instance?	●●●●○	●●○○○	●●●●○	●●●●●
For how much did the case study's interventions impacted the surrounding environment?	●●●○○	●●○○○	●●●●●	●●●●○
How much were the impacts of the case study positive?	●●●●○	●●●●○	●●●●○	●●●●○
How much were the impacts of the case study negative?	●○○○○	●○○○○	●○○○○	●○○○○
For how much was the case study an-economic-situation-changing?	●●●●○	●●○○○	●●●●●	●●○○○
For how much did the case study create job opportunities?	●●●●○	○○○○○	●●●●○	●●○○○
For how much did the case study affected social-equity positively?	●●●○○	○○○○○	●○○○○	●○○○○
For how much did the case study affected social-equity negatively?	●○○○○	○○○○○	●●●○○	●○○○○
Were the solutions afforded environmental-friendly?	●●●●○	●●●●●	●●●○○	●●●●●
For how instance did they reach the objectives?	●●●●○	●●●○○	●●●●○	●●●●○
Was the case's methods applied to different localities?	●○○○○	●●●○○	●●●●●	●●●●●

As we have argued in the previous part, the four case studies analyzed and overviewed, In the table have been shown many similarities and differences between them.

To sum up the studies of cases, we conclude and summarize the information that we reach during the process of research and we found that, the environmental issues were the main concern of all the case studies, this manner is the most important dimension to achieve sustainable development and conserve the resources and energy efficiency and it shows the move into environmental friendly subjects that has been illustrated in the table and above all these matters prepare the ground to reach UM objectives. All the cases intersect in some sectors like:(energy, water, emissions, gas). Plus, Whole the cases have a positive effect as a result of urban metabolism analysis. Notably the case study of Paris has many differences from the others, this matter happens because of the mathematical and theorical way of methods, although all the cases going through the top-down method in their policies, the case of Paris has a different method from them. To be more precious about the significant points, we have:

-Case 4 and case 3 had a similar point of creating a plat form tool which is considered

-Case 1, 2 and 4 had focused on the same approaches which talking about the environmental issues.

-Case 3 and 4 have include policies and practices in the other hand case 2 focused on theorical process.

-Case 1, 2 and 3 have upcycling method for recycling the materials.

-Social and economic aspects are not the factors to ignore in all the cases.

-Cases1,3 and 4 had comprehensive view on specific perspective that enhance the knowledge in this ground.

-We faced to economic-situation changing in cases1 and 3 and as a result of that increasing job opportunity.

The main objective of this research was to search about urban metabolism and knowing about approaches, perspective and criteria to have better vision about this subject and then go through the case studies to know more about experiences that have been applying this subject with different method for having better understanding and in general to have better urban environment to live.

A highly recommended study that could be looked at in the future would be the extent of the use urban metabolism to reaching sustainability in all dimensions like environmental, economy, social matters.

As it has been shown before, one of the finding(BRIDGE DSS project)based on our case studies was about creating a new model by using Multi-Criteria Analysis (MCA) approach based on sustainability objectives and associated indicators addressing specific aspects of urban metabolism for end users like urban planners and architecture and one of the result of this research was inventing a new software that use DSS the outlined methodology, data and models combined into a structured geo-database (ArcGIS).As a result it cannot propose the exact and certain result or ranking based on data and comparison with other decision making model so Future research should further develop and enhance certainly in cases .

Also, if we focus at the most urban metabolic case studies, we will find that many of them use mathematical and theorical methods in their methodologies, data, and equations, without actually applying them, then we can’t relate the results and know how much they affect the surroundings. So, the future proposal for new researchers would be put the light on the practical methods that helping UM achieving its main objectives.

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