

The sustainability of the informal city: An urban metabolism approach

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Abstract. This presentation explores urban sustainability by focusing on the informal city. Cities are responsible for 75% of the global resource consumption and urbanisation is a defining feature of our society. In many world cities urbanisation takes place in the context of informality; as a result infrastructure construction and environmental policies have to understand informal practices and their role in shaping urban sustainability. The informal economy in particular plays a crucial role in managing urban infrastructure and delivering urban services (such as waste management or transport). We propose to analyse the contribution of the informal city to urban sustainability through the lens of urban metabolism (the study of flows of resources and materials through the city). We present an urban metabolism framework that allows for an in-depth analysis of urban informal practices and their contribution to sustainability.

1 Introduction: What does it take to build sustainable cities in a socially just manner?

Urbanisation, a multi-dimensional process of urban change with spatial, demographic and cultural implications, is one of the means through which humanity is transforming the Earth's surface. Since 2010 more people live in cities than in rural areas and it is estimated that by 2050 the number of urban dwellers could rise to 66% of the total global population (United Nations, Department of Economic and Social Affairs, 2014). Cities shape both our contemporary society and society's relationship with its environment. The rate of urbanisation is increasing along with the size of the global population, concentrating particularly in Asia and Africa; this means the demands on infrastructure and resources are constantly expanding. It is estimated that "60 per cent of the built environment required to accommodate the earth's urban population by 2050 remains to be built" (UNEP, 2013). The influx of new urban dwellers to cities has to be met with an adequate provision of urban services (education, health), infrastructure (housing, public transport, waste collection) and jobs. How this infrastructure is built and the services provided will define how the city relates to the natural environment on the long term.

As cities concentrate population and productive activities, they also concentrate around three quarters of the global natural resources consumption and environmental impacts (such as greenhouse gas emissions) (UNEP, 2013). This poses a challenge not only in terms of resource scarcity at the global scale, but also for issues of resource distribution and social equity. The idea of 'just sustainabilities' supports an encompassing framework to

think about how to build fairer communities within the limits of the Earth and the expression of those limits at the local level (Agyeman, Bullard, & Evans, 2003). In a 'just sustainabilities' perspective, environmental quality (the concern for sustainability) and social equity (concern for environmental justice) are inextricably linked and have to be understood as a common set of problems and solutions that manifest at different scales, from local to global. This is an idea that has taken hold of planners as a means to move beyond growth paradigms in urban planning (Rydin, 2013).

Thinking about just sustainabilities requires thinking about how to achieve a fair distribution of environmental goods amongst urban dwellers. Access to land, water, and sanitation has been identified as a key condition for human health and well-being, and forms part of the targets of the Millennium Development Goals (UN Habitat, 2009; United Nations, 2014). However, there are still issues around the fair distribution of these environmental goods. For example, access to drinking water was declared a human right in 2010 by the United Nations and yet, the private sector is responsible for water distribution in many cities, or in parts of them, transforming water into a commodity (Bakker, 2007; Harris & Roa-García, 2013; Miroso & Harris, 2012). In Bangalore, for example, the poorest people with precarious access to housing need to provide themselves water in private markets often at exorbitant prices, much higher than those paid by middle classes in the same city (Ranganathan, Kamath, & Baindur, 2009). Access to water resources, as in this example, raises issues of environmental justice amongst urban dwellers and fairness in terms of access to resources.

In the city's direct surroundings (the 'hinterland'), there is a concern both in terms of access to environmental goods (as the city sucks in resources, the nearby rural areas can be left without the water or biomass necessary for their own development), and of management of environmental burdens. The city's pollution (to the air and water) and production of waste are often felt outside the city, in the peri-urban and rural surrounding areas. Cities' disposal of waste outside of their administrative boundaries can be referred to as environmental dumping, and is an example of an unfair distribution of environmental burdens. Exchanges between the city and its hinterland should also be governed in an environmentally just way, ensuring that the transfer of environmental assets is accompanied by adequate compensations (Haughton, 1999).

One key issue is to recognise the city as it is experienced by urban dwellers, with the difficulties and opportunities that cities offer for sustaining our livelihoods and providing for our wellbeing. There is a need to recognise not an ideal city of maps and statistics, but the material city in which people live every day. From this perspective, urbanisation cannot be understood without a focus on the informal city. Informality refers to patterns of spatial organisation, social relations and economic exchanges and it emerges in a variety of settings, from rapidly sprawling cities in South East Asia to cities in which urbanisation reflects the growing influence of global markets in Africa. We refer to informality as the provision of urban services (housing, employment, and infrastructure among others) that takes place outside of government regulatory frameworks, public interventions and taxation systems (UN Habitat, 2009, p.133). Informality is what is outside of the law; as such,

it has always existed and in many different contexts. In the context of this work however, we refer to the provision of urban goods and services that emerges from the bottom up, and as a response, at least to some extent, to the failure of the government to provide these services for the existing and new population of their cities (Altrock, 2012; Portes, Castells, & Benton, 1989). Informality is crucial not just because it represents an important share of the existing and future urban economy of many world cities, but also because it relates to the myriad of ways in which citizens go about their everyday lives. Indeed, informality is an integrant aspect of how cities function; yet there is little research on informal processes and how they mediate the city's relation with its natural environment. It is thus essential to carry out research in order to understand the co-dependency between informal processes and the flow of materials through the urban infrastructure.

This book chapter proposes urban metabolism as a conceptual framework to undertake the analysis of the linkages between the city and the environment through informal processes. Urban metabolism refers to a compendium of approaches in industrial ecology, social ecology and political ecology which attempt to understand how social-ecological relations are manifested in the resource transferences that take place between the city and the natural environment. Urban metabolism approaches engage with ecological transformations and their relations to the flows of natural resources and materials through the urban system that enable its economic and social reproduction. Here we believe that there is a great potential for urban metabolism to be applied as a planning tool with the normative objective to achieve just sustainabilities. Particularly, we regard urban metabolism as a tool that enables the analysis of environmental limits within a city and in relation to the resource transfers that take place between the city and its hinterland. However, current methodologies of urban metabolism are not designed to look at the informal city: by relying on official statistics and reports, they ignore all those activities and material flows that are not monitored by the state (through, for instance, a taxation system). Thus in this chapter, we advocate for urban metabolism analyses that recognise the vibrancy of informal settlements and their importance in the making of the modern city. These approaches are in their infancy, although there is considerable optimism about the opportunities that urban metabolic analysis opens for more sustainable and more just cities (Castán Broto, Allen, & Rapoport, 2012; Newell & Cousins, 2015). In this chapter we offer some proposals about an urban metabolic analysis that does not ignore but engages explicitly with urban informality. We thus explore what 'informality' means in our cities today in the first section; the potential and the limitations of urban metabolism to address this in the second; and some methodological proposals in the discussion part of the chapter.

1. Defining urban informality

We aim to develop a perspective on natural resource management that is informed, in the first place, by an analysis of the city that actually exists. Such

truism is needed because ideas of urban sustainability and eco-cities are often informed by visions of ideal cities (most often western cities) and driven by neoliberal objectives of large-scale technological investments, which do not reflect the complex realities of life in cities around the world, nor the challenges and opportunities specific to cities of the global south (Caprotti, 2014; Joss, Cowley, & Tomozeiu, 2013; Rana, 2009). In particular, we are interested in a city that is thought of as being invisible, the informal city, and nevertheless being in constant display as we go around our daily businesses. Sustainability research methods such as urban metabolism, however, have hardly accounted for informal processes in the urban system. To start bringing the informal city into urban metabolism we are first looking to situate the notion of informality in relation to the history of the concept and how it has influenced the management of urban environments; and second, to question some key informality myths that obscure our understanding of this urban phenomenon.

1.1 The informal city

Urban informality is a key part of contemporary urbanisation narratives. Informality most often describes the practices and activities that take place in the city in response to everyday necessities of urban dwellers and that emerge from the bottom-up, rather than emerging within a legal or institutional framework, or planned by the government. The term is applied in the case of housing, the economy, and service provision. Informal housing refers to the houses that are built by their future occupants without input from planning agencies, sometimes on land that is not legally owned and deprived of basic services (electricity, water and sewage). The informal economy refers to productive activities that are not regulated by the state, which includes subsistence activities as well as more organised informal service provision (such as waste collection or public transport).

In the global south, informality is a defining characteristic of urbanisation and urban life. Auto-construction is a major urbanisation pattern, which is in many cases an informal process. A report on affordable housing in Latin America and the Caribbean (LAC) states that “a majority of households in LAC address their housing needs outside the formal sector and without reliance on mechanisms of the government”. This generally means that the home is built incrementally by its occupant. The report highlights the exclusion of poorer households from formal financing mechanisms as one of the features of informal urbanisation (UN Habitat, 2011, p.ix, 74).

Informal housing is correlated to a certain extent to a lack of basic infrastructure and services (this is partly due to the fact that informal urbanisation takes place in many cases on un-serviced land) (UN Habitat, 2003). In addition to housing, urban dwellers thus have to build and manage their own infrastructure networks. One successful example is that of the Orangi Pilot Project in Karachi, which shows the capacity of urban dwellers (in a cooperation process with other actors like NGOs and the government) to provide their own sanitation infrastructure (Hasan, 2002). Other services are organised at the neighbourhood or city scale: In many cities waste is collected, separated and transported to the landfill by organisations of

informal waste pickers (Ali, 1999; Wilson, Velis, & Cheeseman, 2006), and taxi and bus routes are organised for collective journeys (Cervero & Golub, 2007). These activities represent an important share of countries' (and in particular urban) economies: in Mexico for example, it is estimated that the informal economy represents 31% of the national GDP (Schneider, Buehn, & Montenegro, 2010). In terms of employment, the International Labour Office estimates that nearly 54% of the Mexican workforce employed in the secondary and tertiary sectors is informal (International Labour Office, 2013). These examples show that aside from informal settlements there are, in all cities, important informal economies.

Informal economies provide essential services for the city insofar as they complement and even sustain the formal sector of the economy. Taking the case study of food consumption practices in Mexico City, Duhau and Giglia make the following observations. First, the increase in the number of supermarkets in Mexico City (the most formalised of food-chain) has been accompanied by an increase in microbusinesses (that is, family-owned, informal food shops). Even though supermarkets chains have adapted their offer to the necessities of poorer urban households, the demand from the urban poor is still satisfied partly by informal food vending, taking the shape of street stalls and markets, small shops, and window-vending (the practice of vending food through one's home's window). One of the advantages of informal vending compared to supermarkets, besides low prices, is the availability of small quantities of food that are well-suited to poor households' consuming patterns, based on day-to-day survival. The other argument that this research presents is that informal food vending sustains (rather than being a mere alternative to) the formal economy. Supermarkets and malls, by paying their employees very low wages, impede the employees' capacity to consume within the formal economy. Thus, it is common to find food stalls surrounding supermarkets and malls feeding the same employees that work within them (Duhau & Giglia, 2007).

The informal economy thus acts as a solution to the lack of services, infrastructure and employment opportunities that urban dwellers encounter. In this sense the human capital (energy, creativity and resources) of informal actors allows the city to function and increases its resilience: Simone makes the case that these human systems are provisional, flexible and adaptable (Simone, 2004), which are key characteristic of resilient systems (Revell, 2010). This contrasts with superficial characterisations of informal economies as simply illegal, or even criminal.¹ Thus, we can speak instead of an 'informal city', an active city that supports multiple aspects of people's lives but which remains nevertheless invisible to sanctioned structures of urban authority.

A key aspect to understand this informal city is the extent to which it participates in urban politics and how it does so. People involved in informal activities such as self-employment, housing auto-construction and service provision, do in some contexts organise themselves to gain power and

¹ In particular, see the OECD definition of the informal economy as the sum of people who avoid tax (Andrews, Caldera Sánchez, & Johansson, 2011), while the World Bank defines it as the productive activities that are "deliberately concealed" from the state (Schneider et al., 2010).

become active both in formal and informal political channels. On the one hand, there are accounts of organised informal actors becoming actors of the formal political and planning process. In the case of informal settlements, the active participation of urban dwellers in cooperation with NGOs and the state in documenting their neighbourhood, through community mapping and enumerations has been a key aspect to be granted a voice in planning processes, thus asserting communities' "right to the city" (Asian Coalition for Housing Rights, 2004; Livengood & Kunte, 2012; Patel, Baptist, & D'Cruz, 2012). Organisation and knowledge transfer across cities and countries seem to be a key part of that process (Patel et al., 2012). Yet, despite these examples, the participation of the informal city in city politics cannot be taken for granted, and much of what is informal represents also those sectors of the city which are unrecognised and dispossessed of their citizenship rights (Perlman, 1980).

On the other hand, informal actors also take part in political decisions through "informal politics": To take the example of Mexico City, the literature describes the organisation of street vendors (Cross, 1998) and of waste-pickers (Castillo Berthier, 2003) around *caciques*. Castillo describes caciquism as the imposition of a local leader which is "autocratic, informal, opportunistic and arbitrary" (Wayne 1972, cited in Castillo Berthier 2003) and which role is to organise informal workers as much as mediate their relations with the state. These relations between the workers and the state through the leader or *cacique* take the form of corporatism (political arrangements, corruption, negotiation and exchanges of services such as political support); both authors suggest that this form of "informal politics" is representative not only of the state relation with informal actors but rather with any urban economic actor, formal or informal (Castillo Berthier, 2003; Cross, 1998).

1.2. A brief history of urban informality as a policy and planning concept

This section develops a historical account of the evolution of the use of the term "informality" in urban research, before critically analysing the assumptions of these historical views and generating a working definition of the term.

The term "informality" appeared in the literature in the early 1970s as a way to characterise a growing proportion of "precarious" urban employment, previously ignored by employment studies and statistics. In particular, Hart (1973) found the term a useful one in order to characterise non-wage-earning jobs in Accra. The urban poor, in particular migrants engage in informal employment either as a full time occupation or as a complement to low-wages jobs, and in a range of activities such as artisans (shoe-makers, tailors, manufacturers), housing and transport providers, street traders, bar attendants, as well as musicians and shoe-shiners, among others. Hart suggests that informal workers could possibly "supply many of the essential services on which life in the city is dependent" (Hart, 1973). Based on these observations, he urges for the development of a new typology of employment types, taking

more accurately into account informal employment. Hart conceives this new typology not as a means to quantify a city's total economy but rather, to understand the implications of the existence and development of informal income opportunities. In this vein, Hart argues for further empirical research to understand the condition of informal workers, in order to investigate the dual role of informal employment, as a means of exploitation and deprivation on one hand, or rather, as a means to develop ways out of poverty on the other. An International Labour Organisation (ILO) report in 1972 came up with the similar conclusions as Hart's for the case of Kenya (Bangasser, 2000). These pieces of research oriented policy objectives in the following years on improving employment and the working conditions of informal workers, that is, focusing on reducing the adverse aspects of informal employment (Bangasser, 2000).

One aspect of the ILO report that was not re-taken in policy is that of the potential positive aspects of informal employment, in particular in terms of its innovativeness and resilience. This idea was developed in the same period by architect JFC Tuner with regards to informal housing provision in the global south (Turner, 1968). He argues that informal housing provision is an efficient and resilient way of providing urbanisation, and makes logical and economic sense. In particular, the fact that urban dwellers can build a house that is adequate to their needs; and the possibility of building the house incrementally, thus saving small amounts of money at a time, are key aspects of the benefits of informal housing construction. Turner thus argues that the government should accompany self-construction of housing by providing legal, technical and financial support; that is, adapting the planning framework to informal processes, rather than attempting to fit these processes to a rigid planning framework. In terms of national and international policy, this meant focusing efforts on slum upgrading and incremental housing improvement, rather than legal aspects such as land tenure (Werlin, 1999).

Some authors warned against this emphasis on the role of the urban dweller to provide its own housing and services. Although urban dwellers have shown capable to build their own neighbourhood in the absence of the state, whether this is a desirable situation is up for debate. In particular, one has to be aware that this can be furthering the exploitation of an already vulnerable sector of society (Burgess, 1977).² This is confirmed by empirical data: in the case of Rio de Janeiro's favelas, Perlman has found a situation of exclusion and exploitation of the urban poor. She found that the urban poor were exemplary citizens (socially cohesive, economically active, politically involved) yet did not receive the benefits of the social contract, in her words, "integration does not necessarily imply reciprocity" (Perlman, 1980). The problem thus is the lack of integration of the urban poor into urban institutions such as health and education services, or into the employment market.

Economist Hernando De Soto shares some of Perlman's diagnostic. In his book "The Other Path", he argues that informality causes poverty as it is a

² A similar argument has been made in the context of the informal economy, characterising informal workers, or "petty commodity producers", as the new exploited class of capitalist societies (Moser, 1978).

factor of exclusion from the formal market (De Soto, 1989). The lack of job opportunities, housing and services that are available to poor urban dwellers forces them to develop their own 'parallel' economy to provide the services and infrastructure they need. Yet, the exclusion from the formal market remains, and their opportunities also remain constrained. De Soto then proposes a policy solution to this problem, and advocates the eradication of informality through various formalisation strategies (such as land titling) as the key to alleviate poverty and social exclusion. The informal economy is therefore depicted as a subsistence activity, from which one would have to "upgrade" to achieve a full integration in the capitalist productive system (Daniels, 2004). The policy deriving from this view is one of formalisation, focusing on providing the legal basis for informal actors to engage fully in the capitalist economy. This strategy of formalisation gained momentum in the 1980s in international organisations and agencies fighting poverty, and was implemented in countries all around the globe (Hendrix, 1995). This strategy has had mixed results: To take the example of Peru, empirical research has shown that although formalisation strategies have had a positive impact by facilitating access to infrastructure (in particular electricity and water provision), there is no evidence that formalisation has eased the integration of households in the capitalist system, as households have not been able to use their property rights to secure credit (Kagawa, 2001). Empirical research in other countries in Latin America and Africa which have adopted formalisation strategies shows that there is no direct link between formalisation and physical consolidation of housing and infrastructure of integration in the economic system ; rather, these effects happen in certain contexts only (Hendrix, 1995). Gilbert also suggests that the correlation between housing improvement and formalisation is not a causal relationship. People tend to improve their houses over time, and formalised houses are usually older (Gilbert, 2002). Gilbert also questions the possibility of entering the market with formalisation: his work in Bogotá suggests that credit can be accessed more efficiently through informal lenders rather than banks, regardless of legal tenure of housing. The literature thus seems to show that land formalisation does not automatically lift the urban poor out of poverty by integrating them to the capitalist system.

This might explain why in the 1990s and 2000s, recommendations for policy have been re-oriented towards "slum upgrading", that is, the provision of infrastructure to informal settlements. In its review of housing informality, UN Habitat points out that national policies towards informal settlements have gradually moved from negative response (such as eviction) towards upgrading of living conditions (UN Habitat, 2003). More recently, it has also advocated the need for planners to recognise the positive role of informal actors in the city, and to work toward a positive response such as regularisation and upgrading, to be negotiated on a case-by-case basis (UN Habitat, 2009). Supporting these approaches requires understanding informality as it happens, which leads to questioning some enduring informality myths.

1.3. Questioning informality myths

Informality is often misunderstood in a variety of ways. In this section, we present two problematic misconceptions that emerge from the historical literature on informality, and we then work on debunking those myths.

The first myth of informality is that it is often thought of representing the evils of the city, and as something that should be eliminated. From Hernando De Soto's prescriptions for land titling as a means of fighting poverty to the formulation of urban development policies in India, informal settlements have been misrepresented as areas of decline and depravation, and informal practices characterised by the misuse of natural resources. This oversimplification of what informality is is widespread: the OECD defines the informal economy as the sum of people who avoid tax (Andrews, Caldera Sánchez, & Johansson, 2011), while the World Bank defines it as the productive activities that are "deliberately concealed" from the state (Schneider et al., 2010).³ As far as the topic of housing is concerned, this issue translates to the generalisations made about "the slum". In many international reports and academic research, slums are presented as a marginal peri-urban area of the city where migrants settle, and that is characterised by vulnerability and socio-spatial exclusion (in particular from urban services and governance processes) (for example, see Davis, 2006; UN Habitat, 2003). This understanding of informality has had strong repercussions in the development industry; Gilbert speculates that international organisations have unintentionally participated in it (in particular by employing the value-laden term of "slums") in order to publicize their work and attract funding in a more efficient way (Gilbert, 2007). This, according to the author, is very worrying because the exclusion of the informal settlements in urban life becomes a self-fulfilling prophecy, which results in counter-productive policy-making.

The second myth of informality is related to a simplified vision of the city where the informal and the formal are separated and distinct. Yet, the formal and the informal are but two aspects of the same city and the boundaries between what is formal or informal are ill defined, contextually based and constantly crossed by flows of people, money and materials: research on the construction sector on Tanzania shows a "symbiotic relationship" between the formal and the informal sectors of the industry (Mlinga & Wells, 2002). We set out to show in this section that thinking about informality as a homogenous and separate entity in the city is a pre-condition for the oversimplification that we have touched upon in the last paragraph. Thus, we want to challenge this simplified understanding of informality as a distinct and homogenous entity in the city; and by doing so we also show that informality is not inherently characterised by poverty, marginality, unsustainability or exclusion.

Informality characterises a majority of urban processes; as such it cannot be thought of as a homogenous set of processes. Simply put: not all urban poverty is located in informal settlements, and not all informal settlements are characterised by poverty (UN Habitat, 2003). Thus, it is important to note that

³ This report uses interchangeably the terms "informal economy" and "shadow economy".

informal actors have different levels of human, economic and social capital. One particularly revealing study is that of Mexico City's street vendors, in which it appears that groups of street vendors have organised over the years in order to gain political leverage, and thus have become powerful actors in urban politics (Cross, 1998). This finding is similar (again, in the case of Mexico City) with the organised groups of informal waste-pickers (Castillo Berthier, 2003), challenging the conception of informal vendors as a vulnerable group.

Informality also exists in some unexpected realms of the city: in the case of informal housing, it has to be pointed out that some middle- and upper-income neighbourhoods, in particular gated communities, are technically informal settlements. In this case informality relates to the process of development of the neighbourhood (bypassing zoning and planning laws with political influence and corruption) and is characterised by a lack of compliance with urban strategies, in particular with environmental policy and land conservation (UN Habitat, 2009).

To summarise, it is not a helpful analytical concept to think of informality as inherently marginal or problematic. The diversity of situations has to be recognised, in particular in terms of poverty and integration into urban life. Besides, it is important to highlight the interdependence between the formal and the informal sectors of the city. In terms of the urban economy in particular, it appears clearly that both sectors of the economy depend on each other, and that there are continuous exchanges between them: from the workers who complement a formal employment with an informal one, to the informal supply chain of a formal company (or on the contrary, a product that is manufactured in a formal context and then sold informally), the interactions are numerous (Daniels, 2004). Research on electronic waste confirms these findings: in the Chinese context, informal recycling of e-waste is found to have a direct impact on the formal economy as it competes with formal companies in terms of recycling of valuable metals, but also as it has the potential, through separation and recycling, to re-introduce these metals in the formal market as inputs to production (Chi, Streicher-Porte, Wang, & Reuter, 2011).

1.4 Urban informality and sustainability

People shape the city through the myriad of individual decisions and actions they take every day (with no intrinsic consciousness of the consequences at the city scale) (de Certeau, 1984). As such, urban informality, for being so important in urban life, has to be a defining characteristic of how cities evolve. If informality is such a defining characteristic of how cities work, then it is essential to assess its role in urban sustainability.

At the urban scale, the sustainability of the consumption and distribution of natural resources depends highly on the design and management of the urban infrastructure (electricity and sewage systems, transport, waste collection systems) which enables material flows (Monstadt, 2009). We also know that the urban infrastructure is managed at least partly by the informal

sector. For instance, infrastructure such as a sewage system can be built informally (Hasan, 2006). The case of waste management is also interesting: in many world cities, most of the waste is managed informally (Castillo Berthier, 2003; Wilson et al., 2006). In a review of formal and informal waste management in six cities and four continents, a research team identifies the informal sector as being more efficient than the formal sector in terms of waste recovery (CWG, 2010). In the cities they study, the informal sector achieves a higher amount of waste valorisation, doing so at a lower cost and with a lower carbon footprint. This is for various reasons: informal workers use man-power rather than machinery, have a more flexible waste-collection system, and separate waste at the source (thus eliminating transport costs and reducing the contamination of recyclables). A modelling exercise shows that eliminating the informal waste management activities would be detrimental economically and environmentally for the municipalities concerned, while a strategy based on acknowledging informal workers and cooperating with them would be a way to increase the efficiency of overall waste management (CWG, 2010).

These findings extend to other economic sectors: a report by the International Institute for Environment and Development studies the potential contribution the informal sector to greening the economy, and finds out that informal economies have the potential to “drive the transition to greener economies” (Benson, 2014, p.5). This is based on the study of various sectors (waste management, agri-food markets, artisanal mining, energy delivery, and housing, infrastructure and food). The report highlights the efficiency and flexibility of these economic sectors, as well as their adaptability to environmental stress. These characteristics make them adequate actors to drive a sustainability transition (Benson, 2014).

These reports have not romanticized the informal economy, and have also documented existing and potential negative sustainability impacts of informal activities. In the case of recycling and waste revalorisation, these concern primarily the health impacts on workers (CWG, 2010), the non-compliance with environmental regulations (Benson, 2014) and the dumping of non-valorisable waste in inadequate sites (Imam, Mohammed, Wilson, & Cheeseman, 2008). All these studies acknowledge both the opportunities and challenges of informal waste management, and formulate policy recommendation that do not suggest either criminalisation or formalisation strategies, but rather to analyse the sector on a case by case basis and to support it through low-scale interventions responding to the sector’s specific needs (CWG, 2010; Imam et al., 2008; Wilson, Araba, Chinwah, & Cheeseman, 2009).

Research on the contribution of informal processes to urban sustainability remains the exception in sustainability studies. Despite the observation that informal processes are crucial in shaping the city and in particular infrastructure management, informality is still poorly understood in urban research, and particularly in the study of urban sustainability. This is for various reasons, but particularly because of the mismatch between the data traditionally used in sustainability and environmental research, and the reality of urban life. Sustainability research is usually environmentally-focused as it

emerges from engineering backgrounds. This leads to a data-heavy approach where the reliance on quantitative, official statistics and reports is important. By definition, informal processes do not appear in these datasets (as informality is defined as the activities that are not monitored by the state). We thus need to design a new way of generating data on informal processes that affect urban sustainability and analysing them alongside formal processes. One possibility is to use existing methodologies emerging from the social sciences, and apply them to the topic of urban sustainability.

As a way of summary, we argue that understanding the different modes of resource consumption of the city, and how resource flows interact with the production of inequality requires understanding the different ways in which informal processes contribute to the making of the city; this can be done through robust research linking issues of informality and sustainability.

2. Urban metabolism as a conceptual framework for urban sustainability

2.1 Introduction: what is urban metabolism?

The previous section of this chapter has shown that relations between the city and the environment are complex and have multiple impacts on different geographical and time-frames. In order to understand them in all their complexity, it is helpful to use a conceptual framework. The one proposed here is that of urban metabolism. Urban metabolism is the process of material exchanges between the city and its natural environment. Using urban metabolism as a framework in urban research involves focusing on material flows within the city as a potential way to uncover environmental, social, economic and political aspects of resource distribution in a holistic way.

The metaphor of urban metabolism makes resource flows *visible*. Modern society is increasingly defined by flows, networks and movement (Castells, 2010; Urry, 2007). Material flows in particular play a crucial role in issues of urban sustainability, regional economic development and well-being: for example, a well-functioning local agricultural system can provide jobs and economic development to peri-urban and rural farmers, healthy food to urban residents, and can reduce the local carbon footprint. Another type of agricultural system could have opposite and undesired consequences. The study of flows can help unpack these interrelated aspects of agriculture, food supply and the urban system. Because of this, researchers have argued that urban resource and material flows is the key “intervention point” to achieve urban sustainability (Hyman, 2013).

This framework of urban metabolism has been used in policy-making: various cities have recognised the importance of resource and material flows in urban sustainability. For instance, the city of York commissioned in 2002 a report on the city’s Ecological Footprint based on a Material Flow Analysis (MFA) (Barrett, Vallack, Jones, & Haq, 2002). The objective of this study was to generate policy recommendations to reduce the city’s environmental impact, with a concern both for environmental conservation and global environmental justice. Using a Material Flows Analysis combined with an

Ecological Footprint enables the researchers to map and understand the co-dependencies between resource use and environmental impact: the MFA documents the city's throughput (the input and output of different materials and resources) while the ecological footprint gives an indication of these materials' environmental footprint (the embodied energy, water, land and other resources that were necessary to their production). As a result, it makes it possible to determine which consumption patterns are responsible for undesirable environmental impacts such as water use, air contamination, or production of waste. Policy formulations can thus be based on evidence that highlights the complexities of environmental change and in particular the co-dependencies between different resource uses.

The metaphor of urban metabolism has been used in variety of academic disciplines, from political economy and political ecology, to engineering, public policy and urban studies. In this section we present the main applications of urban metabolism research in its two main streams: industrial ecology and political ecology. We argue that neither stream addresses fully the contribution of the informal city to urban material flows; the following section will present a framework to do so.

2.2 Industrial Ecology (IE)

In industrial ecology, researchers use the framework of urban metabolism to study urban material flows as quantifiable inputs and outputs into the urban system. As in the study of York, the objective is to optimise the throughput of materials by making the city more resource efficient. Understanding the city's environmental impacts, both in terms of natural resource requirements (inputs) and production of waste and pollution (outputs) is a way to assess the city's contribution to global environmental damage, and propose policy alternatives. These policies can be driven by environmental objectives (such as cities' international commitments on greenhouse gases emissions reduction) as well as concern for global justice (reducing a city's resource requirements to its fair share on a global scale).

The IE approach is based on a view of the city as an ecosystem, and thus attempts to optimise resource use in the city by mimicking natural ecological systems (which are closed and self-sufficient). This is the foundation for research in circularity, in particular in circular metabolism (Girardet, 2004). The idea is to reduce both the inputs and outputs of the urban system by matching them through waste re-purposing. This has led to the design and implementation of zero-waste strategies at the industrial and neighbourhood scale, by identifying "symbiotic opportunities" (Geng, Tsuyoshi, & Chen, 2010; Pandis Iveroth, 2014). In this sense, circularity in resource flows is seen as one of the ways to achieve urban decoupling (continued urban growth with reduced resource use), one of the conditions for green growth (UNEP, 2013).⁴

⁴ For a comprehensive review of urban metabolism research with an industrial ecology approach, see (Kennedy, Pincetl, & Bunje, 2011).

2.3 Urban Political Ecology (UPE)

In Urban Political Ecology, authors use the urban metabolism framework in order to answer a more political set of research questions, concerned not with the city's resource requirements and relation to its surrounding environment; but rather with the intra-urban distribution of environmental benefits and burdens. "Processes of metabolic change are [...] never socially or ecologically neutral" write authors of a seminal book on urban political ecology (Heynen, Kaika, & Swyngedouw, 2006, p.10). Thus, it is important to unpack the politics embedded in material flows. Issues of power and of justice are of particular importance: Which urban actors control metabolic processes? Who wins and who loses from the distribution of environmental goods and bads in the city? In these studies, the city is not 'black-boxed' as in industrial ecology; on the contrary, it is the intra-urban processes that are of particular interest. The urban metabolism framework is thus used to analyse the politics of resource flows and their distribution in a qualitative manner, highlighting issues of social inequity and environmental injustice. One example is Smith and Ruiters' study of water privatisation in South Africa, which addresses some concerns of the "just sustainabilities" perspective (Smith & Ruiters, 2006). Another example is research undertaken in Mumbai on open defecation, which shows that the uneven distribution and access to urban infrastructure (in this case, toilets and sanitation) furthers urban poverty and inequality, in particular by undermining the urban poor's health (Desai, McFarlane & Graham, 2014).

One interesting aspect of urban political ecology studies is the conceptualisation of "the city as a socio-ecological process" (Heynen et al., 2006). In urban political ecology, the dichotomy between the urban system and the natural environment is questioned, as the built environment is seen as a socially produced natural setting. In the city there are no clear margins between the social and the natural, and both realms are interdependent. Because of its focus on flows and its adequate conceptualisation of the city as a socio-environmental process, the urban metabolism framework holds the potential to understand the city in all its complexity, by providing a holistic analysis of the interactions between a city and its environment (Imaz Gispert, Ayala Islas, & Beristain Aguirre, 2014).

2.4 Urban metabolism and informality

The last section has shown the diversity of application of the urban metabolism framework, and its relevance to researching contemporary urban society. However, it has not shown how urban metabolism addresses the informal city, the topic of this book chapter. Indeed, it is because informality is rarely addressed in urban metabolism research.

On the one hand, industrial ecology studies tend to dismiss the informal city (this might be explained by the reliance of this type of research on statistics and reports that do not take into account informality, such as trade databases or environmental statistics). As a result, the research outcomes automatically ignore informal processes and transactions. For example,

“Sustainable Urban Metabolism” (Ferrão & Fernández, 2013), a state of the art book on urban metabolism research design, proposes research methods that are in no way adequate to capture informal processes; that is because they are data-heavy and thus rely on extensive government-produced datasets. As a means of illustration, it is interesting to highlight that the book only deals with the topic of informality when mentioning slums, described as clusters of poverty, ill-health and sources of urban pollution. As a consequence, the pathway to sustainability envisioned for developing countries is to use the concept of urban metabolism to identify the potential for leap-frogging by investing in efficient technologies; while the potential synergies between social and environmental objectives (the “green” and the “brown” agenda) through the development of non-technological solutions are not mentioned. More generally, Industrial Ecology research tends to focus on formal contexts in developed countries. One example is the topic of industrial symbiosis (which is the matching of industrial inputs and outputs within a region in order to reduce waste and resource requirements). Studies of industrial symbiosis focus on the UK, Europe and the US; however, there is very little research on these processes in the global south. Authors’ research in Mexico City show that these processes do exist, and might be more frequent and efficient than in developed countries; however there is no published research using an industrial ecology approach to study these.

On the other hand, in Urban Political Ecology research, some studies do focus on informal practices in the city. Desai’s study of open defecation in Mumbai does have robust and interesting insights on the environmental impacts, social inequities and governance process surrounding the issue at hand (Desai et al., 2014). Shillington’s study of urban agriculture practices in informal settlements in Managua also point out to interesting insights for environmental sustainability and social equity (Shillington, 2013). In these examples, the object of study is informal; and the study thus uncovers essential information about the life of the urban poor, social inequalities and production of space. However it merely focuses on informal realms and do not relate them to their wider urban contexts. These studies on their own are therefore not enough to understand the contribution of particular informal practices to wider urban processes, in particular in terms of sustainability; as there is no attempt to relate neighbourhood-focused findings to wider processes of material flows.

A few studies address explicitly the metabolism of the informal city. With regards to informal housing, a study of an informal settlement in Cape Town is particularly relevant (Royden Turner, 2012). In it, Royden Turner sets out to assess the city’s housing upgrading policy (one of eradication of informal settlements through relocation in affordable new housing) on the basis of social and environmental considerations. Combining the urban metabolism framework with participatory mapping enables the author to produce a Material Flows Analysis of the informal settlement. The main finding of the study is that in an informal neighbourhood, productive and domestic activities can be mixed and the boundaries between them blurred, as they both take place within the home. The combining of these two activities is found to favour the circularity of material flows between the two systems, which improves resource efficiency. This suggests that the way urban metabolism

research currently manages productive and domestic activities (as geographically and materially separate) is inadequate to accurately represent the informal city's everyday practices and their associated material flows.

With regards to the informal economy, one interesting study is that of flows of wood and paper in Cape Town (Nissing & von Blottnitz, 2007). Its objective is to assess the municipal energy strategy and to enable the design and evaluation of policy alternatives. Faced with an absence of data on these flows, the study generates a Material Flow Analysis of wood and paper. The data is extracted from a wide variety of sources, in particular existing publications, public databases, interviews and site visits. The data on the formal use of wood and paper is complemented with interviews of informal stakeholders, that is, inhabitants and wood traders of informal settlements. This allows the authors to track wood and paper flows more accurately through the city, by shedding light on informal transactions, uses and transformations of wood in Cape Town's informal settlements. This research shows that environmental flows pass through the formal and the informal economy during their life-cycle, creating interconnectedness between the two sectors, which is not accurately captured in trade statistics. Thus, a mix of data-collection methods is required in order to track a material flow through the urban system. Authors' own research on the case of waste in Mexico City corroborate these results: they observe that recoverable materials can gain value during the waste management process as they are collected and separated by informal waste-pickers, in order to be sold to the formal recycling industry. Thus, part of the waste that flows through the informal economy re-enters the formal economy after a process of waste valorisation. These flows have to be adequately captured in urban metabolism research.

Both of these works use unconventional approaches to urban metabolism research as they rely on methods such as site visits and interviews; this allows them to assess the contribution of the informal city to urban sustainability. In particular, it appears evident in both studies that environmental and social data cannot be understood separately. In both cases, stakeholders are identified and participate in data collection. As a result, one important aspect of the two studies is that there is a reliance on experiential knowledge that is traditionally not used in environmental research. The research design that is used is one of mixed-methods, as both quantitative and qualitative methods are used to gather data; and triangulation is applied between different techniques to strengthen the validity of results. This seems to indicate that successful research methods in this context need to be mixed and flexible.

The previous sections of this chapter have shown that informality is a key aspect of how cities are built and managed; however it is not adequately integrated in urban metabolism research. The research gaps concern the empirical relation between informality and urban sustainability. Royden Turner's and Nissing's work arguably show that the conceptual framework of urban metabolism is useful in addressing these gaps. In the next section, we build on these examples and discuss the potential for the urban metabolism framework to integrate informal processes in a systematic and robust way.

3. Discussion: A framework for studying the urban metabolism of the informal city

This section now turns to presenting a framework for studying urban metabolism in an informal context. The last section has shown that the urban metabolism framework has the potential to analyse different aspects of sustainability, such as resource efficiency, socio-spatial inequity and governance issues in the city. However, it does not systematically integrate informal processes into its analysis. We suggest that one way to do so would be to combine the principles and research methods of industrial ecology and urban political ecology in one single research design.

Newell and Cousins have written about the potential of a “political-industrial ecology” (Newell & Cousins, 2015); their argument is very relevant to the topic at hand. They argue that neither the industrial ecology approach nor the political ecology approach are sufficient by themselves to adequately conceptualise a city’s metabolism. They observe that the industrial ecology approach, by black-boxing the city, produces an aspatial and apolitical picture of urban material flows. As a result, the analysis is decontextualized (for instance no distinction is made between the local and the global hinterland). On the other hand the urban political ecology approach, by focusing on the politics of resource use, is weaker in its analysis of environmental processes and impacts. The lack of reliable environmental data and the overall domination of qualitative research outputs mean that urban political ecology studies do not generate knowledge on urban-wide sustainability issues.

Newell and Cousins thus argue that in order to reinvigorate urban metabolism research, industrial ecology and urban political ecology approaches may be used in conjunction in a multi-disciplinary manner. Urban metabolism is thus presented as a “boundary object”, that is, a way to unify two research approaches with distinct epistemologies and research methods. Through the boundary object IE and UPE can interact on empirical grounds, through “collaboration without consensus”. As the authors put it, “[t]hrough this engagement, a richer, deeper, more inclusive, and yet still politically engaged metaphorical conceptualization of urban space can emerge” (Newell & Cousins, 2015, pp.17, 20).

What Newell and Cousins suggest is to use a mixed-methods research design, where quantitative and qualitative methods are combined in order to provide a fuller picture of resource flows. Indeed, through their case study of the water infrastructure in Los Angeles (Cousins & Newell, 2015), they show that a traditional Industrial Ecology study (in this case, a Life Cycle Assessment) can be improved on by complementing it with research methods from Urban Political Ecology (interviews and a historical analysis); as a way to provide historical, spatial and political context to water flows and their environmental impact. Thus, the different aspects of the sustainability agenda (low environmental impacts and social equity) can be addressed.

We build on Newell and Cousins analysis and apply it the case of the informal city. Urban Political Ecology research methods that have already successfully been applied to an informal context (such as observation, historical analysis, participatory mapping, interviews...) can be used to

collect and analyse data that can then be imputed to a city-wide material flows study.

This is particularly relevant in the context of informality, as industrial ecology research relies on data sources (such as governmental trade database) that ignore informal processes. Thus, by using research methods from Urban Political Ecology, it is possible to tap into the experiential knowledge of informal actors. These can then be triangulated through observations and compared to urban-wide formal datasets. The case study of the wood and paper flows in Cape Town shows how this can work, as the research output complements the official, quantitative data on the wood trading sector with interviews of informal wood traders (Nissing & von Blottnitz, 2007).

Another important insight from Newell and Cousins' work is the potential for a "political-industrial ecology" approach to analyse multi-scalar material flows. An 'urban' material flow (for instance, water consumption by urban dwellers) has sustainability impacts at the local household, neighbourhood, urban, regional and global scales. All scales must be part of an inclusive sustainability assessment of that flow. Thus, a study of urban sustainability cannot stop at the city boundaries, nor can it black-box intra-urban processes. By combining industrial ecology and urban political ecology, it is possible to combine data from different sources and at different scales: urban-wide material flows can be based in government statistics, studies of infra-urban processes can be based in locally produced data. The urban metabolism framework can be used to navigate through these different scales by focusing on the flow. As McFarlane explains, studying the geographies of one flow (in his case, water) requires moving beyond the city boundaries, from the rural area where the water is extracted to the neighbourhoods when it is finally consumed; and from the household scale of study to the city-wide scale (in order to study water and housing policies). It also requires "more than addressing water alone", as the flow of water is inextricably linked to sewage systems, housing, farming practices, and policy-making (McFarlane, 2013). By doing so, one necessarily will encounter informal flows, that have to be integrated to a robust analysis of urban metabolism.

Conclusions

[Work in progress]

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