Doing more with less (data): complexities of resource flow analysis in the Gauteng City-Region

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Abstract
Urban metabolism is a growing field of study into resource flows through cities, and how these could be managed more sustainably. There are two main schools of thought on urban metabolism—metabolic flow analysis (MFA) and urban political ecology (UPE). The two schools remain siloed despite common foundations. This paper reflects on recent research by the Gauteng City-Region Observatory (GCRO) into urban sustainability transitions in South Africa’s Gauteng City-Region, a large and sprawling urban formation that faces a host of sustainability challenges including water deficits, erratic electricity supply, stretched infrastructure networks and increasingly carbon-intensive settlement patterns. Three GCRO research projects are reviewed. Each project began with the assumption that data collection on the region’s metabolism could enable an MFA or MFA-like analysis to highlight where possible resource efficiency and sustainability gains might be achieved. However, in each case we confronted severe data-limitations, and ended up asking UPE-style questions on the reasons for and implications of the chronic paucity of urban metabolism data. We have been led to conclude that urban metabolism research will require much more than just assembling and modelling flows data, although these efforts should not be abandoned. A synthesis of MFA and UPE is needed, which simultaneously builds a deeper understanding of resource flows and the systems that govern these flows. We support the emerging approach in political-industrial ecology literature which values both material data on and socio-political insight into urban metabolism, and emphasises the importance of multi-disciplinary and multi-dimensional analysis to inform decision-making in urban sustainability transitions.

1. Introduction
Recent commitments such as the Paris climate change agreement, Sustainable Development Goals and New Urban Agenda highlight the critical role of cities in addressing growing global sustainability challenges. Cities are part of the challenge in that they are the locus of concentrated economic production, land cover change, materials consumption, natural resource use and waste generation. But they are also potential sites of innovation for urban sustainability transitions (Dinarès 2014, Swilling 2016).

Urban metabolism is a growing field of study that analyses resource flows through cities and how flows could be better managed to achieve sustainable development (Kennedy et al 2007, Swilling and Annecke 2012, Ferrão and Fernández 2013, Currie and Musango 2016). Urban metabolism likens cities to organisms where resources such as energy, food and water flow into the system and are used, producing in
turn a range of waste outputs (Zhang 2013, Dinarel 2014). The efficiency with which the urban system ‘metabolises’ resources is influenced inter alia by dynamics of population growth and household formation (Currie et al 2013), economic growth paths, consumption patterns, spatial forms and infrastructure networks, storage processes (Kennedy et al 2007), and the existence of internal recycling loops.

Although a range of methods exist to analyse urban metabolism, two schools dominate: metabolic flow analysis (MFA) and urban political ecology (UPE). The two schools have common foundations, and both offer systemic analysis of urban resource flows that may guide policy-making (Castán Broto et al 2012). However they remain largely siloed (Barles 2010, Guibrunet and Allen 2014). On the one hand, industrial ecologists valorise how the technical insights from MFA may inform decisions around infrastructure and managing urban resource flows (Kennedy et al 2007, Barles 2009). MFA mines extensive datasets to model the flow of resources and their interactions within urban systems, and in turn reveal inefficiencies and opportunities to close loops by using waste outputs as resource inputs (Schulz 2007, Barles 2009, Binder et al 2013, Dinarel 2014). Conversely, UPE scholars focus on excavating the politics and power relations embedded in often taken-for-granted patterns of resource use (Rocheleau 2008), particularly where these commodify ‘nature’, increase inequality and become sites of contestation (Heynen et al 2006, Lawhon and Murphy 2012, Loftus 2012, Lawhon et al 2014).

This paper reflects on recent research into urban sustainability transitions in South Africa’s Gauteng City-Region (GCR). The GCR—an extended urban region holding a quarter of South Africa’s population (GCRO 2012, Culwick et al 2015) and generating a third of its economic output (OECD 2011)—faces a host of sustainability challenges. These include a severe water deficit recently compounded by a country-wide drought; occasionally erratic energy supply reliant on aging coal-fired power stations; car-based urban systems whose seemingly relentless sprawl is made doubly inefficient by the fragmented settlement forms left by apartheid (Culwick et al 2015); stretched infrastructure networks; high levels of air, water and soil pollution; and weak cultures and systems of resource conservation and waste recycling (Götz and Schäffler 2015).

The Gauteng City-Region Observatory (GCRO), a policy-facing but academically-rooted urban observatory, has undertaken a number of research projects into sustainability challenges and possible transition pathways in the GCR. This research has traversed both MFA and UPE, albeit in a somewhat peculiar way. Each project assumed that the starting point ought to be data collection on the region’s metabolism for MFA or MFA-like analysis. In each case we came face to face with severe data limitations, asking UPE-style questions on the reasons for and implications of the chronic paucity of urban metabolism data.

In one view, GCRO’s data collection struggles represent failed MFA experiments. From another perspective, however, they have been instructive, providing key insights into the institutional arrangements and governance practices behind the inability to govern resource flows efficiently and lead socio-material transitions. Our core conclusion is that the notion that a city’s metabolism needs to be measured to enable greater resource efficiency and sustainability presumes, or presupposes, a bureaucracy capable of (a) collecting the necessary data, and (b) acting on what the data shows. In many cities in the global South such bureaucratic capacity cannot be taken for granted.

On the applied research front this leaves a quandary. Is the presupposition that operates in metabolic flow measurement, invalid in some cases, nonetheless useful or productive, in that flows analysis may in fact reflexively help to build the necessary state capacity? Or, in light of the constraints, are other lines of enquiry more ‘generative’?

On the theory front, we have been led to conclude that urban metabolism research will require much more than just assembling and modelling flows data. This does not mean abandoning MFA for UPE; rather, a synthesis is needed. Our research journey has led us to draw inspiration from emerging political–industrial ecology (PIE) literature. PIE posits that MFA and UPE can potentially be used in combination to provide both material data on, and socio-political insight into, urban metabolism; simultaneously building a deeper understanding of resource flows and the systems that govern these flows (Cousins and Newell 2015, Newell and Cousins 2015, Cousins 2016). In this paper we describe our research journey and reflect on implications for future policy-change and urban metabolism research agendas.

2. Understanding metabolic flows

2.1. Collecting flows data for an economy-wide material flows analysis

‘As cities and their global impacts grow in importance and urgency, a broad framework that captures the energy and material flows related to an individual city is critical. The urban metabolism methodology is sufficiently robust, standardized, and practical to allow quick uptake by cities and ease of continued monitoring. So it is time for more cities to start measuring their metabolism’ (Kennedy and Hoornweg 2012 p782).

Responding to such calls to action by industrial ecologists (Kennedy et al 2011, Kennedy and Hoornweg 2012), GCRO started a ‘Metabolic flows and infrastructure transitions’ project in mid-2011. The project was advocated in a prior green economy policy initiative—the Green Strategic Programme
(GSP)—that GCRO led with the Gauteng Provincial Government in 2010–2011. The GSP specified that systems were needed to measure urban metabolic flows data to monitor the region’s green economy transition.

A project ‘concept and process plan’ set out a multi-year programme of research, leading from preliminary research scoping, through full data collection and flows modelling, to deeper analysis of the implications for possible infrastructure transitions. Year one, 2011–2012, started with a review of possible modelling approaches. Based on the literature (Kennedy et al. 2011, Niza et al. 2009), agreement was reached that an adapted economy wide material flows analysis (EW-MFA) should be pursued, rather than, say, ecological footprint, input-output or life cycle-assessment approaches (Zhang 2013). EW-MFA is a mass-balance model which measures the transition of a set of natural resources over a systems-boundary into an economy, and the commuting of these inputs into stocks retained within the system or outputs exiting the system as waste, return flows to the environment, or exports to other economies. Flows measurement, following established Eurostat (2001) guidelines, is usually in standardised statistical units like ‘tonnes per year’ in order to calculate resource-productivity relationships between aggregated flows and aspects of the economy, such as total materials consumed per capita or per unit of GDP generated. Our methods assessment concluded that EW-MFA should be supplemented with systems-dynamics and agent-based modelling elements.

On the basis of the methods review, five resource-specific scoping papers, covering food, water, energy, waste and biomass, were completed in mid-2012. Water was an anomalous inclusion as EW-MFA, strictly applied, does not model water flows as part of its mass-balance equations.

Data collection occurred over the second half of 2012 and early 2013, in five areas: food, water, energy, waste, and materials. Biomass was excluded partly because of overlaps with food flows, and because GCRO’s Green Infrastructure (GI) project planned to collect vegetation data for the region. To meet the criteria of an EW-MFA, considerable time was spent ensuring that data collection covered all elements of each flow, and that information was standardised to facilitate integration for the anticipated modelling.

In many ways the data collection saw notable success. Considerable data was collated and time series were assembled for certain resource components. Figures 1–5 and table 1 show a snapshot of some results.

The provisional data in these figures and table suggest a mixed picture. In some areas there appeared to be a dramatic intensification of resource use, notably in cement sales with a growth rate double that of real GDP. This is consistent for the period which saw the the property market expand, and large construction projects underway in the lead up to the 2010 FIFA World Cup. In other resource areas there seemed to be some relative decoupling.

Despite some successful data acquisition, there were also serious challenges in the data collection exercise. These are discussed briefly below under ‘the boundary problem’, ‘data availability’ and ‘data anomalies’. Although data challenges are, of course, to be expected in any MFA (Currie and Musango 2016), we did not expect the degree of difficulty encountered or the low information returns to investment of time and funds. Nor were we prepared for the conundrum presented by certain datasets that were relatively simple to collect but on closer scrutiny appeared nonsensical. By mid-2013, with a year and a half of conceptual, methodological, and data-collection work behind us, we seemed little closer to the envisaged EW-MFA than when we began, and the data modelling part of the project largely stalled. Kennedy and Hoornweg’s (2012) rallying cry for cities to begin forthwith to measure their metabolism with standardised, practical, quick-uptake and easily maintained methods, seemed to ring hollow.

Figure 1. Abstraction of raw water from the Vaal River System, 2001–2011 (July to June municipal financial years), and Gauteng Regional gross domestic product (GDP-R) in R millions at constant 2010 prices (source: Rand Water and Statistics South Africa, GDP-R tables, historical data, first quarter 2016).
Figure 2. Municipal solid waste generated in Gauteng, 2001–2011, and Gauteng Regional gross domestic product (GDP-R) in R millions at constant 2010 prices (source: Gauteng Waste Information System and Statistics South Africa, GDP-R tables, historical data, first quarter 2016).

Figure 3. Liquid fuel consumption in Gauteng, 2001–2011, and Gauteng Regional gross domestic product (GDP-R) in R millions at constant 2010 prices (source: South African Petroleum Industry Association (SAPIA) and Statistics South Africa, GDP-R tables, historical data, first quarter 2016).

Figure 4. Imports of wheat and maize into Gauteng, 2002–2011, and Gauteng Regional gross domestic product (GDP-R) in R millions at constant 2010 prices (source: Department of Agriculture, Forestry and Fisheries (DAFF) and Statistics South Africa, GDP-R tables, historical data, first quarter 2016).
2.2. The boundary problem: which metabolism?

An EW-MFA requires a defined boundary between the environment, from which resources are extracted and to which waste returns, and the economy that utilises the resources and produces waste, as well as between the economy and other economies with which imports and exports are exchanged (Eurostat 2001). Our urban metabolism research struggled with this boundary definition.

Of course, the analytic problem is not unique to the GCR. For example Gustafson et al. (2014), in their analysis of southern Appalachia, identify a measurable metabolism of resource and waste flows even outside strictly urban areas, and therefore resolve to study the ‘exurban metabolism’ of the entire ‘megapolitan region’. However, the highly polycentric nature of the GCR exacerbates the issue.

Although the GCR is primarily centered within the provincial borders of Gauteng, it is commonly acknowledged that the functional city-region has little relation to this administrative area, originally defined to encompass the metropolitan region previously known as Pretoria-Witwatersrand-Vereeniging (Nel et al. 2008, Mabin 2013). A functional city-region is typically defined by short-term commuter flows (Brown and Holmes 1971, Nel et al. 2008, Krygsman et al. 2009, OECD 2011), although in the GCR ‘commuting’ fields should also take into account longer circular migration patterns between the region’s urban centres and surrounding rural hinterlands (Posel 2004, Collinson et al. 2007).

The functional region can be understood in terms of different resource flows. For example, because the region has limited natural water sources of its own, sophisticated transfer schemes making up the so-called Vaal River System (VRS) have been designed to channel water from several catchments—extending across three other provinces and Lesotho—into Gauteng (Haarhoff and Tempelhoff 2007). The outflow of water is also complicated as the province lies on a continental divide, so depending on where rain falls it will terminate in either the Indian or Atlantic Ocean, and very little of this flow ends up in the VRS as a system input. The functional region of Gauteng with respect to water is therefore even more loosely related to the provincial boundary than the labour market.

The GCR’s resource flow boundaries are not only unclear, they are also different depending on the resource in question. In an EW-MFA the relevant boundary is where resources enter into use in the economy, or exit as an output in one form or another. There may or may not be a point of measurement on this boundary, and that point may or may not give a

![Figure 5. Domestic sales of cement in Gauteng, 2001–2008, and Gauteng Regional gross domestic product (GDP-R) in R millions at constant 2010 prices (source: Cement and Concrete Institute and Statistics South Africa, GDP-R tables, historical data, first quarter 2016).](image)

| Table 1. Materials consumption relative to economic growth (sources as above; authors’ own workings). |
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| | Average annual growth rate | For each Rand unit of GDP, consumption of resource . . . |
| | 2001 | 2011 |
| GDP (constant 2010 prices) | 3.98% | R 657 912 499 127 | R 971 893 171 943 |
| Raw water abstraction from Vaal River System | 2.52% | 0,0000017 megalitres per year | 0,0000015 megalitres per year |
| Municipal solid waste | 6.38% | 0,0000030 tons per year | 0,0000038 tons per year |
| Liquid fuel imports | 2.90% | 0,0000024 tons per year | 0,0000022 tons per year |
| Wheat imports | 0.99% | 0,0000015 tons per year | 0,0000011 tons per year |
| Maize imports | –1.32% | 0,0000035 tons per year | 0,0000022 tons per year |
| Cement domestic sales | 7.76% | 0,0000044 tons per year | 0,0000053 tons per year |
boundary that corresponds with an administrative boundary. In the GCR the relevant water boundary would be the point of abstraction from the region's primary raw water source—the Vaal Dam—by Rand Water, which distributes purified water in bulk to Gauteng’s mines and municipalities. Happily, the Vaal Dam forms part of the southern boundary of the province. But this coincidence was exceptionally rare in our analysis. Waste-water outflows, food inflows, power inflows and waste sites all gave different footprints for different flows in, out, and through the urban system—and thus the difficulty in defining a unitary metabolic ‘organism’—remain a key challenge for the analytic metaphor of the ‘urban metabolism’, and a practical challenge in any data collection process.

2.3. Data availability—institutional constraints
Our EW-MFA data-collection process encountered particular challenges with institutional blockages to data availability. A key example was cementitious materials. Until 2008 the Concrete Institute of South Africa kept detailed provincial-level data of monthly cement and concrete sales, measured in tonnes. The institute was a shared initiative, jointly conceived and funded by major cement industry players. However, a case was launched against the industry by South Africa’s mines and municipalities. Happily, the Vaal Dam forms part of the southern boundary of the province. But this coincidence was exceptionally rare in our analysis. Waste-water outflows, food inflows, power inflows and waste sites all gave different footprints for different flows in, out, and through the urban system—and thus the difficulty in defining a unitary metabolic ‘organism’—remain a key challenge for the analytic metaphor of the ‘urban metabolism’, and a practical challenge in any data collection process.

Factors inherent in the logics of different organisations responsible for managing the flow, and who are in turn the custodians of the data, result in the paucity of quality resource-flows data. These factors may broadly be grouped as: institutional (for example regulatory restrictions on the release of data), technological (poor data infrastructure and information management systems) and methodological (sectoral and disciplinary differences in data collection and analysis).

South Africa’s data custodians include government (often national), research organisations and civil society, each varying on the type and scale of data. Custodians are responsible for maintaining data quality and metadata, and ensuring data access. Collecting consistent comparable datasets for metabolic analysis requires coordination, time, commitment and resources (Sahely et al 2003, Pincetl et al 2012). Data is seldom collected in a manner that enables interdisciplinary compatibility and analysis, or that meets the specific requirements for modelling.

Availability and access to fine scale data, particularly at the city-region level, is a considerable challenge. In South Africa, different government spheres and departments are mandated to collect and manage different datasets. National departments are typically custodians of datasets, and they manage standards and data infrastructure. Statistics South Africa (StatsSA) maintains official statistics particularly for population demographics, economy and development. Although national departments manage many resource datasets, local government is responsible for solid waste, air quality and water services infrastructure data. Municipalities have greatly varying capacity to manage data collection, quality control, and the transfer of data into centralised national information systems. Consequently where collection is irregular, or at different spatial scales and time intervals, data can be porous and scattered.

The spatial scale at which data collection and classification occurs can affect the results of analyses of biophysical variables (Rouget 2003, Cash et al 2006, Keskitalo et al 2016). An MFA, or any other social-ecological-systems analysis framework, needs to find a best ‘fit’ between the scale of data collection and the operational jurisdiction of relevant implementing institutions (Folke et al 2007). Any approach, for example the scaling-up or scaling-down of data, in a complex socio-ecological environment, will bring with it its own set of challenges. Biophysical data is often collected at different scales to demographic and economic data, because government jurisdictions and the geographical expanse of networked infrastructures (e.g. potable water or roads) differ to ecosystem boundaries.

In some cases, poor understanding of the importance and purpose of collecting basic resource flows data results in limited investment in maintaining data monitoring infrastructure (Sahely et al 2003, Pincetl et al 2012, SACN 2015). Data collection challenges are also caused by different data access rules, and varying willingness to share information, across institutions. Unwillingness to share data is often due to a fear of data errors being highlighted or underperformance being exposed (SACN 2015). Addressing data challenges for MFA therefore goes beyond merely ensuring adherence to technical standards and proper methods. It also involves systematically demonstrating that, when used collaboratively, good data can assist government to respond to urban resource challenges (Cooper et al 2014).

2.4. Data anomalies
Figure 2 suggests, at first glance, good data for this crucial flow. The data was obtained with some ease from the Gauteng waste information system. However, on closer scrutiny the data was shown to be nonsensical. Fluctuations in the total are largely accounted for by the fact that data for some
municipalities was available for some years and not others. More concerning, even where data was available for a municipality across all years the results for some were not believable. Over 2003–2009, the City of Johannesburg, the most populous and economically productive municipality in the country, showed a waste output averaging 1 415 332 tonnes per year, just over half that of a much smaller municipality, Tshwane, at 2 541 548 tonnes per year.

Reasons for this anomaly were not forthcoming. Perhaps the municipality was reporting incorrectly to the provincial monitoring system? This seemed unlikely given the consistency of the anomaly over years. As we searched for explanations our attention focused on possible root causes in the way that waste data is collected at source, and, after some qualitative investigation, concluded that the most likely reason was that Johannesburg’s weigh-bridges—the facilities at landfills that measure and price the tonnage of waste dumped by municipal and private waste vehicles—were not working properly. Digging deeper we also ascertained that the most likely reason for this was that these facilities had become sites of corruption: low-level officials were taking bribes from private companies to render weigh-bridges inoperable, or to under-report measurements, making total waste-flow figures meaningless.

With these insights the focus of the project turned from trying to collect data whose veracity had to be taken at face-value, to understanding the institutional prerequisites for data integrity.

3. Alternative entry points for valuing green infrastructure

3.1. Green infrastructure data collection

GCRO’s ‘Green Assets and Infrastructure’ project, started in 2011 with the metabolic flows research, has explored how to mainstream a GI approach into urban infrastructure planning and management. Appropriate data is necessary to inform a GI planning approach (CABE 2009, Bobbins 2016), and a compelling argument can be made for changing current approaches with the right datasets.

Early in the project the GCRO commissioned a service provider to collate all relevant, readily-available geographic information system (GIS) data to enable a quantitative ecological assessment for Gauteng. Although a wide range of datasets are available for the province, collecting them was an onerous task as it required the service provider to go to each custodian (e.g. national, provincial and local government departments, NGOs, private sector) to collect datasets.

This involved navigating gatekeepers and scepticism for handing government data to a private company. Despite the effort involved in assembling these datasets the collected data were so poorly aligned they were incomparable: significant gaps existed due to unavailable data, and there was very little metadata to explain how each dataset was compiled and classified.

Realising the insufficiency of available data for the intended analysis, the GCRO commissioned another service provider to assemble two datasets to enable us to quantify any changes in official parks and open spaces in Johannesburg between 2001 and 2012. The service provider spent significant time finding an approach that GCRO was satisfied with and that was feasible with available datasets. The final datasets integrated four GIS layers including parks and 2.5 m land-cover layers with municipal allocation of green spaces. The final data again proved unsatisfactory, with some of the city’s parks excluded (e.g. Joubert Park, one of Johannesburg’s oldest standing parks), and included areas clearly not green spaces (e.g. in the middle of a highway).

The primary motivation for collecting and analysing green asset data was to influence green asset management by demonstrating ways of incorporating GI into government budgeting and planning. To this end, GCRO commissioned a third study to explore tools and techniques for including GI into municipal finance and accounting practices. This study included an ecosystem service valuation for Johannesburg, intended to demonstrate the value of Johannesburg’s green spaces. Due to data availability limitations, the indicative valuation was restricted to the recreational and aesthetic values of green open spaces. The applied value estimates were based on Cape Town’s GI economic valuation study (De Wit et al 2009). The financial values demonstrated that Johannesburg derives significant value from its open spaces (between R38 million yr\(^{-1}\) and R77 million yr\(^{-1}\), in 2012). However, similarly to the Cape Town study (Cartwright and Oelofse2016), it remains unclear how such large values can be incorporated into municipal planning and budgeting. Furthermore, the use of ‘aesthetic and recreational’ values, instead of other options such as the value of well-maintained natural systems for flood attenuation, or the value of air pollution improvements associated with green assets, rendered the study of little value for municipal planning.

3.2. Exploring new approaches to ‘land’ ideas with policy makers

In the context of unresolved data issues and our experience with economic valuation of green assets, we faced the challenge of finding alternative methods to influence decision-makers to adopt green infrastructure strategies. The GCRO embraced this challenge by launching a CityLab in early 2014, where a range of stakeholders from government and academia engaged around how to incorporate GI

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*A green infrastructure approach deliberately incorporates ecological systems into urban areas through preserving, maintaining and investing in ecological systems, in a way that enhances the functioning of urban infrastructure networks and benefits for society (Bobbins and Culwick 2016).*
into planning and decision-making (Vogel et al 2016). The GI CityLab was held every two months over the course of a year. Each seminar focused on a different aspect of applying a GI approach in Gauteng and each was deliberately designed to facilitate debate and draw insights from academia, government and beyond.

The CityLab’s initial aim was to create a platform of engagement to collectively develop a consistent method for gathering, classifying, storing and presenting green asset data, which would enable the types of analysis that the GCRO was initially interested in. We originally anticipated the CityLab outcomes would inform the structural and managerial expertise required to represent, quantify and value green assets in the GCR. However, as the CityLab evolved it became clear that there was a wide range of interests, opportunities and challenges, beyond data issues, that the CityLab could explore. Participants highlighted that even where appropriate data and modelling exists, shifts in urban development decision-making are not automatic. Participants emphasised that technical data has to partner with an appreciation of the value of GI. While data issues remained a concern throughout the CityLab, the most interesting insights and mutual learning arose from discussions around how to intervene in the planning and budgeting processes despite the paucity of ‘necessary’ data. CityLab participants directly influenced the GI project research agenda, which deliberately focused on addressing the knowledge gaps revealed through the group discussions.

The limitations of relying only on valuations became clear through the CityLab, and that focusing on the benefits and services provided by ecosystems may be taken more seriously by decision-makers than the financial valuation of green assets. Furthermore, to ‘land’ ideas with decision-makers, a common understanding and goal are required. This can be facilitated by building an evidence base of case studies that demonstrates the value of GI. Decision-makers must also be empowered with strategies for how to change planning approaches, and operations and maintenance processes.

4. Towards an ethnography of government water data

In 2013, as the metabolic flows data collection wound up, GCRO initiated a project entitled ‘Political economy of infrastructure choices: municipal water pricing and sustainable water use in the GCR’. It was based on the premise that GCR municipalities are hard-pressed to strike a balance between efficiency, equity and sustainability in supplying water services. Water prices and billing mechanisms are key to holding this balance. Using econometric methods and micro-level data the project set out to analyse variations, across different municipalities, in: the price and income elasticities of demand for water given divergent pricing mechanisms, supply techniques and social assistance packages; the distributional effects of different water price structures in use; and the potential impact of new water pricing structures on the overall water balance in the GCR.

Household-level water consumption data—ideally at a stand level—was identified as essential for this exercise. Johannesburg and another smaller municipality, Mogale City, were approached for this data, together with information about methods by which stands were billed for water-use. Despite Johannesburg’s acknowledgement that we had a legal basis to access the data, the city’s water utility, Johannesburg Water, denied the request on claims that there were ongoing conflicts in some communities related to prepaid meters, and concerns that the data might be misused. After many months negotiating access to the data we abandoned efforts. In the case of Mogale City, our request was redirected to a private service provider responsible for holding billings data. This custodian did not feel obliged to assist because they were a commercial operation. It was clear from communication with Mogale City officials that they had limited control over the company, and indeed lacked any interest in possessing the data themselves.

While the request for data, with its genuine objective of measuring water flows to poor communities, was unsuccessful, the processes of trying to get the data was revealing, illuminating not just difficulties in accessing government information, but also key complexities in the structure of local administrations. Given this the project refocused on an ethnographic exploration of how infrastructure decisions are made in Johannesburg and how data is collected, held and circulated between the city and its external entities.

Initial insights from this ethnographic research are that Johannesburg’s outsourcing of service delivery to private service providers has resulted in multiple sites of data production and use within and beyond the city. This produces fragmentation between data collection and use, as well as blurred lines of accountability and responsibility. In addition, water-related data ought to be used to plan for improved service delivery; but in Johannesburg it is also deployed to measure staff performance targets in a way that sees it become politically sensitive, in turn resulting in a loss of data integrity and increasing ‘siloing’ of and defensiveness around data holdings.

5. Implications for future research and policy-change agendas

GCRO’s three research projects aimed to build evidence for sustainability transitions, but each confronted major data issues and could not achieve initial objectives. In light of this there are two possible paths for future research and related policy agendas.
5.1. Alternative approaches to collecting MFA data

Despite our data collection struggles, we remain convinced that MFA is valuable in guiding urban decision-making. A wide-angle assessment of metabolic flows across the city region remains essential to build a case for, and track the implementation of, large-scale sustainability transitions. If appropriate data did exist, enabling a comprehensive EW-MFA for Gauteng, this would help guide urgent policy decisions needed to steer the GCR towards more efficient patterns and forms of urban settlement, more multifunctional and less wasteful infrastructure designs, greater resource security especially in the areas of food, energy and water, and a greener economy en route to relative and absolute decoupling.

A wider literature on the feasibility of EW-MFA (e.g. Zhang 2013, Currie et al 2015, Currie and Musango 2016, Schwab et al 2016, Schindler 2017) suggests a range of alternative methodologies that could help in data-scarce contexts. Currie et al (2015) demonstrate a method to develop typologies for African cities by down-scaling national-level data using city-level population and economic data, and then clustering cities with similar overall resource profiles. In the absence of quality data at the national level, proxies could be used to represent the missing resource flow data (Zhang 2013). Sector-level supply chain analyses and life cycle assessment could also potentially be used to improve industrial resource estimations (e.g. cement).

Another fruitful avenue could be the build-up of city-wide pictures through micro data from the household and neighbourhood level. Domestic resource data could be collected through household surveys, such as GCRO’s biennial Quality of Life survey, and used to develop resource profiles by housing type and suburb. For example, past surveys have asked respondents to identify the household’s total waste generated weekly. Mean waste volumes can be extrapolated by dwelling type, population group or income. This kind of data can be spatially variegated, and used in combination with downscaled city profiles, to show policy-makers which neighbourhoods are more or less resource efficient and thus how cities could be built or retrofitted to address inefficiencies. This research would make decision-makers more attuned to the need for improved data. However, MFA is largely an analysis oriented framework and thus research could lead to debate into the value of MFA for policy, and possibly point to other socio-ecological systems methods better suited as decision-making tools (Binder et al 2013).

5.2. Refocusing on institutions and infrastructures

While efforts to collect MFA data will continue, we glimpse new research prospects in the fact that when we asked tough UPE-style questions into the reasons for data paucity and inadequacy, they provided insights into institutional arrangements that underpin not only data availability but also government’s ability to manage resource flows. Where data did exist, we often found it fragmented between custodians with misaligned data collection and maintenance methods, suggesting in turn that co-ordination between key agents for a required infrastructure transition would be difficult to orchestrate. Data that was available, but patently wrong, pointed to street-level bureaucrats likely to be structurally disincentivised to avail accurate information. Those same actors would likely give little support to systemic changes that depended on more accurate measurement. The GI project revealed an additional barrier—even where useful data exists, government is not necessarily able or willing to respond to the evidence and change existing approaches, because of systemic fixes or path dependencies. In essence, data inadequacies beg institutional questions that, when asked, reveal larger problems to be addressed.

On the one hand, this suggests that without deeper understanding of the underlying institutional and power dynamics, data collection will remain challenging, and even where some form of MFA is possible its insights may prove less valuable than hoped in guiding urban sustainability transitions.

On the other hand, and more optimistically, we see scope to expand the urban metabolism research agenda through a pluralist approach that puts the institutions and infrastructures underpinning resource flow dynamics as the central object of research. This approach would incorporate urban history, sociological institutionalism, resource economics, network analysis and ethnographies of the state in an effort to stir a deeper conversation between MFA and UPE. Three interconnected sites of potential analysis might prove useful.

The first could focus on unearthing deep context—how did we come to build the city that we have? Here, research might aim to uncover histories of resource flows, how they came to be constituted as ‘flows’, and the infrastructural developments and spatial forms they occasioned. It would further explore historical sociologies of the institutions, bodies of expertise, taken for granted knowledges (especially in the field of engineering) and political economy logics that structure these flows.

A second research site could excavate ‘the way things work now’ in order to challenge traditional notions of ‘flow’. These could include network analyses and supply chain analysis of current flows and their nodal points of interconnection, studies of alternative and ‘informal’ resource flows (such as attempts by households or whole neighborhoods to move ‘off the grid’), as well as investigations into flows that aren’t flowing (such as GI or storage sites). Deep ethnographies of state institutions, experts and ‘stakeholders’ would be especially useful here. Ethnography not only analyses discourse, but also practice: for example how the packaging and
transmission of flow 'data' (through what indicators and models) is enacted in routinised, everyday practices and instrument-use (Cousins 2016). A third site would be more activist and experimental. We see scope to develop the CityLab concept into an action research platform where participants can collaboratively explore possibilities and pitfalls of advancing ‘urban metabolism’ thinking. Other sites of experimental research include analysing available data for ‘unseen’ and uncounted flows; modelling different pricing regimes for resource extraction and consumption and the political economic scaffolding that could undergird those regimes; and designing different kinds of indicators that might in turn alter the type of data collected.

Despite the methodological and theoretical eclecticism across these zones of research, all components of this expanded urban metabolism research agenda ought to be grounded in the specificity of place; a defetishisation of current ‘flow logics’; analysis that is historically and institutionally-attuned to why things work the way they do; and a commitment to understanding how to change underlying logics and practices—reflected as they are in what data is available—for greater sustainability (Dinarès 2014).

We not only caution against uncritical calls for building the data required for MFA, but also challenge the siloed nature of MFA and UPE. We echo calls by Castán Broto et al (2012) for diverse, multi-disciplinary and multi-dimensional streams of research that facilitate dialogue between urban metabolism approaches. Research is needed that balances MFA and UPE in iterative and mutually productive lines of enquiry that draw on, and reciprocity reinforce, the strengths of each school of thought.

In order to effect urban sustainability transitions, government must rebalance the complex systems that have led to unsustainable and inequitable resource flows. Research that tries to inform such decision-making must do the same to ensure its relevance.

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