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Integrated sustainable waste management in developing countries

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This paper uses the lens of 'integrated sustainable waste management' to examine how cities in developing countries have been tackling their solid waste problems. The history of related concepts and terms is reviewed, and ISWM is clearly differentiated from integrated waste management, used mostly in the context of technological integration in developed countries. Instead, integrated sustainable waste management examines both the physical components (collection, disposal and recycling) and the governance aspects (inclusivity of users and service providers; financial sustainability; coherent, sound institutions underpinned by proactive policies). The data show that performance has improved significantly over the last 10 years. Levels of collection coverage and controlled disposal of 95% in middle-income and 50% in low-income cities are already commonplace. Recycling rates of 20–30% are achieved by the informal sector in many lower income countries, at no direct cost to the city – presenting a major opportunity for all key stakeholders if the persistent challenges can be resolved. The evidence suggests that efficient, effective and affordable systems are tailored to local needs and conditions, developed with direct involvement of service beneficiaries. Despite the remaining challenges, evidence of recent improvements suggests that sustainable solid waste and resources management is feasible for developing countries.

1. Introduction

What constitutes good practice in solid waste management in developing countries? How far have developing countries generally progressed with 'modernising' their solid waste management systems? How should a city decide on what are the appropriate next steps in developing its solid waste system? What makes a solid waste system sustainable?

This paper aims to address such questions. It draws heavily on work carried out by two of the authors as part of a global team to prepare the seminal book *Solid Waste Management in the World's Cities* for UN-Habitat (Scheinberg *et al*., 2010b). All three of the current authors were involved in the subsequent analysis of the new set of consistent data collected for 20 reference cities in all six continents as part of that work (Wilson *et al*., 2012).

The analytical framework used here is a version of 'integrated and sustainable waste management' (ISWM). The use of the terms 'integrated' and 'sustainable' to describe solid waste management systems, both in developed and developing countries, is examined before elaborating on a version of ISWM that considers both physical components and governance aspects and is used here as a 'lens' for viewing solid waste management in a city. This lens is used to examine, in a systematic way, both the current realities in developing countries and the challenges they face, with the aim of identifying some of the opportunities for sustainable solutions. The paper elaborates what appears to be an emerging consensus: that viable and sustainable solutions for solid waste management in developing countries need to be designed for the specific local circumstances and conditions. Two short case studies are presented, showing that local solutions can work.

2. 'Integrated' and 'integrated sustainable' waste management

2.1 History and meanings of 'integrated waste management'

This section provides a concise overview of the historical use of the term 'integrated' in association with solid waste management and navigates its particular meanings. The term had become standard by the mid-2000s, as suggested by its wide adoption by the research community and reflected in names of newly establishing waste-related academic research centres such as 3R: Residual Resources Research, a PhD research school on integrated resource and waste management of DTU, Denmark, the Integrated Waste Management Centre of Cranfield University, UK, Integrated Waste Systems of The Open University, UK, the CSIR Centre for Integrated Waste Management, South Africa and the Center for Integrated Waste Management of the University at Buffalo in the USA.

To the best of the authors' knowledge, in the peer-reviewed literature the term 'integrated' was first associated with solid waste management during the 1970s (see Murray *et al.*, 1971; Tobin and Myers, 1974) and there has been an exponential increase in use of the term since then. A search on the Scopus research citation database carried out in March 2012 revealed only 10 papers published with all the terms 'integrated' 'waste' 'management' in the title by 1980, 31 by 1990 and 203 by 2010.

Such usages appear in a wide variety of contexts, as summarised in Table 1. However, all these uses imply a systems theory approach, separating out identifiable discrete entities ('items', 'elements' or 'units') to describe relationships among them. Most of these uses reflect two of the dictionary meanings of 'integrated' (see, for example, http://dictionary.reference.com/)

(*a*) combined or composite, made up of parts that work well together or
(*b*) combining separate things, bringing together processes that are normally separate.

However, some uses do also reflect the third dictionary meaning

(*c*) open to all people, as in integration by, for example, race, ethnicity, religion, gender or social class, which somehow relates to the social/human capital of sustainable development.

Inspection of Table 1 reveals that most uses of the terms 'integrated waste management' and 'integrated solid waste management' are largely technical, focusing on how to integrate various technical elements into a more complete and/or regional system, and sometimes on using computer-aided tools to assist with that integration. Most of the references are also related to developed countries. An important variation interprets integration in the sense of addressing all of the levels of the waste hierarchy, from prevention through recycling to disposal.

The notion of sustainable development came to global prominence by way of the report *Our Common Future*, published by the World Commission on Environment and Development (WCED) in 1987, but it consolidated on and interpreted precursor versions (Mebratu, 1998). Agenda 21 – the action plan on sustainable development agreed at the United Nations Conference on Environment and Development in Rio de Janeiro in 1992 – has been influential in solid waste management. Diaz *et al.* (1996) argued for a holistic and systems approach to 'integrated and sustainable solid waste management (SWM)', addressing all three aspects of triple bottom line interpretation of sustainability (environmental, social and economic) with a particular emphasis on spatially combining solid waste management, wastewater treatment, energy production and food production facilities.

2.2 The origins of integrated sustainable waste management (ISWM)

Interestingly, the characteristic of integrated waste management, being open to all the actors or stakeholders according to the third dictionary definition stated in Section 2.1, seems to have been explicitly taken up primarily in the context of developing countries (e.g. Sudhir *et al.*, 1996).

In the early 1990s, many international agencies and non-governmental organisations (NGOs) active in developing countries became disenchanted with the failure of the conventional, exclusively technical, approach (often called the 'technical fix' (Wilson, 2007)). A collaborative programme on municipal solid waste management in low-income countries was set up by UNDP, UN-Habitat and the World Bank, with funding from the Swiss Agency for Development and Co-operation. A workshop convened in Ittingen, Switzerland, in 1995 resulted in a conceptual framework for integrated municipal SWM in low-income countries (Figure 1) (Schübeler *et al.*, 1996). This novel approach essentially built upon the holistic, all-inclusive, comprehensive notion of sustainability on multiple levels. It distinguishes between three principal dimensions, each denoted by a question, shown in Figure 1 as one side of a cube.

- What? – the scope, which includes the physical components of a waste system but goes much further by identifying a number of other planning and management issues that need to be addressed, such as strategic planning, public participation, financial management and so on.
- Who? – focuses on the stakeholders or actors, as per the third dictionary definition.
- How? – how strategic objectives and issues should be addressed introduces for the first time a series of strategic

Thematic use	Description – system components	Selected references
Waste and wastewater processing integration	Integrating solid waste management with wastewater treatment, and sometimes also with energy generation and food production	Murray *et al*. (1971); Ingelfinger and Murray (1975); Diaz *et al*. (1996)
Solid waste processing integration	Integrating various technical elements into a single waste treatment process (e.g. as in modern mechanical biological treatment plants)	Crocker (1983); Diaz and Golueke (1989); Smith (1990)
Facility integration	Integrating different types of solid waste treatment and disposal facilities in close proximity, often with various treatment processes and a landfill site co-located	McQuaid-Cook and Simpson (1986); Diaz *et al*. (1996)
Integrated solid waste management in industrial parks	Exploring industrial symbiosis and economies of scale in managing solid wastes of industries located in the same park, as a part of the industrial ecology approach to resource management	Geng *et al*. (2007)
Integrated planning for a region/metropolitan area	Integrating a number of neighbouring political units into a region for the purposes of analysis/planning/siting and permitting common facilities to serve the whole region. Often the term implies the use of a systems approach or mathematical modelling	Tobin and Myers (1974); Barlaz *et al*. (1995); Huang *et al*. (1997); Zotos *et al*. (2009); Xi *et al*. (2010)
Integration (consolidation) of disparate legislation and policies	Consolidating disparate, disconnected or partly overlapping/contradicting legislation and policies into strategies or overarching initiatives, for example as emerging from EU regulations and directives (e.g. Race against Waste programme (see www.raceagainstwaste.ie) in Ireland)	Rudden (2007)
Integration of decision makers	Consolidating contradictory suggestions from multiple institutional statutory bodies involved in solid waste management decision making	Clarke *et al*. (1999)
Integrated (solid) waste management (using the waste hierarchy)	Integrating SWM according to principles of the waste hierarchy, combining waste prevention or reduction, reuse, recycling/composting, energy recovery and disposal, or discussing the role of particular technological solutions	Smith (1990); Johnke (1992); USEPA (2002); Heimlich *et al*. (2005); Memon (2010); Consonni *et al*. (2011)
Integrated analysis of SWM options with other (environmental, economic) aspects	For example, integrating analysis of SWM options with air pollution in a city, energy consumption, cost–benefit analysis, etc.	Karagiannidis and Moussiopoulos (1995); Daskalopoulos *et al*. (1998); Thorpe (2001)
LCA	‘Integrated waste management’ and ‘integrated solid waste management’ are terms that have been used to describe life-cycle assessment (LCA) approaches to waste management	Constant and Thibodeaux (1993); Huang *et al*. (1997); McDougal *et al*. (2001); Thomas and McDougall (2005); Bjorklund *et al*. (2011); Giugliano *et al*. (2011)

Table 1. Different uses of the terms ‘integrated waste management’ and ‘integrated solid waste management’

Thematic use	Description – system components	Selected references
Integrated resource management	Integration of waste with resources management, often in the context of a 'closed-loop' recycling, eco-design/ recyclability of new products or general 'circular economy'	Pontin (1980); Nilsson (1991); Lisney *et al*. (2004); Amos (2005); Deutz *et al*. (2010); Carter (2012)
Integrated sustainable waste management (ISWM)	Integrating across three dimensions – all the elements of the waste hierarchy, all the stakeholders involved and all the 'aspects' of the 'enabling environment' (political, institutional, social, financial, economic and technical). Used particularly in developing countries	Schübeler *et al*. (1996); Van de Klundert and Anschütz (2001); Anschütz *et al*. (2004); Scheinberg *et al*. (2010b)

Table 1. Continued

aspects: political, institutional, social, financial, economic and technical.

Some of these are also identified as forming the broader local context – political, economic, socio-cultural and environmental – that needs to be taken into account (depicted in the corners of Figure 1, defining the space within which the cube is situated).

Some of the early thinking underpinning the conceptual framework can be attributed to Arnold van de Klundert of the Dutch institute-type NGO WASTE. The Dutch government funded WASTE to undertake a six-year Urban Waste Expertise Programme (UWEP) from 1995, which built further on the conceptual framework to develop what was for the first time termed integrated sustainable waste management (ISWM) as both an analytic tool and a development framework (Van de Klundert and Anschütz, 2001). As shown in Figure 2(a), this maintains the three dimensions, but simplifies the 'What?' into just the physical components (elements) of the system.

Through the 2000s, the concept of ISWM was further refined and is gradually becoming the norm in discussion of solid waste management in developing countries. A second phase of UWEP resulted in a guideline on using the ISWM assessment methodology (Anschütz *et al*., 2004). An EU-funded programme on ISWM in Asia (www.issowama.net) used ISWM to develop a project-specific approach to assess typical success and failure factors (Zurbrügg *et al*., 2013). The original international collaborative programme evolved into a collaborative working group (CWG) on solid waste management in low- and middle-income countries – a number of international workshops have further elaborated on ISWM (www.cwgnet.net). The CWG formed the backbone of the 35-strong international team who prepared *Solid Waste Management in the World's Cities* for UN-Habitat (Scheinberg *et al*., 2010b); this adapted the three-dimensional ISWM framework, for the purposes of a systematic comparison of the cities, into what can be described as two overlapping triangles (Figure 2(b)).

2.3 The ISWM analytical framework used here

The first triangle in Figure 2(b) comprises the three key physical elements – linked to the key drivers for solid waste management (Wilson, 2007) – that *all* need to be addressed for an ISWM system to work well and to work sustainably over the long term

- public health (linked primarily to waste collection)
- environment (protection of the environment throughout the waste chain, especially during treatment and disposal)
- 3Rs – reduce, reuse, recycle (driven by resource values and more recently by 'closing the loop' and returning both materials and nutrients to beneficial use).

The second triangle focuses on ISWM 'software' – the governance strategies that *all* need to be addressed to deliver a well-functioning system. The system as a whole needs to

- be inclusive, allowing stakeholders to contribute as users, providers and enablers
- be financially sustainable, which means cost-effective and affordable
- rest on a base of sound institutions and proactive policies.

This analytical framework is used in the following sections both to document the existing realities in developing countries and also to explore some of the challenges and opportunities for solutions.

3. Realities and challenges: physical elements

3.1 Public health (collection)

The safe removal and subsequent management of solid waste sits alongside the management of human excreta (sanitation) as two

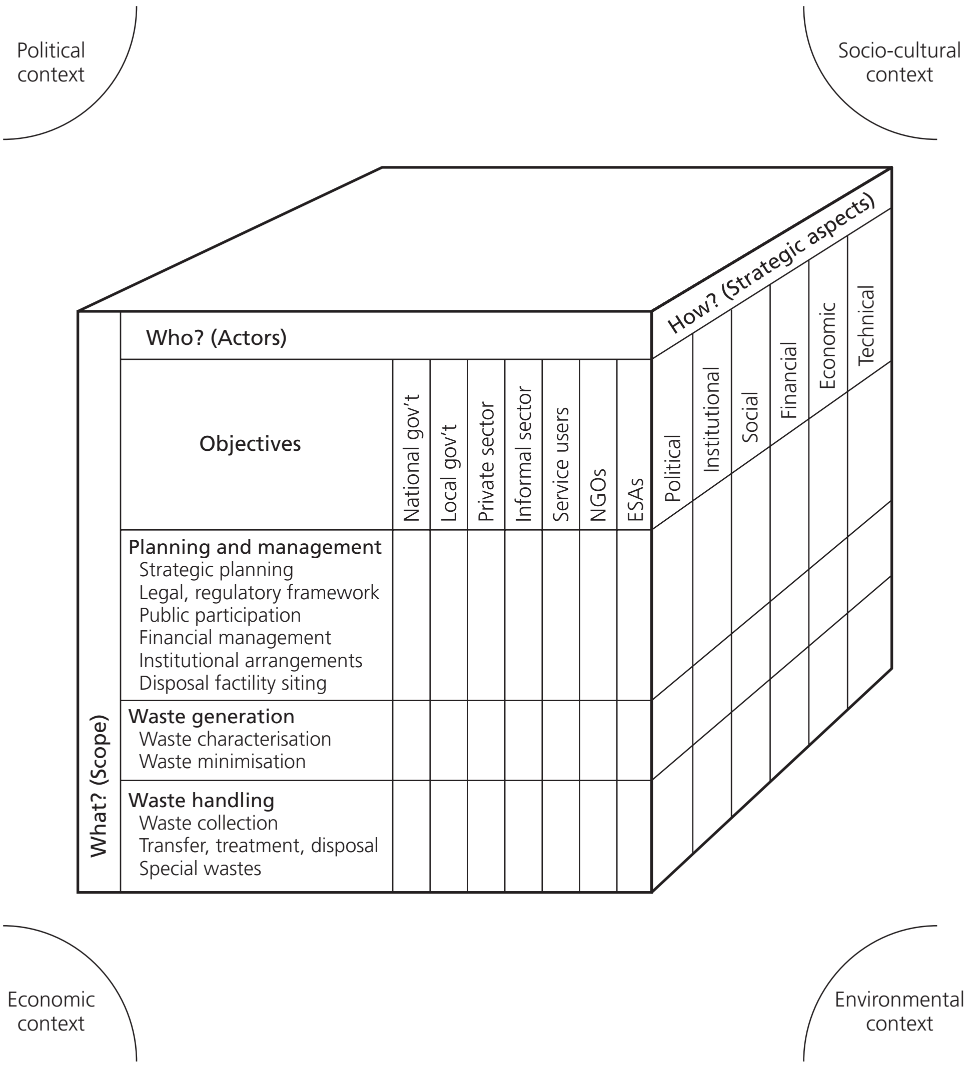

Figure 1. The conceptual framework for integrated municipal solid waste management. Each side of the cube shows one of the three primary dimensions of ISWM, denoted by a question (source: Schübeler *et al*. (1996); reproduced by permission of SKAT). ESAs, external support agencies

of the most vital urban environmental services. The primary driver is public health; cholera epidemics in the nineteenth century led to fairly comprehensive, municipal solid waste collection services in major European and US cities by 1900 (Tarr, 1984; Wilson, 2007). Uncollected solid waste is still a serious public health issue in developing countries. Health data (UN-Habitat, 2009: p. 129) show significantly higher rates of diarrhoea and acute respiratory infections for children living in households where solid waste is dumped or burned in the vicinity, as compared with households in the same cities that receive a regular waste collection service. Uncollected waste also blocks drains and causes flooding and subsequent spread of water-borne diseases: this was the cause of a major flood in Surat in India in 1994, which resulted in an outbreak of a plague-like disease affecting 1000 people and killing 56 (Gupta, 2010).

Comparative data on waste composition show high plastics contents of solid waste irrespective of income level of a country (average across 20 reference cities: 10% on a weight-for-weight basis) (Scheinberg *et al*., 2010b). The annual floods in low-lying parts of Kampala, Uganda are blamed in part on plastic bags, locally known as *buveera*, blocking the drains (Tenywa *et al*., 2008). In West Africa, floods have been blamed on the uncollected small plastic pouches in which drinking water is sold (IRIN, 2004). After the devastating floods in 1998, when plastic bags clogged drains and delayed water levels falling, Bangladesh

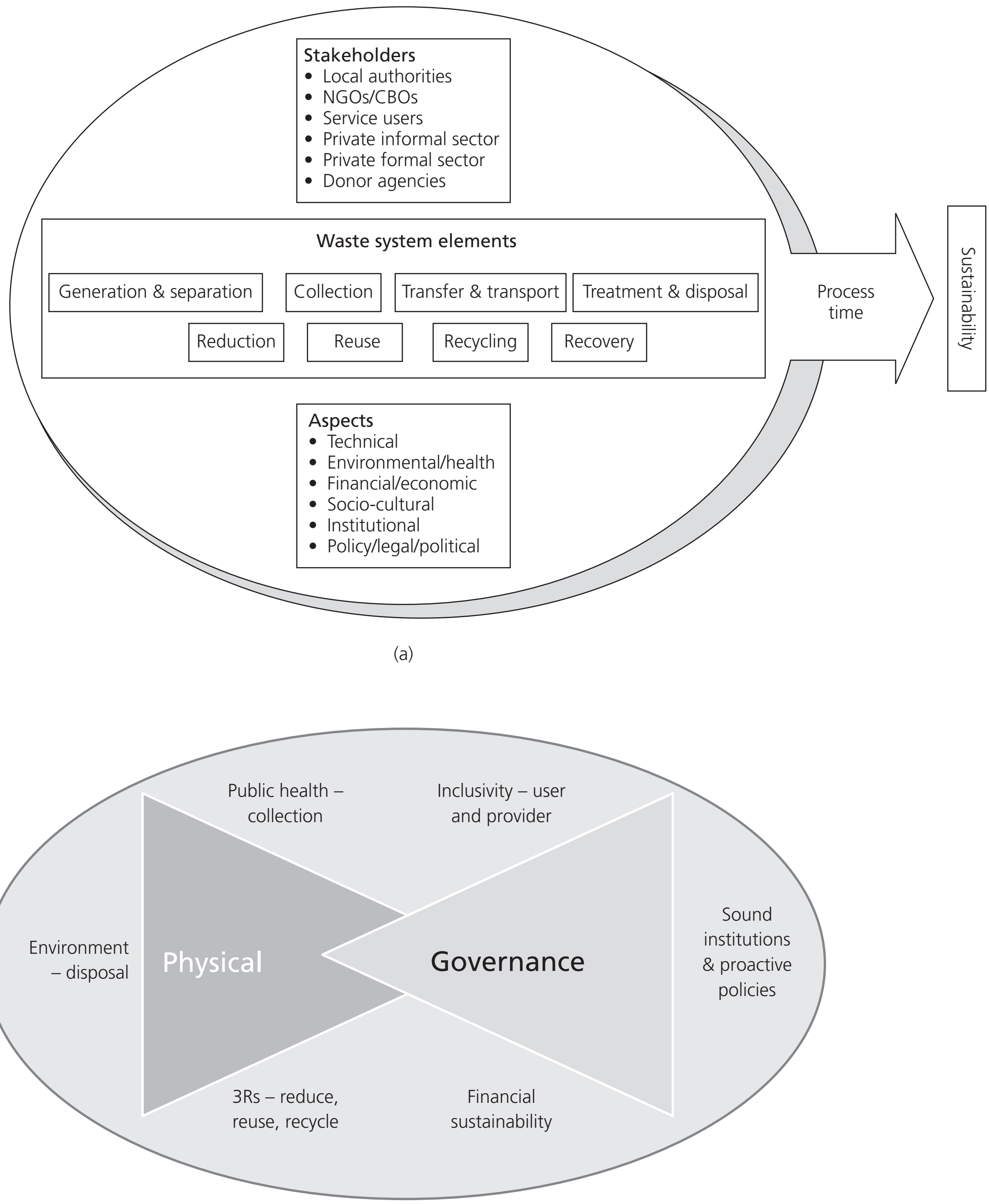

Figure 2. The ISWM framework. (a) Original version (sources: van Klundert and Anschütz (2001) and Anschütz *et al*. (2004); reproduced by permission of WASTE). (b) 'Two triangles' representation (© David Wilson, Costas Velis, Ljiljana Rodic; concept adapted from Scheinberg *et al*. (2010b))

was the first country in the world to ban plastic bags in 2002 (Reazuddin, 2006). Similarly, in response to the disastrous consequences of the monsoon flooding in Mumbai and the entire state of Maharashtra, India in August 2005, including over 900 deaths and billions of rupees (hundreds of millions of US dollars) in material damage, the state of Maharashtra banned the manufacture, sale and use of plastic bags as they were found to have clogged the drains and thus aggravated the situation (Talwar Badam, 2005). The thinnest plastic bags have also been banned in several East African countries (BBC, 2007).

Waste collection is a merit good – a good (service) deemed so important that the law requires that it is provided for the benefit of the entire society, regardless of the interest of the market to supply it or the users' ability (or willingness) to pay for it. The key indicator here is collection coverage or the percentage of the population that has access to waste collection services – in principle, this should be 100%. As of July 2012, The World Bank website was still stating that it is 'common that 30–60% of all the urban solid waste in developing countries is uncollected and less than 50% of the population is served' (World Bank, 2012) – which was the case in the 1990s. The data collected in 2009 on 20 reference cities in six continents for the UN-Habitat book (Scheinberg *et al.*, 2010b) demonstrate that this no longer reflects current reality, as shown in Figure 3.

Over the last decade, cities have made considerable efforts to increase service coverage: almost half of the reference cities, including all but two of the cities with a human development index (HDI) of 0·75 or more (or a gross national income (GNI)/cap above $1600 (Wilson *et al.*, 2012)), report coverage rates of 99–100%. The poorest performing of the middle-income cities have collection coverage in the range of 70–90% population served, while all six of the low-income reference cities show collection coverage in the range 45–60%. Our conclusion on recent progress is reinforced by a recent World Bank report (Hoornweg and Bhada-Tata, 2012) that gives average collection coverage of 86% in upper-middle, 68% in lower-middle and 41% in low-income countries – these figures are somewhat lower than those suggested by data collected by the current authors; the figures come from a much larger sample size, but are somewhat older, with a median date of 2001.

However, all such figures conceal the gap between the 'haves' and 'have-nots'. Within many cities, the central business district and affluent neighbourhoods have near 100% coverage, while low-income and illegal settlements often have none. This clear gap in the performance of the least developed cities means that improving collection must still be their first priority, together with water and sanitation, if public health is to be protected.

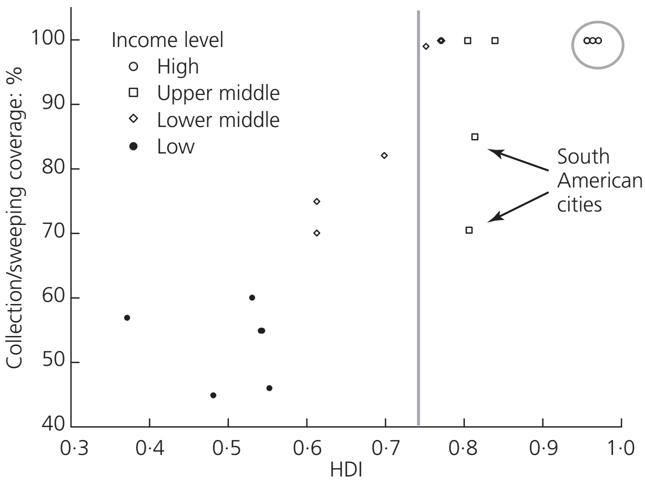

Figure 3. Scatter plot of collection/sweeping coverage against human development index (HDI). HDI measures a country against three basic dimensions of human development – a long and healthy life, knowledge and a decent standard of living (UNDP, 2009). A clear positive correlation is evident. The adjusted squared coefficient of determination R^2_{adj}, indicating the level of variability of collection coverage that can be explained by HDI, is 0·74 for all cities considered and 0·83, if the four western developed country cities at maximum HDI of 1 (circled in the graph) and the two South American cities (arrows) are excluded, suggesting a linear relationship (Pearson's linear correlation coefficient: $r = 0{\cdot}92$, $p < 0{\cdot}001$). A similar correlation is suggested with the logarithmically transported gross national income (GNI) level ($R^2_{adj\ log10GNI} = 0{\cdot}76$) (Wilson *et al.*, 2012). It seems that above an HDI of about 0·75 (vertical line) (corresponding to a GNI/capita of $1600), most cities are capable of achieving a high level of collection coverage (>94%), with the exception of the South American cities. All cities seem able to deliver coverage of at least 45% for an HDI above 0·35. Low-income countries have an HDI < 0·55 and collection sweeping coverage below 60%, forming a separate group (© David Wilson, Costas Velis, Ljiljana Rodic; data from Scheinberg *et al.* (2010b) and Wilson *et al.* (2012))

The barriers and constraints to extending service coverage are often predominantly related to the 'soft' governance issues, as discussed later. Tailoring services to local conditions is particularly important. In informal settlements with poor access, primary waste collection using hand, animal or bicycle carts will likely be appropriate – modernisation does not have to mean motorisation (Coffey and Coad, 2010). In Kunming, China, tricycle carts bring waste to more than 120 small transfer stations where the waste is then transferred to modern vehicles for secondary transport to disposal sites; similar small transfer stations are becoming common in Vietnam and Egypt (Coffey and Coad, 2010).

A major difference between countries is in waste composition: organic content in developed countries averages 28% while that in developing countries is around 67% (Wilson *et al.*, 2012). This makes developing country waste significantly wetter and denser, so that compaction is generally not required to achieve the maximum vehicle loads that the local roads can carry. The use of imported vehicles, for which spare parts are often unavailable, and weak infrastructure for local maintenance are frequent sources of system failure – it is not uncommon for half or more of a city's collection fleet to be out of service at any one time (Coffey and Coad, 2010; Scheinberg *et al*., 2010b). Further discussion of waste collection problems and solutions is provided in a parallel paper (Vaccari and di Bella, 2012).

3.2 Environmental protection (waste treatment and disposal)

When the current phase of solid waste modernisation began in the 1960s, the major driver was newly emerging environmental concerns. The developed countries proceeded in a series of steps (Wilson, 2007), first phasing out or upgrading open dumps to 'controlled disposal' (Rushbrook and Pugh, 1999) and then gradually increasing the standards of leachate and gas control. Progress was relatively slow, so that by 1990, uncontrolled disposal was still significant in five of the then 12 EU member states, with levels over 50% by weight in three (ERL, 1992).

In July 2012, the World Bank website reported that 'in most developing countries, open dumping with open burning is the norm' (World Bank, 2012) – this was the case in the 1990s. However, recent data again suggest that the current reality constitutes a significant improvement (Scheinberg *et al*., 2010b; Wilson *et al*., 2012). Based on 20 reference cities, Table 2 summarises the percentage of collected waste destined for state-of-the-art facilities, simpler 'controlled' disposal sites or uncontrolled disposal. The table shows that both upper- and lower-middle income cities are achieving an average of 95% of their municipal waste collected destined for controlled disposal, while low-income cities are around 50%; such progress over the last decade is impressive when compared to the slow early take-up in Europe up to 1990.

Income level	State-of-the-art disposal: %	Disposal at simple controlled sites: %	Uncontrolled disposal: %
High	100	0	0
Upper-middle	75	20	5
Lower-middle	45	50	5
Low	29	23	49

Data collected in 2009; figures rounded

Table 2. Environmental control – waste disposal across 20 reference cities (adapted from Wilson *et al*. (2010b), Wilson (2011) and Wilson *et al*. (2012))

An engineered, properly operated and controlled landfill site is an essential part of any modern waste management system (Ball and Rodic, 2010; Rushbrook and Pugh, 1999). The driver to improve waste disposal and/or develop engineered landfills has mainly been environmental protection, but often it has taken a disaster to draw the attention of both the public and politicians. In the USA and Western Europe in the 1980s, the impetus was provided by widely publicised incidents of uncontrolled hazardous waste sites, such as Love Canal (e.g. La Grega *et al*., 2000). In a number of developing countries, it has been major accidents involving landslides on unstable waste slopes at uncontrolled solid waste dump sites killing tens or hundreds of people, such as in Istanbul, Turkey in 1993 (Kocasoy and Curi, 1995), Manila, Philippines in 2000 (Kavazanjian and Merry, 2005) and Bandung, Indonesia in 2005 (Koelsch *et al*., 2005). Currently, due to strong protesting from citizens and the sites becoming full, megacities such as Delhi and Mumbai are closing down their existing dump sites (Rodic and Gupta, 2012).

Waste disposal remains a major problem for many low-income countries. The barriers and constraints to improving disposal are often governance issues. Both high capital investment and high operating costs are key barriers. Capital costs are often addressed by seeking international development aid funding (e.g. Lusaka, Zambia – Danish funding by DANIDA; Dhaka, Bangladesh – Japanese funding by JICA). However, most aid agencies will not contribute to ongoing operating costs, so a city's ability to manage operations and pay these costs is critical. Some cities in low-income countries (e.g. Bamako, Mali) have delayed construction of an engineered landfill partly due to the unresolved problem of financing for transport and operation (Keita *et al*., 2010). Other cases include the Jam Chakro landfill in Karachi (Rouse, 2006), where a state-of-the-art landfill site built with aid funding has quickly reverted to an uncontrolled dump due at least in part to a lack of funds for proper operation. In this context, carbon-development mechanism funding for methane recovery from landfills has been significant, as money is only paid out when evidence of proper operation has been provided (Dulac, 2010). Kunming in China and Belo Horizonte in Brazil are among the cities that have done this, but it could be more widely used. Further discussion of waste disposal problems and solutions is provided by Vaccari and di Bella (2012).

Safe disposal by way of thermal processing combined with energy recovery and the numerous variations of mechanical biological treatment plants play a major role in modern advanced solid waste management in developed countries. Much like in Europe in the 1960s, 1970s and 1980s when modern thermal processing technologies were developed and applied to treat growing amounts of waste, large Chinese and Indian cities are considering or opting for thermal processing of their municipal waste. Such technologies, however, are yet to establish their positive track record under the prevailing conditions in developing countries, where municipal solid waste is high in organic content and subsequently moisture, thus possibly rendering waste unsuitable for thermal processing without pre-treatment or the use of support fuel (see, for example, Zhao *et al*. (2012) for the situation in China and Narayana (2009) for India), and where affordability and institutional capacities for adequate operation, maintenance and emissions monitoring are still major issues.

3.3 Three Rs – reduce, reuse, recycle

Prior to the industrial revolution, most cities had few material resources, money was scarce and households had more needs than they could meet. The predominant driver for what we now call solid waste management was the market value of materials and products: wastage was minimised, products were repaired and reused, materials were recycled and organic matter was returned to the soil (Strasser, 1999). Extensive private, entrepreneurial (or 'informal') recycling systems flourished.

Emerging formal municipal waste collection systems in the late nineteenth century displaced these informal recycling systems, which, in combination with increasing availability of goods from cheap mass production, contributed to a decline in recycling practices (Velis *et al*., 2009; Wilson, 2007). With the exception of the two world wars, recycling rates from post-consumer municipal solid waste gradually declined to low single-figure percentages by 1980.

Since the 1980s, high-income countries have been rediscovering the value of recycling (which in this context includes composting) as an integral part of their SWM systems, and have invested heavily in both physical infrastructure and communication strategies to increase recycling. By 1990, the Netherlands and Germany had rebuilt recycling rates to 15–20%wt, with an average of 8%wt over the then 12 EU member states (ERL, 1992); the average recycling rate across the 27 EU members in 2009 was 42%wt (Eurostat, 2011). The driver is not primarily the commodity value of the recovered materials, which was the only motivation of the earlier, informal or private sector, systems. Rather, recycling markets offer a competitive 'sink' as an alternative to increasingly expensive landfilling, thermal processing or other treatment options (Scheinberg, 2011).

Many developing and transitional country cities still have active informal sector and micro-enterprise recycling, reuse and repair systems, driven entirely by the market value of the materials and (discarded) products. These often achieve recycling rates of 20–30%wt, as shown both by the recent data in Table 3 (Wilson *et al*., 2012) and by older literature data (Wilson *et al*., 2009). Moreover, by handling such large quantities of waste that would otherwise have to be collected and disposed of by the city, the informal recycling sector has been shown to save

Income level	Range: %	Average: %	Average contributed by the informal sector: %
High	30–72	54	0
Upper-middle	7–27	15	15
Lower-middle	6–39	27	16
Low	6–85	27	26

Data collected in 2009

Table 3. Recycling rates across 20 reference cities (adapted from Scheinberg *et al*. (2010b), Wilson *et al*. (2010b) and Wilson (2011))

the city perhaps 20% or even more of its waste management budget (Scheinberg *et al*., 2010a, 2011). In effect, the informal recycling sector – in most cases the city poor – is subsidising the rest of the city. There is a major opportunity to build on these existing recycling systems

- to increase further existing recycling rates
- to protect and develop people's livelihoods
- to address the actual and perceived problems of such activities (occupational and public health and safety, child labour, uncontrolled pollution, untaxed activities, crime and political collusion)
- to reduce still further the costs to the city of managing residual wastes.

These challenges of integrating the informal sector with the formal can be addressed, but only if a systematic approach is followed and mutual difficulties are openly acknowledged (Velis *et al*., 2012).

Interestingly, there is some evidence that recycling rates are lower in some of the more developed upper-middle income countries (Table 3), perhaps reflecting the history of the developed world where the early formalisation of solid waste management as a municipal service displaced pre-existing informal recycling systems.

The performance of some countries in the developed world on all of the benchmark indicators discussed so far – collection coverage, controlled disposal, recycling rates – has been exemplary, so one might conclude that they have 'solved' the solid waste management problem. However, when one looks at waste generation rates, the data (Figure 4) show a statistically significant increase in waste amounts generated per capita across cities as the level of development increases (Wilson *et al*., 2012). Moreover, the problem has worsened over recent decades – average household waste generation in the EU was 329 kg per capita per year in 1990 (ERL, 1992) and for the

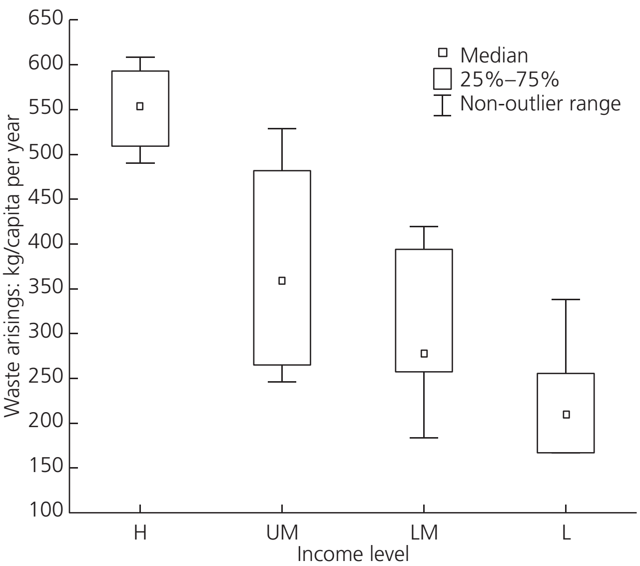

Figure 4. Per capita municipal waste generation across 20 reference cities. Box plots of non-parametric statistics: median, inter-quartile range (25–75%) and non-outlier range are shown. Income level of country cities belong to H (high), UM (upper-middle), LM (lower middle) or L (low). (© David Wilson, Costas Velis, Ljiljana Rodic; data from Scheinberg *et al*. (2010b) and Wilson *et al*. (2012))

same 12 countries, municipal waste generation in 2009 averaged 591 kg (Eurostat, 2011). Even allowing for possible changes in definition, the increase is large – despite recent decreases in some countries, which may reflect efforts to decouple waste generation from economic growth, as well as the effects of the economic recession (Karak *et al*., 2012).

The priorities of good waste management, at the top of the waste hierarchy, are expressed by the '3Rs' – reduce, reuse, recycle (Memon, 2010). Waste prevention, or reducing the quantities of waste being generated, may eventually become the new focus of modernisation in developed countries (Cox *et al*., 2010; Wilson *et al*., 2010a). If development continues on recent trends, then a combination of population growth, rural–urban migration and increases in per capita waste generation are forecast to double municipal solid waste quantities in middle- and low-income countries by 2025 (Hoornweg and Bhada-Tata, 2012), so they too need to be directing attention to bringing waste growth rates under control. Reuse – directly or following repair, refurbishment or re-manufacture – extends the useful life of products. Recycling can be usefully split between 'dry' recyclables, which can be separated, processed and returned to industrial value chains, and organic wastes. The latter include plant and animal wastes from public green spaces, kitchens, gardens and urban agriculture, together with safely managed and treated human excreta. These are sources of organic matter and key nutrients for the agricultural value chain, and their proper utilisation by way of use as suitably processed animal feed, composting or anaerobic digestion is important to soil vitality and food security (Stuart, 2009).

4. Realities and challenges: governance aspects

4.1 Inclusivity

The municipal government is legally responsible for solid waste management in a city, but cannot deliver on that responsibility by prescribing or undertaking measures in isolation, entirely on their own, without active participation of other stakeholders who each have their distinct roles and responsibilities within the system. Besides the municipal authorities, stakeholders include

- users and potential users, who are the waste generators as well as the 'clients'
- providers, including the local municipal department or enterprise, and both the formal and informal private sectors, who actually offer the service
- external agents in the enabling environment, including national government, neighbouring municipalities, producer responsibility organisations and external support agencies (see Figures 1 and 2(a)).

Both (potential) users and service providers are often represented in an inclusive policy and governance process by various NGOs and women's unions; the latter can be important as women more often take the role of 'users' and are prominent as informal service providers (e.g. www.wiego.org).

Good practices in user inclusivity were demonstrated in the reference cities, for example Bamako in Mali, Belo Horizonte in Brazil, Bengaluru in India and Quezon City in the Philippines. Examples include (Rodic *et al*., 2010; Scheinberg *et al*., 2010b)

- communication and consultation of users in strategic planning and siting facilities
- communication and involvement of users in the organisation of day-to-day services
- institutionalising inclusivity through a solid waste 'platform'.

Inclusive plans, prepared in a participatory manner (IJgosse *et al*., 2004; Memon, 2010; Wilson *et al*., 2001), are essential to serve equitably all parts of the (potential) user community, as well as to open economic niches to a range of private formal and informal service providers.

Inclusivity in service provision is important, particularly where municipal services lack the capacity to provide a full service to poor communities and informal settlements – extending service coverage to the whole city is a key priority. A typical example is in Bamako, Mali, where a group of young, educated women founded the first waste collection cooperative as a means of self-employment in 1989. There are now over 120 such Groupement d'Intérêt Économique (GIE) – self-employed micro- and small enterprises that provide primary collection services in the district of Bamako, based on private-to-private arrangements, covering some 57% of households and collecting an estimated 300 000 t of waste per year (Keita *et al*., 2010). Similar community-based enterprises are common in other African capitals, including Lusaka in Zambia, Nairobi in Kenya and Dar es Salaam in Tanzania. Primary collection services may also be provided by groups of informal sector workers organised by NGOs, for example in Delhi, India, and by waste picker cooperatives, for example in Belo Horizonte, Brazil (Scheinberg *et al*., 2010b; Wilson *et al*., 2012). In these cases, organising such a semi-formal collection service also ensures pickers' access to better quality materials for recycling.

Parallel papers in this issue examine vulnerability and resilience in community-based solid waste management, focusing on decentralised composting schemes in India (Zurbrügg and Rothenberger, 2013) and the role of the informal sector in both collection and recycling (Aparcana *et al*., 2013; Linzner and Lange, 2013).

4.2 Financial sustainability

Modern waste management in the developing world is expensive, often costing US$75 or more per capita per year (Brunner and Fellner, 2007; Wilson *et al*., 2012). As a result, financial sustainability is perhaps the most challenging issue for cities in developing countries (Table 4). Recent data show that typically 3–15% of the total recurrent budget of a city is spent on solid waste management (Scheinberg *et al*., 2010b). With budgets typically in the range of US$1–10 per capita, it is all the more remarkable that cities in low- and middle-income countries have achieved the improvements in waste collection coverage and control of disposal facilities already reported. It is imperative that the further necessary improvements are made in a financially sustainable manner. Making service delivery more efficient should reduce unit costs, but many cities can expect to see costs rise substantially due to increases in population, waste generation per capita and standards of disposal. The challenge is thus how to increase regular sources of revenue while at the same time securing significant amounts of investment finance.

However, the current relatively low levels of spending often already stretch what citizens can afford (Table 4). Still, even in slum areas, people are normally willing to pay for appropriate primary collection services in order to keep their immediate living environment clean – particularly if they have been consulted on the service levels, the charging system is transparent and services are provided for locally acceptable prices. Persuading users of the need to pay for modern disposal facilities meeting international standards is considerably more challenging because the benefits are less visible.

Cost recovery from paying users – although considered important – is certainly not the central feature of financial management in developing country cities, as elaborated in Table 4. Waste service fees are just one of several sources used to (re)cover the costs of the system. A few examples include the following (Rodic *et al*., 2010; Scheinberg *et al*., 2010a; Wilson *et al*., 2012).

Income level	City SWM budget per capita: US$	City SWM budget per capita as % of GNI per capita		SWM fee as % of household income	% of population that pays for collection	Reported cost recovery % by way of fees
		Range	Average			
High	75	0·03–0·40	0·17	0·44	99	81
Upper-middle	33	0·14–1·19	0·59	1·40	56	36
Lower-middle	10	0·40–1·22	0·69	0·26	28	27
Low	1·4[a]	0·14–0·52[a]	0·32[a]	0·90	59	22

[a]Budget data only available for three of the six low-income cities (for 16 out of 20 cities in total)
Data collected in 2009

Table 4. Financial sustainability – affordability and cost recovery in 20 reference cities (adapted from Scheinberg *et al*. (2010b), Wilson *et al*. (2010b) and Wilson *et al*. (2012))

- While deliberately keeping the fee low, Belo Horizonte (Brazil) is dedicated to provide 100% coverage and getting all users to pay.
- Kunming (China), Bengaluru (India) and Managua (Nicaragua) also keep the fee low but seem to accept the low payment rate of 40–50%.
- Moshi (Tanzania) and Curepipe (Mauritius) operate cross-subsidising – poor people do not pay.
- In Ghorahi (Nepal), no waste fee is charged to households.

As alternatives, costs are being recovered from a combination of other sources including budgets allocated from central government (Kunming, China), franchise fees (Lusaka, Zambia), property taxes and the sale of municipal land and equipment (Belo Horizonte, Brazil).

4.3 Sound institutions and proactive policies

A strong and transparent institutional framework is essential to good governance in solid waste. Indeed, it was suggested at the 2001 UN-Habitat World Urban Forum that the cleanliness of a city and the effectiveness of its solid waste management system could be useful as a proxy indicator of good governance (Whiteman *et al*., 2001). In order to improve solid waste management, a city needs to address underlying issues relating to management structures, contracting procedures, labour practices, accounting, cost recovery and corruption. The adequacy of services to lower income communities also reflects how successfully a city is addressing issues of urban poverty and equity.

Private sector involvement in service delivery is one option for improving both cost-effectiveness and service quality and coverage. However, private sector involvement in waste management is not simple 'privatisation' – rather, the municipal authorities remain responsible and, as the contracting body, need to have sufficient understanding and capacity to carry out their 'client' function. The conditions necessary for successful private sector involvement include competition, transparency and accountability. They are all required to help ensure that the contracting process is free from corruption and citizens receive the services as contracted (Coad, 2005; Cointreau and Coad, 2000). The concept of pro-poor public–private partnerships (5Ps) develops this approach more explicitly by addressing the need to engage users, the rights of small and micro enterprises and the informal sector, and the obligation to serve poor communities fairly and effectively (see earlier examples in Section 4.1).

In developed countries, public service providers often opt for the principles of so-called 'new public management' (Mongkol, 2011), using instruments normally deployed in the private sector in order to improve performance and increase efficiency. These principles include market orientation, autonomy and decentralisation of authority, and accountability. Some of these principles have also been applied in institutional reforms in developing countries. Arguably, the municipal departments in charge of SWM in developing countries are increasingly developing their customer orientation and are increasingly accountable to the service users through various participation and complaint mechanisms. Due to local conditions, their market orientation is low as they do not strive for cost recovery from fees. Both institutional coherence and financial autonomy are areas that could be improved. While clear budgets and lines of accountability are essential in an efficient and cost-effective organisation, solid waste functions are often dispersed widely through the municipality, so that there is no single department or manager responsible for all the component functions and budgets (Scheinberg *et al*., 2010b).

5. Local solutions can work: two case studies

Research in the 20 reference cities showed that where there is strong political commitment and leadership, and where the local community is actively involved, solutions that are locally appropriate and affordable can be found. The case studies here showcase two of the smaller cities.

Moshi is a small municipality at the foot of Kilimanjaro in north east Tanzania. It has a clear focus on the cleanliness of the city, driven by concerns over public health. The citizens are very supportive – the local Chaga and Pare tribes both hold cleanliness in high esteem in their culture, regardless of income level, and are outspoken if someone litters the street. A stakeholder platform on solid waste has been active since 1999, making strategic and action plans that are subsequently implemented. Pilot projects have been used to test new models of service delivery, involving both the local private sector and community-based organisations (CBOs) that provide primary collection in unplanned settlements. As a result of these joint efforts by multiple stakeholders, Moshi has won the official title of the cleanest city in Tanzania for several years in a row. This is a result of a broader commitment of the council and citizens to urban infrastructure and governance issues, as demonstrated by their active participation in various countrywide initiatives such as the Sustainable Cities Programme and the Urban Sector Rehabilitation Programme. In order to keep the city clean and provide waste collection services to as many people as possible, the service is free to 36% of residents, based on income (Ishengoma, 2010).

Ghorahi is a small and relatively remote municipality in south western Nepal. The municipality has very limited human and financial resources but, due to a clear vision, strong commitment by the authorities and active participation of key stakeholders, it managed to develop a well-managed state-of-the-art waste processing and disposal facility (one of only three in the country) without any form of foreign involvement. The facility includes waste sorting and recycling, sanitary landfilling, leachate collection and treatment, and a buffer zone with forests, gardens and a bee farm that shields the site from the surrounding area. A small initial investment from the municipality budget was used to commission geological studies from the national Department of Mines and Geology and identify a very suitable site that was accepted by the general public. In turn, this convinced the Ministry of Local Development to mobilise national financial support for the construction. The site was brought into operation within 5 years, in 2005. A strong landfill management committee involving local people and key stakeholders ensures that the site is properly managed and monitored, and also giving a sense of ownership – and even pride – regarding the landfill (Tuladhar, 2010). Activities are ongoing to expand waste collection and strengthen recycling in the municipality.

6. Conclusion

Improving solid waste management is a major challenge in developing countries. Obtaining reliable information has been a problem, but recent data collected for 20 reference cities in six continents shows that the current reality has improved significantly over the last 10 years. Collection services are now being provided to 99% or more of urban populations in most countries with a gross domestic income per capita above $1600/day, with coverage of 45–70% in lower income countries. Most cities in middle-income countries are achieving at least a basic level of control for the disposal of more than 95% of their wastes, with control levels of at least 50% in many low-income countries. Extending service coverage to all citizens and eliminating uncontrolled dumping of wastes remain key priorities in most low- and lower-middle income countries.

Recycling rates vary widely, but 20–30%wt is achieved by the informal recycling sector in many low- and lower-middle income countries. This is a stand-alone private sector activity, guided and supported entirely by market prices, and taking place at no direct cost to the city. Building on existing informal sector recycling and integrating it in the formal system presents a huge win–win opportunity precisely because it is already saving many cities millions of dollars and providing livelihoods to large numbers of the urban poor. Such integration will also allow many of the persistent challenges of such activities to be addressed.

A successful solid waste management system needs to address both the physical (technical) elements (collection, disposal, recycling) as well as the 'soft' governance aspects – just think of the public opposition that most (high-income) countries face when siting waste treatment or disposal facilities, or the challenges of changing people's behaviour to increase separate collection for recycling or waste prevention. It is interesting that, despite this, most uses of the term 'integrated waste management' in high-income countries are predominantly technical, focusing for example on integration across the waste hierarchy or with other sources of waste. In developing countries, on the other hand, ISWM is becoming the accepted paradigm in practice, explicitly focusing on both the physical elements *and* the governance aspects (such as inclusivity of both users and service providers), achieving some form of financial sustainability and strengthening institutions to perform their public tasks. This may have to do with different realities – there have been numerous examples where 'proven' technologies have failed in developing countries because sufficient attention was not paid to the 'soft' governance aspects – addressing both sets of factors is essential for a locally sustainable solution. That said, there would seem to be many advantages in applying the ISWM frame, as used here, also to high-income countries.

This paper has used the lens of ISWM to examine how cities in developing countries around the world have been tackling their solid waste management problems, with examples taken largely from 20 reference cities. A basic recommendation is that there are no universally right or wrong answers. Rather, solutions need to be developed locally and tailored specifically to local needs and conditions. Users and potential users need to be involved in designing their own services which, in turn, need to be delivered by a diversity of types of service provider. Critically, those services must be provided at a cost that is locally affordable.

This work has left the authors optimistic – the current reality of solid waste management in developing countries is much better than it was 10 years ago. Although there are still many serious problems and numerous challenges, there are equally many opportunities and examples of city authorities and their communities working together to achieve locally appropriate and sustainable solutions. The evidence suggests that sustainable solid waste and resources management is feasible for developing countries and that further steady progress can reasonably be anticipated.

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