‘Wasteaware’ Benchmark Indicators for Integrated Sustainable Waste Management in Cities

David C Wilson*[,1], Ljiljana Rodic[2], Michael J Cowing[3], Costas A Velis[4], Andrew D Whiteman[5], Anne Scheinberg[6], Recaredo Vilches[1], Darragh Masterson[1], Joachim Stretz[7] and Barbara Oelz[8]

[1] Civil and Environmental Engineering Department, Imperial College London, United Kingdom
[2] Education and Competence Studies, Wageningen University and Research Centre, The Netherlands
[3] Independent Consultant, St Lucia
[4] School of Civil Engineering, University of Leeds, UK
[5] RWA Group, Sofia, Bulgaria
[6] WASTE, Gouda, The Netherlands
[7] Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ), Cairo, Egypt
[8] GIZ, Eschborn, Germany

* Corresponding author: David C Wilson. E-mail: waste@davidcwilson.com. Telephone: +44 118 946 1117. Address: Department of Civil & Environmental Engineering, Imperial College London, Skempton Building, South Kensington Campus, London SW7 2AZ, UK.

ABSTRACT

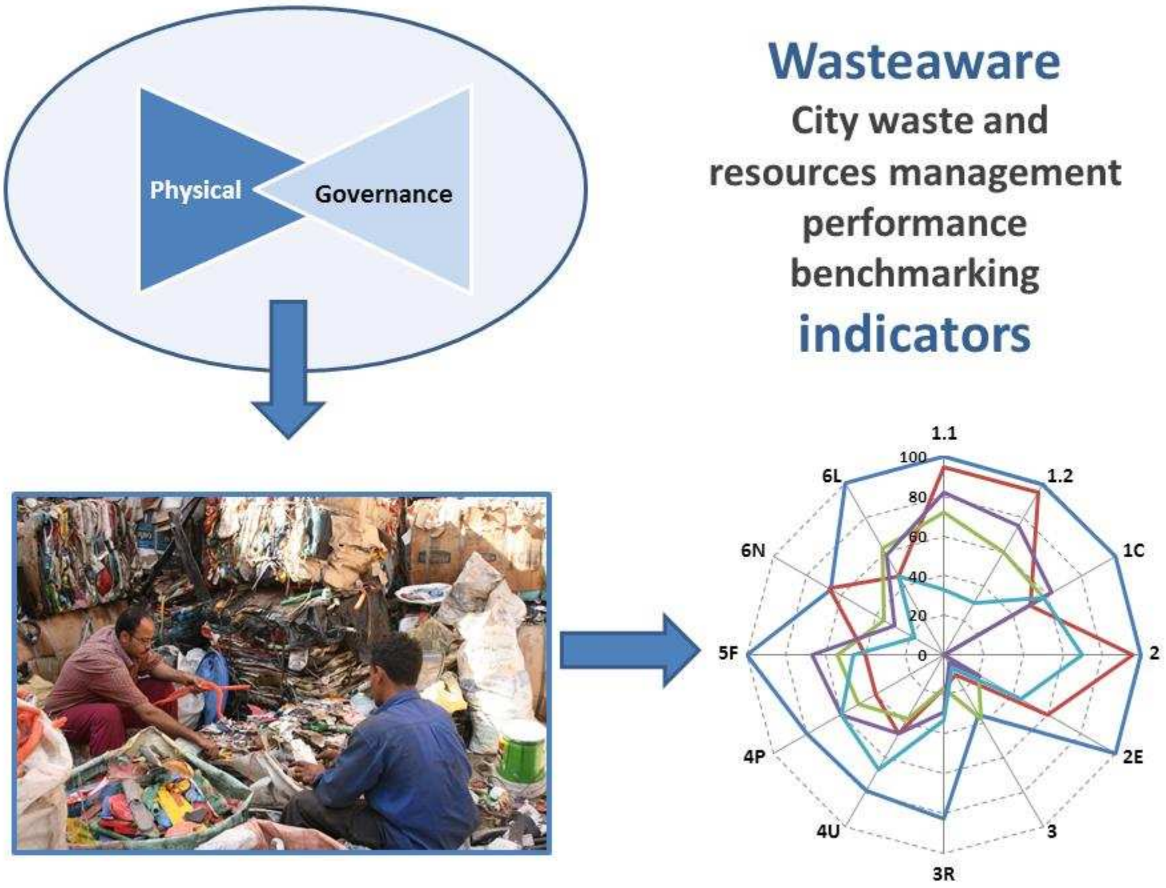
This paper addresses a major problem in international solid waste management, which is twofold: a lack of data, and a lack of consistent data to allow comparison between cities. The paper presents an indicator set for integrated sustainable waste management (ISWM) in cities both North and South, to allow benchmarking of a city’s performance, comparing cities and monitoring developments over time. It builds on pioneering work for UN-Habitat’s *Solid Waste Management in The World’s Cities*. The comprehensive analytical framework of a city’s solid waste management system is divided into two overlapping ‘triangles’ – one comprising the three physical components, i.e. collection, recycling, and disposal, and the other comprising three governance aspects, i.e. inclusivity; financial sustainability; and sound institutions and proactive policies. The indicator set includes essential quantitative indicators as well as qualitative composite indicators. This updated and revised ‘Wasteaware’ set of ISWM benchmark indicators is the cumulative result of testing various prototypes in more than 50 cities around the world. This experience confirms the utility of indicators in allowing comprehensive performance measurement and comparison of both ‘hard’ physical components and ‘soft’ governance aspects; and in prioritising ‘next steps’ in developing a city’s solid waste management system, by identifying both local strengths that can be built on and weak points to be addressed. The Wasteaware ISWM indicators are applicable to a broad range of cities with very different levels of income and solid waste management practices. Their wide application as a standard methodology will help to fill the historical data gap.

KEYWORDS: benchmark indicators; performance monitoring; solid waste management; governance; developing countries; collection coverage; recycling rates; controlled disposal

ABBREVIATIONS USED[1]

[1] (Non-standard) abbreviations used in the paper: ISWM - integrated sustainable waste management. 3Rs - reduce, reuse, recycle. GIZ - Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH. GNI - Gross National Income. MSW - municipal solid waste.

GRAPHICAL ABSTRACT



HIGHLIGHTS

- Solid waste management (SWM) is a key utility service, but data is often lacking
- Measuring their SWM performance helps a city establish priorities for action
- The Wasteaware benchmark indicators:
    - measure both technical and governance aspects
    - have been developed over 5 years and tested in more than 50 cities on 6 continents
    - enable consistent comparison between cities and countries and monitoring progress

1. INTRODUCTION

Solid waste management is one of the most important functions of a city government, as a key utility service on which the public health and the external 'image' of a city depend. On the one hand, uncollected solid waste is still a serious public health issue in many developing countries, with both direct effects on child health, and indirect effects through blocked drains causing the spread of water-borne diseases and widespread flooding (Wilson, et al., 2013c); on the other, a clean city is attractive to tourists, business people and investors. It has been suggested that the effectiveness of a city's solid waste management system can be used as a proxy indicator of good governance (Whiteman, et al., 2001), and hence of a local government who can be trusted and with whom one can do business. Appropriate benchmark indicators allow a city to judge its own performance regarding delivery of solid waste management services, provide information for decision-making on priorities for the limited funds available for service improvements, and monitor changes over time. In addition, internationally consistent indicators, which make possible comparison of the cities' performance irrespective of their income level, are useful in various contexts, including for example, development cooperation efforts aiming at better protection of public health and the environment, increased resource recovery, and better urban governance; and also in comparing different policy approaches in 'similar' countries.

Interest in performance indicators for solid waste management is long-standing. MacDonald (1996) examined bias issues in the then-standard set of three benchmark indicators: waste generated per capita; proportion of waste being managed by different methods; and proportion of households with a regular collection service. Similar indicators are still used as part of composite sustainable development indicators in cities (Tanguay, et al., 2010); an example is the Global City Indicators Facility (GCIF, 2012), which does promise an improvement in the current level of availability of comparable data as more cities sign up. Currently the best that the literature can offer on a worldwide basis is compilations of older data, of dubious comparability and often just at the national level (Chalmin & Gaillochet, 2009; Hoornweg & Bhada-Tata, 2012; Karak, et al., 2012).

There has been much recent attention to developing indicators for particular aspects of 'modernising' a solid waste management system. Most of the published research has focused on high-income countries, with only a few that have focused on developing countries (designated here with a *). Examples include indicators for waste prevention (Wilts, 2012), for zero waste management systems (Zaman and Lehmann, 2013; Zaman 2014 a, b) and for 3R (reduce, reuse, recycle) policies to transition from waste management to resource management (Hotta, 2014*); for extended producer responsibility systems (Wen, et al, 2009); for tracking compliance with European Union requirements (Cifrian, et al., 2010, 2012, 2013; Fragkou, et al., 2010; Nicolli, 2012) or to rank the performance of US cities (Greene and Tonjes, 2014); for recycling systems (Suttibak and Nitivattananon, 2008*); for selective collection for recycling (Bringhenti, et al., 2011*; Caio and Fernando, 2013*; and Passarini et al., 2011); for waste collection (Kagiannidis, et al., 2004; Huang, et al., 2011); and for comparing technologies for waste treatment, recycling and disposal (Machettini et al., 2007; Chirico et al., 2010; Handakas and Saragiannis, 2012; Coelho, et al., 2012*; Manikpura, et al., 2012, 2013*). Indicators for comparing and selecting technologies overlap with the use of life cycle analysis (LCA) in solid waste management. The literature here has been reviewed for example by Cleary (2009), Del Borghi et al. (2009), Michaud, et al. (2010) and Laurent et al (2014a, b).

A notable recent attempt to develop benchmark indicators and apply them to the comparison of cities both North and South was the report prepared for UN-Habitat on the state of solid waste management in the World's cities (Scheinberg, et al., 2010). A large international team took up the challenge of collecting new data for 20 'representative', reference cities in low-, middle- and high-income countries across all six inhabited continents; and a set of Integrated Sustainable Waste Management (ISWM) benchmark indicators was defined for waste systems, covering both physical components and governance aspects. A detailed comparison of the results for the 20 reference cities was subsequently undertaken (Wilson, et al., 2012). The results also inspired the authors to revisit what we really mean by 'good practice' in solid waste management (Wilson & Scheinberg, 2010; Wilson, et al., 2013c).

The UN-Habitat work is not the only recent attempt to develop benchmark indicators to compare solid waste management systems in cities. Several proposals and/or theoretical frameworks for indicator sets have been made: Desmond (2006) proposed an indicator set for use in Ireland; Beccali, et al. (2007) proposed the application of the Dashboard of Sustainability; Armijo, et al. (2011) proposed an indicator set using the Driving Force-Pressure-State-Impact-Response (DPSIR) model; and Guimarães, et al. (2010) proposed a Balanced Scorecard (BSC) approach. Some proposals have been tested in one case study city, e.g. Polaz and Teixeira in Brazil, Sharma, et al. (2010) in India and Mendes, et al. (2012,2013), who applied a BSC methodology in Portugal. Munizaga and Garcia (2013) have recently proposed an indicator set termed the 'Garbometer', which is currently being tested in Spain. Perhaps the most developed of these alternative approaches is the ten solid waste management indicators which are being tested in over 400 urban local bodies in the two Indian states of Gujarat and Maharashtra as part of a 5-year project to develop and demonstrate a performance measurement framework for urban water and sanitation (CEPT University, 2010).

The work reported here has used the set of ISWM benchmark indicators developed in the original work for UN-Habitat as its starting point – they remain the broadest in their coverage of both physical and governance components; the most widely tested across a number of countries; and the only indicators that have both the ambition to be, and the experience of having been, applied across the full range of income levels. Experience in their use led first to an intermediate update, which was tested in a further five cities as part of a 2012 GIZ project (Soos, et al., 2013), and subsequently reported on at the ISWA World Congress 2013 (Wilson, et al., 2013b). This intermediate update was further tested in another 12 cities, with the cumulative results and feedback used as the basis for the comprehensive update and revision presented in this paper.

We have called the final indicator set the 'Wasteaware' ISWM benchmark indicators, in order to reflect one of their primary purposes of raising stakeholder awareness of the state of the local solid waste management system. If they are widely applied in the future as a standard methodology, that will help to address the historical lack of comparative data on solid waste management in the World's cities.

2. METHODOLOGY & APPROACH TO DEVELOPING THE BENCHMARK INDICATORS

2.1 Analytical framework – ISWM and 'UN Habitat' ISWM indicator set

The analytical framework is built around the concept of integrated sustainable (solid) waste management (ISWM) (Schübeler, 1996; Van de Klundert & Anschütz, 2001; IJgosse, et al., 2004). The ISWM framework distinguishes three dimensions for analysis of solid waste management and recycling systems: the physical system and its technological components, sustainability aspects (social, institutional, political, financial, economic, environmental and technical) and the various groups of stakeholders involved. This was simplified in the UN-Habitat work to two 'triangles' as shown in Figure 1 below, the physical components and the governance aspects, with the stakeholders implicitly included in the measures around "inclusivity".

The first 'triangle' focuses on three key drivers for development of waste management (Wilson, 2007), corresponding to the three key physical, 'hardware' components: protection of public health which depends on a good waste collection service; environmental protection particularly during waste treatment and disposal; and resource value, the '3Rs' – reduce, reuse, recycle. The second 'triangle' focuses on ISWM 'software', the governance strategies to deliver a well-functioning system. These have been identified as inclusivity, allowing stakeholders to contribute and benefit, both as service users and service providers; financial sustainability, ensuring that solid waste management services and activities are cost-effective and affordable; and a base of sound institutions and pro-active policies.

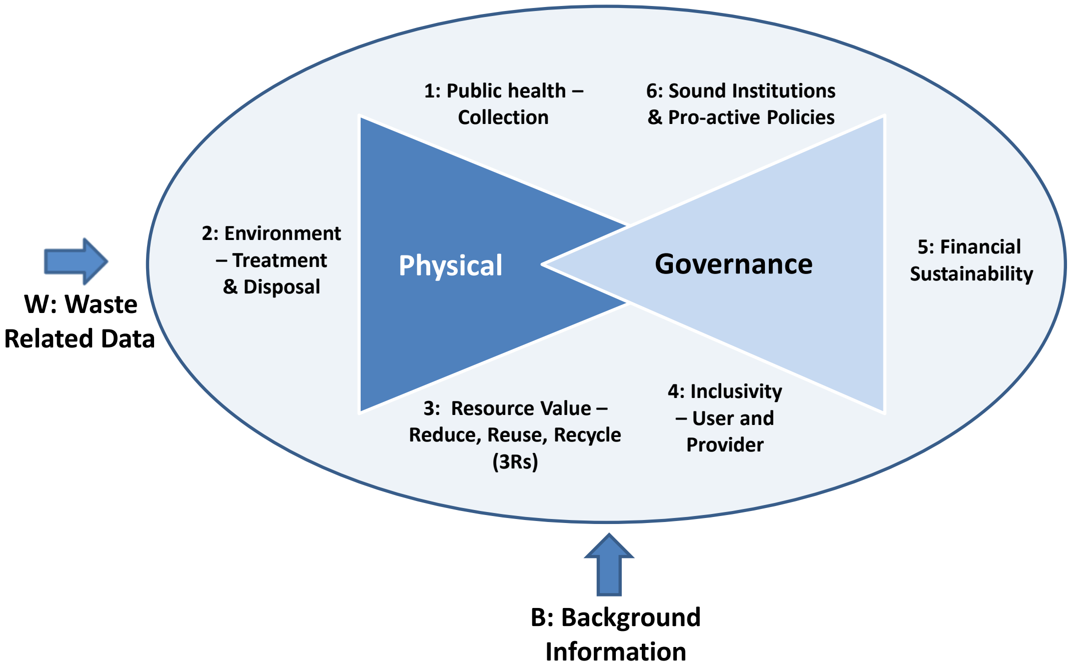


Figure 1: The Integrated Sustainable Waste Management (ISWM) framework used by the Wasteaware indicator set. This is a simplified version of the original ISWM concept (Schübeler, 1996; Van de Klundert & Anschütz, 2001; IJgosse, et al., 2004). This 'two triangles' analytical framework was first devised for the UN-Habitat methodology (Scheinberg, et al., 2010), grouping together the three physical components and the three governance aspects, as represented by the two triangles. This version of the figure was drawn by Darragh Masterson. Figure © David Wilson, Ljiljana Rodic, Costas Velis.

Accordingly, the original 'UN-Habitat' ISWM benchmark indicators were developed using – and recombining – the 300 data-points for which information had been sought for each city. One quantitative indicator corresponded to each of the three physical components. Two of these – percentage waste collection service coverage corresponding to public health and percentage recycling corresponding to resource value (3Rs) – follow widespread international practice (GCIF, 2012). The third, pertaining to disposal for environmental protection, was novel, being the percentage of total waste which goes to any sort of controlled disposal (Rushbrook & Pugh, 1999) or treatment facility rather than to open or uncontrolled dumping or open burning. In addition, a fourth quantitative indicator, total waste captured by the waste management and recycling system, was introduced to provide a useful cross-check on both collection coverage and controlled disposal.

For financial sustainability, a range of quantitative data points was available related to the solid waste budget and the effectiveness and affordability of cost recovery mechanisms; unfortunately, data on actual costs, and particularly on costs per tonne of waste handled by the system, were often either unavailable or inconsistently reported in the initial 20 cities. Consequently, the quantitative indicator ultimately selected was the percentage of total number of households both using and paying for waste collection services. For the remaining governance aspects, qualitative indicators were constructed for user and for provider inclusivity, and for sound institutions & pro-active policies, each comprising five or six criteria, which were assessed on a nominal scale (yes/no answers to a series of questions) (Scheinberg, et al., 2010; al-Sabbagh, et al., 2012; Sim, et al., 2013).

The UN-Habitat methodology was tested on at least 25 cities, the results for 22 of which have been published (Wilson et al, 2012; Al Sabbagh, et al., 2012; Sim, et al., 2013). The cities were chosen to provide a wide representation across all six inhabited continents and the four standard categories of income level (low-, lower-middle-, upper-middle- and high-income; World Bank, 2012). The new approach proved to be both very useful and a substantial step forward from the then existing situation in terms of adequately measuring performance for both 'hard' physical components and 'soft' governance aspects, and in prioritising 'next steps' in developing a city's solid waste management system by revealing both the local strengths that can be built on and any weaker points which would merit priority attention. Moreover, the UN-Habitat methodology departed from most previous work on indicators by comparing cities on a consistent basis even when they have very different levels of income.

The comparative analysis revealed some interesting and perhaps unexpected findings, including the significant progress that has been made in middle income countries over the last decade in improving collection coverage and introducing basic environmental control over disposal; the relatively high recycling rates in some of the lowest income countries, due to an active informal recycling sector that makes their livelihood from extracting saleable materials from the waste; and relatively patchy performance against the qualitative governance indicators even among the high income countries (Wilson, et al., 2012; Wilson, et al., 2013c).

2.2 The methodology for updating the indicator set

Experience with using the original UN-Habitat ISWM indicator set also pointed up some weaknesses and opportunities for improvement, which have been addressed in a series of phased updates, resulting in the 'Wasteaware' indicator set presented in this paper. These improvements are discussed below, as appropriate.

The first major revision was carried out in 2012 in conjunction with a study commissioned by GIZ which focused on comparing the 'operator models' used to deliver waste management services in cities around the world (Soos, et al., 2013; Garcia Cortes, et al., 2013; Wilson, et al., 2013a). For the project, an interim revised indicator set was first developed and used in five locations in low and middle-income countries; user feedback then led to some additional modifications, and the indicators for the five locations were updated. In doing so, the project developed five case studies: Maputo Mozambique (low-income); Qena Egypt and Surat India (lower-middle-income); Castries St Lucia and the CIGRES inter-municipal association Brazil (upper-middle-income); the indicator set was used to provide a uniform methodology for their characterisation. This first or intermediate update of the ISWM indicator set became available at the end of 2012; it was described in a 'progress report' to the 2013 ISWA World Congress (Wilson, et al., 2013b); and both the user manual and full indicator forms for the five case studies have been published (Wilson and Cowing, 2013).

The intermediate update of the ISWM benchmark indicators was further tested during 2013 across a wide range of cities: of the 11 cities for which results became available within the timeframe, four were updates of earlier UN-Habitat indicator sets (marked *), while seven were new applications, across a range of income levels. The cities were: Dhaka* Bangladesh and Monrovia Liberia (low-income); Bangalore* India, Jakarta Indonesia, Kampala Uganda and Lahore Pakistan (lower-middle-income); Sofia Bulgaria (upper-middle-income); Adelaide* Australia, Bahrain*, Belfast Northern Ireland and Singapore (high-income). Additionally, the intermediate indicator set was used to establish the baseline situation in 19 cities and larger villages in one country (Egypt) (Zaki, et al., 2013). The cumulative results and feedback from all the users to date, and from a number of independent experts acting as peer reviewers, provided the basis for the comprehensive update and revision presented in this paper. Again, this second round of major revision and updating was carried out in two stages, with an interim version being prepared and further tested ('debugged') in Guadalajara in Mexico (which filled an obvious gap – a developing, upper-middle-income country – in the list of test cities), prior to finalising the revisions.

Since the Wasteaware ISWM benchmark indicators have been completed, an automated excel indicator form has been developed to make them easier to use in practice. This has been further tested and debugged in a number of cities as follows, both to update an earlier version of the indicators: Rotterdam* Netherlands (high-income); Castries St Lucia (upper-middle-income); Nairobi* Kenya and Bishkek* Kyrgyzstan (low-income); and in additional cities: the conurbation of Buenos Aires Argentina (upper-middle-income); Warangal India (lower-middle-income); and Dar-es-Salaam, Tanzania (low-income).

3. REVISED ISWM INDICATORS: OVERVIEW

The aim of the Wasteaware ISWM benchmark indicators is to use existing data, not to carry out primary survey work. The results are intended to provide an overview of a city's solid waste management performance, to reveal clearly those aspects which are performing well and not so well, in order to point the way to next steps on the road to improvement, and to allow benchmarking against other cities. It is important to note that this is not a 'scoring' mechanism, and the intention is not to produce any single overall or absolute number as a performance index.

The scope includes all municipal solid wastes – defined as waste from households plus waste of a similar composition from other sources in the city (Scheinberg et al, 2010). This generally means including some commercial and industrial wastes from small shops and offices, together with small-scale construction and demolition wastes from household repairs. Commercial and industrial process wastes from larger industries and 'bulk' construction and demolition wastes are generally excluded. It is important for transparency that each city reports clearly the precise definition that it is using – these do vary a lot among countries.

The system boundary includes both public and private activities in waste management, along with reuse and recycling of valuable resources contained in the waste. This has become standard practice over the last 30 years as solid waste management systems have been modernised in high-income countries, although the 'waste industry', responsible inter alia for municipal recycling, and the long established secondary materials industry are still in many ways separate industrial sectors (Scheinberg, 2011). In addition, many city authorities in developing countries view their waste management systems as quite distinct from the largely informal recycling systems which exist alongside (Linzner and Lange, 2013; Wilson, et al, 2013c): both are explicitly considered here. Informal service providers working in the private waste service sector are defined primarily in terms of their lack of a formal, recognized status within the municipally-organised solid waste management system – they can be and often are registered with the authorities and pay taxes (Velis, et al., 2012).

The analytical framework of the 'two triangles' version of ISWM has been retained. The graphical representation in Figure 1 now explicitly shows that a summary of background and waste-related data is required to interpret the indicators and provide a proper comparison between cities.

The supporting information has been reduced to a reasonable minimum, so as to complement the indicators. General background information comprises the gross national income (GNI) per capita for the country and the corresponding income category (World Bank, 2012); the population; and the total municipal solid waste (MSW) generation. Key waste-related data comprise the calculated MSW generation per capita per year and six components of MSW composition which both vary most between cities (Wilson, et al., 2012) and are important for resource recovery and/or technology selection. The six items are four basic composition categories: organic (food and green waste) fraction; paper and cardboard; plastics; and metals; plus two over-arching physical parameters: waste density, and moisture content.

The original three main quantitative indicators for the physical components have proved their merit in terms of their being informative, practical and available, and have been retained. The fourth, waste captured by the system, proved quite difficult to measure on a consistent basis, and was not included in the published comparison of the original 20 cities (Wilson, et al., 2012). However, feedback from the subsequent testing of the first updated indicator set suggested that in some cases collection coverage could be high, but that this did not adequately measure uptake of collection services – the recommendations for an additional indicator were very similar to the original 'waste captured', so this has now been reinstated.

The experience with the application of the existing quantitative indicators in various cities also revealed a need to refine them beyond a numerical score so as to discern significant differences in performance levels between cities with apparently similar scores: e.g. even if collection coverage in a middle income city is close to 100%, the quality of the collection service may not yet be comparable to the best systems in the region. So the quantitative % indicator(s) for each physical component are now complemented by a composite, multi-attribute 'quality' indicator assessed against five or six component criteria.

Separating the physical components of a waste and resource management system into just three parts is a simplification and requires some compromise judgments to be made. Component 1 is driven primarily by public health and focuses on waste collection, but also includes waste transport and transfer prior to delivery at a treatment or disposal facility. As such, it is not even on the waste hierarchy. Component 2 is driven by environmental protection and focuses both on eliminating uncontrolled disposal, bringing waste management onto the bottom level of the waste hierarchy, and also on the technologies for proper treatment and disposal.

Component 3 is driven by the resource value of the waste, and focuses on the '3Rs' at the top of the waste hierarchy - reduce, reuse, recycle.

One key issue is under which component the various available technologies for waste treatment are assessed. The conventions adopted here can be summarised as follows:

i. Component 3 includes materials recycling but not energy recovery, as per the definition of the 3Rs and of the waste hierarchy.
ii. Organics valorisation (including composting, anaerobic digestion and animal feeding) and dry materials recycling from both waste sorting and waste treatment facilities all 'count' towards the recycling rate, indicator 3.
iii. All waste treatment facilities are assessed for their environmental impact under component 2.
iv. As discussed below, one of the multi-attribute components of criterion 2E explicitly assesses energy efficiency, for those cases where energy recovery is a major objective of the treatment system.

Linking the physical components with key drivers is very useful for ease of presentation, but is a simplification of reality. Public health is the primary driver for waste collection (component 1) – but health and safety are included as an explicit criterion in assessing all three 'quality' indicators 1C, 2E and 3R. Similarly, environmental protection is the primary driver for component 2, where the focus is on waste treatment and disposal – but environmental protection in collection and in reuse and recycling is considered as well, in at least two criteria under 1C and as an explicit criterion under 3R.

Most of the governance indicators in the original UN-Habitat indicator set were composite, qualitative indicators, but that for financial sustainability was quantitative: the % of total households both using and paying for waste collection services. While being novel and informative, this addressed just one specific component of financial sustainability. So a composite, multi-attribute 'qualitative' financial sustainability indicator has been devised instead, assessed against six criteria.

The original UN Habitat qualitative indicator for sound institutions and pro-active policies used a mixture of criteria, some of which were assessed at the national and some at the city level, which made it relatively insensitive to differences when comparing the performance of cities within the same country. In the revised version, there are now two separate indicators, one for the National Framework (which will generally remain constant for all cities within the same country, although allowance is made for it to vary between different States or Provinces in a Federal country), and the other for Local Institutions. The criteria for both user and provider inclusivity have also been extensively revised.

In the revised Wasteaware ISWM indicator set, there are now eight composite, multi-attribute, 'qualitative' indicators, based on assessment against five or six criteria for each. This assessment was originally at a nominal scale (yes/no, or latterly yes/maybe/no in Sim, et al. (2013)); this has now been changed to an interval scale (Stevens, 1946), consisting of a standardised, five-fold scoring system with a score of 0, 5, 10, 15 or 20 being assigned against each criterion. The scores for each of the criteria comprising a qualitative indicator are summed together into a score for that indicator, which allows the very different aspects of performance – each ideally being assessed by its own distinct and traceable criterion – to be combined into one indicator. Methodologically, this assessment is consistent with Likert type measurement scales (Likert, 1932; Carifio and Perla, 2008), where the scores are assigned to answer choices to individual questions (Likert items that measure the same concept); these scores are summed together to get the overall Likert score for the qualitative indicator.

The resulting score is then converted into a qualitative assessment of the system's performance regarding that indicator. This qualitative assessment is also five-fold, to match the scoring system for the individual criteria comprising the indicator. In addition, resulting ranges of scores have also been colour-coded using a 'traffic lights' system, to assist with a rapid visual assessment of the tabulated data and to illustrate, at a glance, areas of performance requiring immediate attention – as denoted by the colour red. The convention used is that an assessment of LOW corresponds to an overall score in the range 0-20% and is coded as red; LOW/MEDIUM to 21-40% and red-amber; MEDIUM – 41-60%, amber; MEDIUM/HIGH – 61-80%, amber-green; and HIGH – 81-100%, green. In the examples shown later, the colour amber (orange) is also shaded, to make the colour coding more legible for the colour-blind as well as when printed in black and white.

The same traffic lights coding system from LOW to HIGH has been used to rate performance for each quantitative indicator. The values that are currently considered good practice differ, which means that the indicators do not follow the same gradation pattern when assessing relative performance, and that gradation is not linear. This ‘normalisation’ is presented in Section 4 below.

A complementary means of visualising the results is through a radar diagram, which shows a city’s performance against all 12 indicators on a zero to 100 scale. The main difference is that the traffic lights ‘normalise’ performance against all the indicators into a five-fold scale from ‘low’ (red) to ‘high’ (green), while the radar diagram shows the scores against each indicator without such normalisation. Hence, the radar diagrams omit the normalisation step for the quantitative indicators against an agreed standard of good practice, which is likely to change over time as better performance standards are achieved worldwide; as a result, the radar diagrams do require more interpretation on the part of the user.

The role of the ‘user’ – the person or persons applying the indicators – is very important; ideally this will be (or include) a local solid waste professional who is familiar with the local situation, covering both the formal solid waste and possible informal recycling parts of the overall system. Consistency in application of the Wasteaware ISWM benchmark indicators is critical – eight of the 12 main indicators here are composite indicators based on a qualitative assessment against a series of criteria where the user needs to apply their professional judgment. So the User Manual provides detailed guidance on definitions used, interpretations and the scoring system used for each criterion– this is provided as Supplementary Information accompanying this paper. Prospective users are also provided with one or two worked examples, showing how the indicators have been applied to other cities to assist in orientation. It is important that the Indicator Form completed by the user contains as much detail as possible on the sources, assumptions, local definitions (e.g. the definition of ‘municipal solid waste’), information used and the rationale behind the scores; such traceability is essential also for the transparency of the assessment process, so that anyone reading the assessment report can immediately know where the information came from and how it was scored. Wherever possible, the user should provide supplementary evidence, such as available reports, photographs of the waste management system, and other sources, alongside the completed Indicator Form.

4. REVISED ISWM INDICATORS: PHYSICAL COMPONENTS

The Wasteaware ISWM benchmark indicators for the physical components of the system include four quantitative indicators, as shown in Table 1, plus three multi-attribute, composite indicators of the ‘quality’ of service provision for each component, as shown in Table 2, 3 and 4.

In Table 1, indicator 1.1, waste collection coverage, focuses on access to a reliable waste collection service; indicator 1.2, waste captured by the system, quantifies the actual percentage of waste generated that is handled by the waste management system; and indicator 2 represents the percentage of waste destined for treatment or disposal that is handled in at least a ‘controlled’ facility. Each requires information from a materials flow diagram for their accurate estimation. An excellent system will score 100% for all three; but in cities still developing their solid waste management system, these three indicators when taken together reveal complementary information about complex local realities. Where wastes are collected regularly by either formal municipal or informal sector collectors, this counts towards a higher value of indicator 1.1; but if the waste is then disposed off at a ‘wild’ dumpsite rather than an officially recognised site that charges a gate fee, or even dumped into a nearby river, this information will be revealed and reflected in a lower value of indicators 1.2 and 2. Similarly, indicator 1.1 will measure ‘access’ to a pay-for-use service, while indicator 1.2 will measure the actual uptake of that service, as users may opt out of the system, choose not to pay, and instead burn or ‘fly-tip’ their wastes – such practices are quite widespread, for example in many neighbourhoods in African cities and in apartment blocks across the former Soviet Union.

The User Manual provides further elaboration of the definitions used for each of the quantitative indicators. Indicator 3, the recycling rate, includes both formal and informal recycling (Velis, et al., 2012); and both dry recyclables and organic valorisation (from composting, anaerobic digestion and animal feed); quantities collected for recycling should be adjusted downwards to allow for any materials subsequently rejected and sent to disposal or thermal treatment; and materials recycling from treatment plants, including e.g. paper or plastics recycling at MBT plants or metals recovery from waste-to-energy bottom ash, is ‘counted’ here.

Table 1: The four quantitative indicators for the physical components of a solid waste management system

No.	Physical component	Indicator name and definition	Traffic light colour coding				
			LOW	LOW/ MEDIUM	MEDIUM	MEDIUM/ HIGH	HIGH
1.1	Public health - waste collection	**Waste Collection Coverage**: % households who have access to a reliable waste collection service	0-49%	50-69%	70-89%	90-98%	99-100%
1.2		**Waste Captured by the solid waste management and recycling system:** % of waste generated that is collected and delivered to an official facility	0-49%	50-69%	70-89%	90-98%	99-100%
2	Environmental control - disposal	**Controlled treatment or disposal**: % of the total municipal solid waste destined for treatment or disposal which goes to either a state-of-the-art, engineered or ‘controlled’ treatment / disposal site	0-49%	50-74%	75-84%	85-94%	95-100%
3	Resource value - ‘3Rs’ - Reduce, reuse, recycle	**Recycling rate**: % of total municipal solid waste generated that is recycled. Includes materials recycling and organics valorisation (composting, animal feed, anaerobic digestion).	0-9%	10-24%	25-44%	45-64%	65% and over

As explained in Section 3, the complementary multi-attribute composite or ‘qualitative’ indicators are summarised as a fivefold assessment of relative performance, corresponding to a ‘traffic-light’ coding. Table 1 provides a similar conversion for the quantitative indicators, showing what values for each indicator can be considered as demonstrating both relatively good and relatively poor performance. Obviously, the values that are currently considered good practice differ for each physical component, which means that the indicators do not follow the same gradation pattern when assessing relative performance, and that gradation is not linear. For example, collection coverage or waste capture or controlled treatment and disposal at 50% is relatively low, while a recycling rate of 50% is relatively high. It is worth noting that reaching agreement on Table 1 was one of the major challenges faced by the project team – assigning the categories is both a matter of judgment and would vary from the point of view of countries at different stages of the modernisation process. Table 1 thus represents a compromise that is reasonably applicable across the full span from high- to low-income countries. It would be possible to define alternative versions for use in particular applications where the focus of comparison is narrower, such as comparing cities across a single country, or comparing cities across the European Union.

These quantitative indicators are now supplemented by a multi-attribute, composite indicator of the quality of service provision for each physical component, assessed using best professional judgment against a defined set of six criteria. The User Manual provides full details of the assessment and scoring systems defined for all of these ‘qualitative’ criteria. To encourage consistent assessment by users in different cities, the User Manual is as explicit as possible, but the level of detail possible varies widely between the criteria. Regarding the allocation of scores, one frequently used scheme is to explain for the particular criterion what a high compliant operation would look like: scoring is then based on the users assessment - no compliance scores 0, low compliance scores 5, medium 10, medium/high 15 and high 20.

Table 2 sets out the six criteria used to assess the quality of the municipal waste collection service. The first three criteria focus on ‘primary collection’, the first step of getting waste from communities into the solid waste management system, and on the inter-related service of street cleaning. Criterion 1C.4, Efficiency and effectiveness of waste transport, focuses on the next step, getting the waste to (perhaps more distant) final treatment or disposal facilities. The last two criteria, 1C.5 and 1C.6, examine respectively the appropriateness of service planning and monitoring, and health and safety of collection workers, with the User Manual providing guidance on what is considered ‘appropriate’ planning and monitoring for service provision by both the public and private sectors, and on the reference requirements for ‘appropriate’ personal protection.

Table 2: Criteria used to assess Indicator 1C: Quality of the waste collection and street cleaning service

No.	Criterion	Description
1C.1	Appearance of waste collection points	Presence of accumulated waste around collection points/containers
1C.2	Effectiveness of street cleaning	Presence of litter and of overflowing litter bins
1C.3	Effectiveness of collection in low income districts	Presence of accumulated waste/ illegal dumps/ open burning
1C.4	Efficiency and effectiveness of waste transport	Appropriate public health and environmental controls of waste transport
1C.5	Appropriateness of service planning and monitoring	Appropriate service implementation, management and supervision in place
1C.6	Health and safety of collection workers	Use of appropriate personal protection equipment & supporting procedures

Table 3 summarises the six criteria used to assess indicator 2E, the degree of environmental protection in waste treatment and disposal. The first three criteria focus in turn on different aspects of environmental protection at a treatment / disposal facility: 2E.1 looks at waste reception and general site management; 2E.2 at the specific waste treatment and disposal processes and the operating procedures for their proper use; and 2E.3 focuses on environmental controls. Criterion 2E.4 assesses efficiency of energy generation and use. This is an ‘optional’ criterion: it should only be assessed if thermal treatment and/or energy recovery is a substantial part of the overall mix of technologies used for waste treatment and disposal. It should always be used where there is a thermal treatment facility accepting municipal solid waste, including incineration of residual wastes, advanced thermal treatment (e.g. gasification or pyrolysis) or production of a refuse-derived or secondary recovered fuel (RDF or SRF) for combustion elsewhere (e.g. in an industrial plant). The last two criteria focus on technical competence (2E.5) and on occupational health and safety (2E.6).

For criterion 2E.2, the nature of controls required will depend on both the process employed and on the potential emissions. For land disposal, the guidance given in the User Manual generally follows that of the World Bank (Rushbrook & Pugh, 1999; Hoornweg & Bhada-Tata, 2012); detailed guidance has also been attempted for thermal treatment. Similar principles should be followed for other types of treatment; however the detail will vary with the type of process, so that it is not possible for example to generalise windrow composting, in-vessel composting and anaerobic digestion into one set of guidance for ‘biological treatment’. For the purposes of counting towards the overall quantitative % of ‘controlled treatment or disposal’ under Indicator 2, the threshold is now set as a score of 10 under criterion 2E.2. This is a ‘tightening up’ from earlier interpretations to ensure consistency: for example, in applying the original UN-Habitat indicators to the city of Bishkek in Kyrgyzstan, Sim et al. (2013) assessed the local landfill sites as semi-controlled (which would now score 5), which was counted as ‘controlled’, whereas it would now count as ‘uncontrolled’. This can make a substantial difference: for Bishkek, a score of 92% for controlled disposal is now a score of 0%.

Table 3: Criteria used to derive Indicator 2E: Degree of environmental protection in waste treatment & disposal

No.	Criterion	Description
2E.1	Degree of control over waste reception and general site management	This criterion should be applied to all treatment and disposal sites, whatever the specific process being used.
2E.2	Degree of control over waste treatment and disposal	The focus here is on the waste treatment or disposal process in use at each site and over any potential emissions. This covers both the presence of the necessary technologies, and the operating procedures for their proper use.
2E.3	Degree of monitoring and verification of environmental controls	Includes the existence and regular implementation of: robust environmental permitting/ licensing procedures; regular record keeping, monitoring and verification carried out by the facility itself; AND monitoring, inspection and verification by an independent regulatory body.
2E.4	Efficiency of energy generation and use (Used for energy recovery facilities only)	Assesses the energy efficiency of those facilities for which a major purpose is (or could be) energy recovery.
2E.5	Degree of technical competence in the planning, management and operation of treatment and disposal	An assessment of the level of technical competence at three points in the system: (i) the authority responsible for service provision; (ii) the management of the treatment and disposal facilities; and (iii) the frontline operational staff
2E.6	Occupational health and safety	Use of appropriate personal protection equipment & supporting procedures

Table 4 summarises the criteria used to assess indicator 3R, the Quality of 3Rs - reduce, reuse, recycle - provision. The first two criteria focus on the quality, of recycling for dry recyclables (3R.1) and of valorisation for organics (3R.2): each is assessed on the basis of the proportion of the total recycled material that is separated at source (the quantitative indicator 3, the % recycled, is adjusted down to allow for materials collected for recycling but later rejected). Criterion 3R.3 assesses the policy and practical focus on the 'top of the hierarchy': for a higher waste generating city, above 1kg capita^{-1} day^{-1} (365 kg capita^{-1} yr^{-1}), this means reduction and reuse, whereas for lower waste generating cities, below the threshold, it is primarily diversion from treatment and disposal to recycling. Criterion 3R.4 Integration of community and/or informal recycling sector with the formal SWM system recognises the role of the 'community sector' in high-income countries and of the informal recycling sector in middle- and low- income countries. Detailed guidance for assessing informal sector integration (part of 3R.4) follows the recent framework developed for the International Solid Waste Association (ISWA)'s Task Force on Waste and Globalisation (Velis, et al., 2012; Mavropoulos et al., 2014), which examines four key aspects of integration initiatives: one focuses on organisation and capacity building of the informal sector; while the other three focus on its interfaces with formal solid waste management, secondary material markets and society as a whole. The last two criteria focus on the environmental protection (3R.5) and health and safety (3R.6) aspects of the recycling system – which have been dealt with in a similar way to collection under 1C.

Table 4: Criteria used to derive Indicator 3R - Quality of 3Rs- reduce, reuse, recycle - provision

No	Criterion	Description
3R.1	Source separation of 'dry recyclables'	Assessed on the basis of the proportion of the total quantity of materials collected for recycling that are collected as clean, source separated materials The focus here is on the relative % of clean, source- separated materials that are recycled, as opposed to materials that are sorted out from 'mixed' wastes – where there will inevitably be much higher levels of contamination. Detailed guidance is provided in the User Manual.
3R.2	Quality of recycled organic materials	A qualitative assessment of the likely quality of the recycled product (i.e. animal feed, compost, and the organic product (digestate) from anaerobic digestion) – assessment guidance based on both separation at source and quality control.
3R.3	Focus on the top levels of the waste hierarchy	An assessment of the degree of both policy and practical focus on promoting reduction and reuse in 'higher waste generating cities'; and on the '3Rs' – reduction, reuse, recycling – in 'lower waste generating cities'.
3R.4	Integration of community and/or informal recycling sector with the formal SWM system	An assessment of how far and how successfully efforts have been made to include the informal recycling sector (in low and middle-income countries) and the community reuse and recycling sector (in higher income countries) into the formal solid waste management system.
3R.5	Environmental protection in recycling	Environmental impacts of the recycling chain, from collection through to the separation and processing of the separated materials. NOTE: the environmental impact of waste treatment facilities that also produce materials for recycling (e.g. composting, MBT plants) is considered elsewhere under Indicator 2E.
3R.6	Occupational health and safety	Use of appropriate personal protection equipment & supporting procedures.

5. REVISED ISWM INDICATORS: GOVERNANCE ASPECTS

A major principle in developing the ISWM benchmark indicators has been that they should reflect also the 'soft', inherently difficult to measure, governance aspects. If adequate attention is not paid to these governance aspects, then any attempt to modernise solid waste management systems through technological improvements are likely to fail (Scheinberg, et al., 2010). So the indicators here are again 'qualitative', multi-attribute, composite indicators assessed in each case against five or six criteria.

Inclusivity addresses the degree of involvement, interest and influence of key groups of stakeholders, with separate indicators for user and provider inclusivity (Table 5). For user inclusivity, criterion 4U.1 Equity of service provision, assesses the extent to which all citizens, irrespective of their income level and whether they live in planned neighbourhoods or in slums, receive a good service which they can afford, which meets their expressed needs, and which protects public health and environmental quality. Criteria 4U.2 - 4 focus on assessing the degree to which users, or potential users, of the solid waste services (i.e. households, business and other waste generators) are involved in the planning, policy formation, implementation and evaluation of those services. The remaining criteria address complementary aspects of public awareness and education: 4U.5 assesses the level of activity and 4U.6, its effectiveness in achieving the desired behaviour change.

Table 5: Criteria used to assess Indicators 4U and 4P: Degree of user and provider inclusivity

4U - Degree of user inclusivity			**4P - Degree of provider inclusivity**		
No	**Criterion**	**Description**	**No**	**Criterion**	**Description**
4U.1	Equity of service provision	Extent to which all citizens (users and potential users), irrespective of income level, receive a good solid waste management (SWM) service- i.e. a service which they can afford, which meets their expressed needs, and which protects public health and environmental quality.	4P.1	Legal framework	Degree to which laws and/or other legal instruments are in place and implemented at national or local level, which enables both the public and private sectors to deliver solid waste management services on a stable basis.
4U.2	The right to be heard	Do authorities have a legal obligation to consult with and involve citizens in decisions that directly affect them?	4P.2	Representation of the private sector	Organisations or structures in place which represent the private waste sector and actively participate within solid waste management planning forums, task forces, committees and/or steering-groups
4U.3	Level of public involvement	Evidence of public involvement at appropriate stages of the solid waste management decision-making, planning and implementation process.	4P.3	Role of the 'informal' and community sector	Evidence of acknowledgement and recognition of the role of the organised 'informal' and community sectors within the formal solid waste management system
4U.4	Public feedback mechanisms	Existence and use of public feedback mechanisms on solid waste management services.	4P.4	The balance of public vs. private sector interests in delivering services	Degree to which appropriate checks and balances are in place locally, so that waste services are being delivered by either the public or private sector, in a manner that is mutually beneficial and does not substantially disadvantage either party.
4U.5	Public education & Awareness	Implementation of comprehensive, culturally appropriate public education, and/or awareness raising programmes - focus here on the level of activity	4P.5	Bid processes	Degree of openness, transparency and accountability of bid processes.
4U.6	Effectiveness in achieving behavior change	Change in habits and behaviours of both the public and businesses regarding their waste management/ handling practices - focus here on the effectiveness of education and awareness programmes	-	-	-

The indicator for provider inclusivity, 4P, represents the degree to which service providers from both municipal and non-municipal (including the formal private, community or 'informal') sectors are included in the planning and implementation of solid waste and recycling services and activities. This is in line with recent evidence that all forms of 'operator model' for the delivery of solid waste and recycling services can be appropriate, with each model likely to be more suitable in particular 'niches' and according to the local circumstances (Soos, et al., 2013). The criterion 4P.1, Legal framework, assesses the presence of legal instruments which enable both the public and private sectors to get involved in providing stable waste management services. Criteria 4P.2 and 4P.3 focus in turn on representation of the private sector and acknowledgement of the role of the informal/community sectors respectively. Criterion 4P.4 looks at the balance of public and private sector interests, and assesses whether appropriate contract terms, checks and balances are in place for a mutually beneficial system. The User Manual elaborates relevant contract features, including objectives, performance measures, duration, flexibility, incentives and penalties. Criterion 4P.5 assesses the bid process, to ensure that: there is a level playing field (i.e. bidding and/or contract management is not corrupt); the process is open to all interested parties from the formal private, community-based and/or organised ‘informal’ sectors; and the contract is clear and fit for purpose.

Indicator 5F is assessed against six criteria covering the full spectrum of financial sustainability (Table 6). Criterion 5F.1 assesses transparent cost accounting procedures; 5F.2 the adequacy of the total budget, irrespective of the source of revenues; 5F.3 local cost recovery from households; 5F.4 affordability of user charges; 5F.5 coverage of disposal costs, focusing on how far disposal is ‘priced’, as the evidence suggests that such price signals are necessary if solid waste management is to be taken seriously by waste generators and handlers (Scheinberg, 2011); and 5F.6 ability to raise capital for investment. The guidance in the User Manual on scoring against each criterion is particularly detailed for this indicator, partly because the assessments combine any available quantitative data with qualitative information; but also to ensure that the indicator can be applied to both high- and to low-income cities, which is particularly challenging. To take just one example, criterion 5F.3 focuses on the % of households who pay at least some direct contribution to the cost of primary collection – that is the part of the service which ensures that waste is removed from individual properties, either via some sort of individual service or via the provision of communal collection points. Primary collection has been selected here because experience shows that even in slum areas of low-income cities, people are prepared to pay to keep their neighbourhood clean and thereby help protect their children’s health. Payments can be either through a direct charge for waste services, or indirect, e.g. via property tax, communal service charges or a utility bill or a component of a utility bill linked to water/wastewater or electricity bills.

Table 6: Criteria used to assess Indicator 5F: Degree of financial sustainability

No	Criterion	Description
5F.1	Cost accounting	Extent to which the solid waste management accounts reflect accurately the full costs of providing the service and the relative costs of the different activities within solid waste management; and whether the accounts are open to public scrutiny.
5F.2	Coverage of the available budget	Is the annual budget adequate to cover the full costs of providing the service?
5F.3	Local cost recovery – from households	Percentage of the total number of households both using and paying for primary waste collection services. The focus here is on the number of households, NOT on the percentage of the total costs which they pay.
5F.4	Affordability of user charges	Are practices or procedures in place to support charges for those who can least afford to pay?
5F.5	Pricing of disposal	Degree to which all the wastes coming to the final (treatment or) disposal site(s) are charged at a rate that covers (at least) the operating costs of (treatment or) disposal.
5F.6	Access to capital for investment	Has adequate provision been made for necessary capital investments, both to extend collection coverage to any un-served areas; to upgrade standards of waste disposal; and to replace existing vehicles, equipment and sites at the end of their life?

Two benchmark indicators are defined for sound institutions and proactive policies, allowing separate assessment of the national framework and the local institutions, enabling the comparison of cities within a country. Table 7 summarises the six criteria used to assess each. Indicator 6N assesses the adequacy of the national solid waste management framework and to what degree it has been implemented. The criteria cover the basic legislation and implementing regulations (6N.1); an approved and recent national strategy and clear policies (6N.2); guidelines for local government on implementation (6N.3); the designation and capacity of a single national responsible authority for solid waste management (6N.4); the environmental regulatory agency responsible for enforcement (6N.5); and the use of extended producer responsibility (EPR) policy instruments (6N.6). EPR is increasingly being used in industrialised countries as a means to share at least some of the costs of the municipal solid waste management service with the companies responsible for the products that either form a large – and further increasing – proportion of the solid waste stream, such as packaging; and/or that often contain hazardous and/or scarce substances, such as batteries and e-waste. Both the growing quantities of such ‘end-of-life’ products and chronic budget shortages for the solid waste management service for their adequate treatment, make this an attractive policy for countries with developing economies as well; therefore EPR is included here as a ‘normal’ part of a national framework for all countries.

Indicator 6L is a measure of the institutional strength and coherence of a city’s solid waste management functions, with the individual criteria including organisational structure, institutional capacity, availability and quality of data and inter-municipal co-operation.

Table 7: Criteria used to assess indicators for sound institutions and proactive policies:
6N - National framework and 6L - Local institutions

6N - Adequacy of national framework for solid waste management (SWM)			**6L - Degree of local institutional coherence**		
No	**Criterion**	**Description**	**No**	**Criterion**	**Description**
6N.1	Legislation and regulations	Is there a comprehensive national law(s) in place to address solid waste management requirements? Does the legislation require regulation in order to bring it to force and have these regulations been put in place?	6L.1	Organisational structure / coherence	The degree to which all solid waste management responsibilities are concentrated into a single organisation or department, that can be held accountable for performance, or if multiple organisations, the presence of a significant concentration of responsibilities in one named agency.
6N.2	Strategy/ Policy	Is there an approved and recent national strategy for solid waste management, and clear policies in place and implemented?	6L.2	Institutional capacity	An assessment of the organisational strength and capacity of the department(s) responsible for solid waste management
6N.3	Guidelines and implementation procedures	Are there clear guidelines for local authorities on how to implement the laws and strategy? Are there effective mechanisms in place for facility siting?	6L.3	City-wide SWM strategy & plan	Is there a recent strategy or plan in place & being implemented at the city (or regional) level for solid waste management?
6N.4	National institution responsible for implementing SWM policy	Is there a single institution at the national level which is charged with the responsibility of implementing, or coordinating the implementation of, solid waste management strategy/policy?	6L.4	Availability and quality of SWM data	Is there a management information system (MIS) in place? Are data regularly measured, collected and monitored?
6N.5	Regulatory control / enforcement	Is there a well organised and adequately resourced environmental regulatory agency? Does it enforce the legislation so as to ensure a ‘level playing field’ for all?	6L.5	Management, control and supervision of service delivery	A measure of the strength of control by the city, as ‘client’ for solid waste management, over the on-the-ground delivery of solid waste management services. The services may actually be delivered by the private or public sector, or a combination of the two.
6N.6	Extended producer responsibility (EPR) or Product Stewardship (PS)	Has engagement been made with national and international companies who produce the packaging, electronic goods and other products that end up as MSW? Do they share at least some of the costs of the solid waste management service and/or recycling?	6L.6	Inter-municipal (or regional) co-operation	Waste collection is often delivered at a local level, while treatment and disposal may require co-operation city-wide or at a regional level. Regulatory control may be organised at regional or national level. How well does such co-operation work?

Again, detailed guidance is provided in the User Manual on assigning the scores against each criterion. For example, for criterion 6N.4, national institution responsible for implementing solid waste management policy, detailed guidance is given on how to assign the scores depending on the degree of integration and autonomy of that institution and its separation from the environmental regulator. For criterion 6L.2, institutional capacity, the assessment considers three questions: Is there a detailed organisation chart of the solid waste management department(s)? Are all key positions filled and are staff suitably qualified? Is there structured career progression and are staff provided with appropriate training – both in the class-room and the field?

6. COMPARING CITIES

Using the revised Wasteaware ISWM benchmark indicators to assess the solid waste management system in a city results in a set of detailed tables containing not only values of the four quantitative indicators and assessments/scores assigned to the eight qualitative indicators, but also documenting the data used to calculate the quantitative indicators, and how 'best professional judgment' has been applied to assign scores against the criteria used to calculate each of the qualitative indicators. This level of detailed reporting is essential, so that it is possible to audit and check the assessment and to ensure that a consistent approach is applied when cities are compared with each other. Notwithstanding the above, it is also important that a one-page summary of the indicators is available, in an attractive and easy-to-interpret format such as the use of the "traffic light" colour coded system and/or the radar diagram, for a concise presentation to local and national decision makers and also to international agencies with an interest. In this way, areas of good or satisfactory performance are easily identified and attention is drawn to the priority areas for potential improvement in each individual city. Both the 'traffic light' assessment and the complementary radar diagrams are helpful to allow easy comparison between cities.

To illustrate the use of the ISWM indicators, Table 8 presents the results for a selection of five cities, ranging from low- to high-income. The data presented are taken from the 'summary page' of the Indicator Form, and shows first selected background information on the city and the key waste-related data, followed by the 12 indicators for both physical components and governance aspects. Figure 2 presents the corresponding radar diagrams.

Examining the data in Table 8 and Figure 2, one can see evidence of serious efforts for solid waste management improvement in all of the middle and low-income cities. While waste collection coverage is still very low at 33%, Monrovia in Liberia is working particularly on controlling disposal, with a new sanitary landfill site opened in 2012; in contrast, Maputo in Mozambique (Stretz, 2013) and Lahore in Pakistan (Massood et al., 2014) have focused on extending collection coverage above 70% but have little or no controlled disposal yet. Guadalajara in Mexico has reached 95% for both of these indicators. Belfast is interesting as a city in a high-income country that admits to less than 100% waste captured and disposal controlled, as they find illegal disposal practices difficult to eliminate completely. Recycling is highlighted as a major priority for further improvement in a number of the cities: interestingly, the highest recycling rates among the five cities are estimated for Lahore and Belfast, although both their recycling systems and their 'quality' indicators 3R are very different; proposals which would address this in Lahore, concerning integration of the informal recycling sector, have been made by Masood and Barlow (2012). Performance against the governance indicators is rather mixed, with no clear trend as income levels rise: in several of the cities, a particular priority would appear to be to improve the national policy framework (indicator 6N). In most cases, the indicators would suggest that further improvement in the physical components is likely to require a parallel focus on some of the pertinent governance aspects.

Table 8: Summary results for the Wasteaware ISWM benchmark indicators in five case study cities

No	Category	Indicator	Monrovia	Maputo	Lahore	Guadalajara	Belfast
			Results				
City			Monrovia	Maputo	Lahore	Guadalajara	Belfast
Country			Liberia	Mozambique	Pakistan	Mexico	UK - Northern Ireland
Background information on the city							
B1	Country income level	World Bank income category	Low	Low	Lower-middle	Upper-Middle	High
		GNI per capita	$370	$450	$1,140	$9,640	$38,250
B2	Population	Total population of the city	1,021,768	1,131,149	8,160,000	4,664,924	218,000 City only
B3	Waste generation	MSW generation (tonnes/year)	287,000	508,000	1,916,000	2,000,000	149,000
Key Waste-related data							
W1	Waste per capita	MSW per capita (kg per year)	230	316	219	440	683
W2	Waste composition:		4 key fractions - as % of total waste generated				
W2.1	Organic	Organics (food and green wastes)	50%	65%	65%	53%	35.1%
W2.2	Paper	Paper and card	5%	8.5%	2%	9%	21%
W2.3	Plastics	Plastics	13%	8%	12%	10%	6%
W2.4	Metals	Metals	2%	2.5%	0.1%	1.4%	3.3%
Physical Components							
1.1	Public health – waste collection	Waste collection coverage	33% (L)	82% (M)	77% (M)	95% (M/H)	100% (H)
1.2		Waste captured by the system	30% (L)	75% (M)	80% (M)	95% (M/H)	98% (M/H)
1C		Quality of waste collection service	M (58%)	M/H (63%)	M (58%)	M (50%)	H (100%)
2	Environmental control – waste treatment and disposal	Controlled treatment and disposal	70% (L/M)	0% (L)	8% (L)	95% (H)	98% (H)
2E		Degree of environmental protection in waste treatment and disposal	M (45%)	L/M (21%)	L/M (37%)	M (60%)	H (100%)
3	Resource management – reduce, reuse and recycle	Recycling rate	8% (L)	<5% (L)	35% (M)	12% (L/M)	35% (M)
3R		Quality of 3Rs – Reduce, reuse, recycle – provision	L/M (33%)	L/M (29%)	L (17%)	L (13%)	H (83%)
Governance Factors							
4U	Inclusivity	User inclusivity	M/H (67%)	M (46%)	L/M (37%)	M (46%)	M/H (79%)
4P		Provider inclusivity	M (60%)	M (60%)	M (50%)	L/M (40%)	M/H (80%)
5F	Financial sustainability	Financial sustainability	M (46%)	M/H (67%)	M (54%)	L/M (40%)	H (100%)
6N	Sound institutions, proactive policies	Adequacy of national SWM framework	L (17%)	L/M (29%)	L/M (29%)	M/H (67%)	M/H (66%)
6L		Local institutional coherence	M (46%)	M (58%)	M/H (62%)	M (46%)	H (100%)

Key: GNI - Gross National Income; MSW - Municipal solid waste. Indicators assessed into five categories and colour coded: low performance (L) – red; low/medium performance (L/M) – red-amber; medium performance (M) – amber (orange - shaded here to be easier to read); medium-high performance (M/H) – amber-green; and high performance (H) – green. For scaling of the quantitative indicators 1.1, 1.2, 2 and 3, see Table 1.

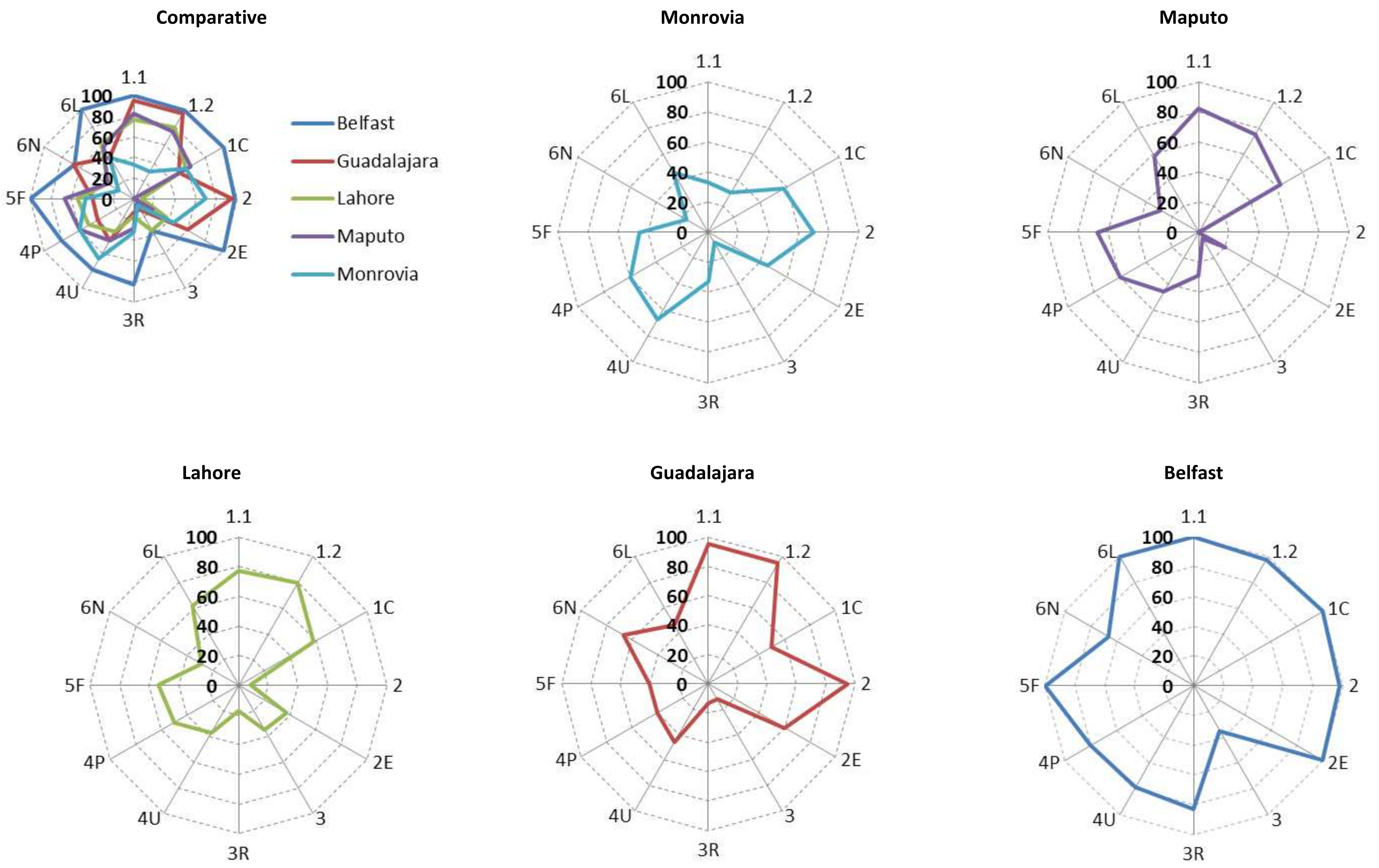


Figure 2: Radar diagrams summarising the 12 Wasteaware ISWM benchmark indicators for the five cities for which the data is presented in **Table 8**, where the indicator numbers (1.1 to 6L) are also defined. Ordered from low-income (Monrovia) to high-income (Belfast).

7. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

One of the primary purposes of the Wasteaware ISWM benchmark indicators presented here is to raise stakeholder awareness of the state of the local solid waste management system. The indicator set combines relatively well-established quantitative indicators for the three main physical components – collection, (treatment and) disposal, and recycling – with a corresponding, qualitative, composite indicator for the 'quality' of service provision for each physical component, as well as five qualitative, composite indicators which assess performance for the three main aspects of governance, namely inclusivity of stakeholders, financial sustainability, and sound institutions and proactive policies.

The Wasteaware ISWM benchmark indicators have been nearly five years in development, and have gone through three major iterations. They have benefitted from the experience of testing various prototypes in 39 cities around the world, and in a further 19 cities within one country (Egypt). Feedback from a variety of users and reviewers confirms their utility in prioritising 'next steps' in developing a city's solid waste management system, by identifying both local strengths that can be built on and weak points to be addressed. The strengths of the Wasteaware ISWM indicator set include its comprehensiveness in enabling performance measurement and comparison of both 'hard' physical components and 'soft' governance aspects; and its applicability to a wide range of cities with very different levels of income.

A lack of up-to-date and detailed data is often the norm for realities in solid waste management, particularly in developing country cities. In practice, this can either constitute a barrier to action, or allow potentially incorrect assumptions to lead action into a wrong direction. The ability of the Wasteaware indicators to provide an overview of the system performance even in the relative absence of detailed data is an important strength. Having the user apply their best professional judgment based on knowledge of the local situation and input from local stakeholders – and documenting exactly how this has been done – allows for the results to be a starting point that can be checked and improved in the future. It is suggested that the initial results be used to facilitate discussion among the full range of local stakeholders, both about the performance of the solid waste management system and also during the subsequent stages, in which decisions are taken about the priorities and future actions to improve the system.

Feedback suggests that the Wasteaware indicators are relatively easy and quick to apply. As previously stated, the user will ideally be a local solid waste professional who is familiar with the local situation. Where such a user is found, then our experience is that filling in the indicator form is not so onerous – it can take anywhere between a few hours and a few days. It is also very useful and appropriate to have a level of independent verification or 'arbitration', to ensure consistency of interpretation between assessors in different cities.

An alternative approach to the assessment could be to use a multi-criteria analysis (MCA), which would involve soliciting the views of many stakeholders on each criterion making up all the indicators. However, such an approach would negate some of the advantages of the current indicator set, as it would significantly increase the complexity and reduce the practicality of the process, and involve considerable training to ensure that all the stakeholders share a common understanding of each criterion and indicator. In addition, most applications of MCA go a step further than the Wasteaware indicators regarding amalgamation of the individual indicators into an average 'performance index' (using stakeholder-derived weighting factors), which results in a loss of valuable information on the specific aspects of the system's performance.

We are aware that our objective of having one set of indicators that can be applied to all cities has resulted in a number of compromises, particularly in relation to the evaluation of more advanced technologies for waste treatment – we could instead have come up with two different indicator sets each optimised for the comparison of high-income cities, or of developing and emerging country cities – but we have chosen to develop a common set because we all live in the one globalised economy where resources are finite and it is useful to compare all cities, North and South, on a common basis. For particular national or regional applications, however, it would be equally valid to substitute a more tailored version of Table 1 assigning 'traffic light' gradings to the four non-linear quantitative indicators. For example, the Wasteaware indicators have already been used to establish a baseline for 19 cities in Egypt: a more tailored version of Table 1 would facilitate their use in monitoring progress over the next few years towards step-by-step national targets for improvement of the solid waste management system.

The Wasteaware indicators have been designed primarily to be applied at the city level. However, indicator 6N does provide a useful assessment of solid waste management performance at the national level.

The Wasteaware ISWM benchmark indicators have now reached a level of maturity where they can be made available for widespread use. If widely applied as a standard methodology, the Wasteaware indicators will help address the historical lack of comparative data on solid waste management in the World's cities. The indicators will allow rapid benchmarking of a city's solid waste management performance; comparison of cities, both high- and low-income, on a common basis; and monitoring the progress of a city over time, towards a sustainable solid waste management system which meets the needs and aspirations of its citizens and contributes to sustainable resource management.

Recommendations which have been incorporated into our future plans include the development of learning instruments to help the user apply the indicators; a procedure for quality control, to check consistency in interpretation; developing a database for comparison of cities on a consistent basis; and compiling feedback on the use of the ISWM indicators. A further review and update of the Wasteaware ISWM indicator set should be undertaken in a few years, so that this remains a living tool which evolves in parallel with developing policies and practices for solid waste management and resources management around the world.

CONFLICT OF INTEREST STATEMENT

The authors do not have any potential conflicts of interest to declare.

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APPENDIX A. SUPPLEMENTARY MATERIAL

The User Manual for the Wasteaware ISWM benchmark indicators is provided as supplementary data associated with this article, which can be found in the online version.

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