Introduction

Solid waste management (SWM) is both an essential utility service and a key tenet of sustainable development. Regular waste collection in cities was first introduced to protect public health in the mid-19th century. Final disposal of collected waste remained largely uncontrolled until the 1970s, when local environmental protection became a driver (Wilson, 2007). Since then, a wide diversity of strategies have evolved, both for the environmentally sound management (ESM) of solid wastes as the end point of the linear economy and for their reduction, reuse and recycling as SWM begins to transform into waste and resource management (WaRM), driven by resource scarcity, a shift towards a circular economy (Tudor & Dutra, 2021) and in response to climate change (Wilson et al., 2015a).

Despite this progress, UNEP’s inaugural Global Waste Management Outlook (GWMO) (UNEP and ISWA, 2015) estimated that more than two billion people around the world are still living without access to waste collection and more than three billion without access to controlled waste recovery or disposal facilities (UNEP and ISWA, 2015). Not only does unmanaged and mismanaged waste cause severe local impacts on public health, the environment and the economy, it is also the major source of plastics entering the oceans (Borrelle et al., 2020; CIWM and Wasteaid UK, 2018; Jambeck et al., 2015; Lau et al., 2020), which has emerged as a major new driver of action (Pew and Systemiq, 2020). Without concerted action, the quantities of mismanaged wastes in cities and other urban areas in low- and middle-income countries (LMICs) will double within 15–20 years, as population increases, migration from rural areas continues and waste generation per capita increases with economic development (Hoornweg et al., 2015; Kaza et al., 2018; UNEP and ISWA, 2015).

A new conceptual framework

The purpose of this paper is to present a novel conceptual framework for the development of WaRM systems across the world.
Our basic hypothesis is that it is possible to characterise WaRM systems into a small number of ‘development bands’ (DBs) and to allocate a city or a country at least roughly to one of those bands. Although the level of WaRM development at any one time often varies within and between regions/cities, particularly in LMICs, it is possible to identify a ‘centre of gravity’ that roughly correlates to one band. The evolution of WaRM systems over time, associated with economic and social development, can then be described as a progression between DBs.

We have identified nine current DBs in place around the world, hence the name ‘9DBs conceptual framework’. The 9DBs framework is in effect as a global theory of waste and development: it provides a road map, allowing an overview of the ‘big picture’, where does this country, region or city fit into the overall spectrum of WaRM sector development?

In this paper, we first present our methodology, then describe and justify our selection of the nine bands. We next test the 9DBs conceptual framework against the historical journeys of example countries, which have already progressed to well-functioning WaRM systems. We then explore how it can be applied to facilitate the journeys of LMICs, which are still struggling to provide basic services to bring municipal solid wastes (MSWs) under control. We end with some reflections and conclusions.

Our aim is to demonstrate that the 9DBs conceptual framework is a powerful addition to the waste practitioner’s toolkit, filling a key gap by focusing on the initial framing of the problem at the early scoping or prioritisation stage. It helps a city or country assess where it currently stands, consider the appropriate next steps and move towards a sustainable WaRM system that will work in their specific economic, social and cultural context. Placing the current position in one DB, and the desired destination in that of a different DB, enables an intended development ‘programme’ or ‘project’ to be designed and sense checked so that interventions are effectively targeted and sufficiently tailored to the particular local situation and context.

The intended audience of this paper goes beyond academics to include both waste and development practitioners and related professionals; decision-makers and managers in development agencies, national governments, regions and cities and also non-governmental organisations (NGOs), community-based organisations (CBOs) and activists who wish to enhance their contribution to WaRM sector development.

Methodology

Building on sound foundations

The 9DBs build on several existing analytical frameworks and tools. The primary foundation is Integrated Sustainable Waste Management (ISWM), developed by waste practitioners over the last 25 years. Up to the early 1990s, the focus in analysing and planning SWM systems had been largely on optimising usage of the technologies available (e.g. Wilson, 1985). A recognition of the failure of that approach led to the development of ISWM by the Collaborative Working Group on Municipal Solid Waste Management in Low- and Middle-Income Countries (CWG). ISWM has evolved through several iterations (IJgosse et al., 2004; Schübeler, 1996; Scheinberg et al., 2010; Van de Klundert and Anschütz, 2001; Wilson et al., 2013) into the simplified ‘two triangles’ (Figure 1(a)), which emphasises the need to focus both on the ‘hard’ physical components, each related to a primary driver (Wilson, 2007), and the ‘soft’ governance aspects. ISWM combines the collection and disposal elements of formal SWM with the often informal ‘3Rs’ to form an integrated WaRM system. UNEP’s GWMO used the physical components as the basis for their recommendations on what needs to be done to improve a country’s or a city’s WaRM system, summarised as five global waste (GW) targets interlinked to the sustainable development goals (SDGs); while how to do it focuses mainly on the governance factors, which it analysed in detail (Rodic and Wilson, 2017; UNEP and ISWA, 2015).

Another analytical framework used in developing the 9DBs is the waste hierarchy (Figure 1(b)). This is a generalised priority order for managing waste once it has been collected. Many representations start with landfill as the ‘bottom’ rung; this version emphasises that the initial step is to move from uncontrolled disposal onto the bottom rung of the hierarchy, controlled disposal, before progressing to full control landfill (UNEP and ISWA, 2015).

Other complementary tools are also based on the ISWM framework. The Wasteaware Benchmark Indicators (WABI) (Wilson et al., 2015b) measure the performance of a city’s existing WaRM system, against all six components of the two triangles, which is critical for identifying the next appropriate steps in developing a city’s or a country’s WaRM system. The first two quantitative WABIs correspond directly to GW targets GW1 to extend waste collection to all and SDG indicator 11.6.1(a), proportion of MSW collected out of total generated; and GW2 to stop uncontrolled disposal and open burning and SDG indicator 11.6.1(b), proportion of MSW managed in controlled facilities out of total generated. These targets provide important milestones on the journey towards target GW3, corresponding to SDG target 12.4, ESM of all wastes.

The Waste Wise Cities Tool (WaCT) provides the methodology for assessing SDG 11.6.1 (UN-Habitat, 2021), including collection of primary data on the WaRM system. The WaCT provides ‘ladders of control’, one for the service level of waste collection, and others for the control level of waste management facilities. Each distinguishes five levels of service or control, from ‘none’, though ‘limited’ to ‘basic’, then ‘improved’ and ‘full’ (Figure 2). For the purpose of meeting SDG 11.6.1, universal collection coverage must meet at least the ‘basic’ level of service (regular collection of mixed waste); and facility management the ‘basic’ levels of control, which are defined separately for landfill, incineration and other recovery. The control ladders also allow measurement of ESM (SDG 12.4), which corresponds to ‘full control’.

A complementary tool, the Waste Flow Diagram (WFD), enables material flows to be mapped and ‘leakages’ (including plastics potentially entering the oceans) to be estimated (GIZ, University of Leeds, Eawag-Sandec, Wasteaware, 2020). The
WaCT primary data also allows monitoring of other WaRM-related SDG targets and indicators, including targets SDG 1.4 on access to basic services and SDG 14.1 on marine litter; and those related to the 3Rs, SDG 12.5 on recycling (which equates directly to global waste target GW4), and SDG 12.3 on food waste prevention (equates to GW5). Indeed, it has been argued that improving WaRM systems can make direct, measurable contributions to six of the high-level SDGs, as well as direct but difficult to measure contributions to six more SDGs and indirect contributions to the remaining five (Rodic and Wilson, 2017; Wilson, 2021).

Reference is also made to the essential institutional/organisational functions which need to be in place for a WaRM system to be effective. Six functions were defined in the World Bank’s Strategic Planning Guide for Municipal Solid Waste Management (Wilson et al., 2000); a seventh function, that of ‘change agent’, was added later (Whiteman, 2010). Here, we further differentiate the ‘regulator’ into three separate functions, the environmental, technical and financial regulators, as each comes into focus at different stages of WaRM development. So, a total of nine functions are shown schematically in Figure 3, alongside a summary of the responsibility of each.

**Approach to defining the development bands**

The 9DBs concept has grown out of the three co-authors’ combined experience of some 100 years as WaRM sector practitioners. We are all deeply engaged in WaRM sector development practice in LMICs but have also worked in high-income countries. We all...
have an interest in waste history and the evolution of the WaRM sector, and two of us have for many years been part of an international community of practice, the CWG, which has been instrumental in developing many of the foundations on which the 9DBs is built, notably the ISWM framework. The nine bands are based on empirical evidence from observations of how WaRM systems have evolved in the past to where different countries sit now. This DB hypothesis was first conceived by the first author in preparation for a major UN conference in Tokyo (Whiteman and Soos, 2011); it has been discussed with various colleagues while relaxing after many a day’s work in the field and has been presented at several formal workshops and informal gatherings over the years. The version presented here has thus grown out of extensive practical work in the field, much discussion and debate and the contribution of a great many colleagues. It has also been tested by being used in the field to scope the key WaRM issues being addressed in a diversity of locations including, Albania, Australia, Bulgaria, China, Cyprus, Egypt, Ethiopia, Grenada, India, Indonesia, Kenya, Kosovo, Sierra Leone and South Africa.

Relating the 9DBs conceptual framework to existing WaRM frameworks and tools

The novel 9DBs conceptual framework fills a clear gap in the WaRM practitioner’s toolkit by focusing on the initial framing and scoping of what are the appropriate next steps in a country’s WaRM development. The nearest existing tools include some of those on which the 9DBs has been built, such as ISWM itself or the development drivers (Wilson, 2007); for example, the latter was recently used as a framework to compare waste policy reforms in India and Brazil (Pereira et al., 2020), and the Policy–Environmental–Socio-economic–Technology (PEST) thematic framework (Iyamu et al., 2020).

Once an overall development initiative has been scoped, or in parallel with such scoping, other more detailed benchmarking tools can then be used in the detailed design of implementation programmes and projects, including, for example the Waste Wise Cities Tool (WaCT; UN-Habitat (2021) to measure SDG indicators 11.6.1), the WFD (GIZ, University of Leeds, Eawag-Sandec, Wasteaware, 2020) and the WABI (Wilson et al., 2015c), all of which build on the ISWM framework. Many other tools are available to assist with programme and project planning and implementation (reviews include Allesch and Brunner, 2014; Asefi et al., 2020) – other specific sources are referenced below when discussing the application of the 9DBs in LMICs.

The nine development bands

The 9DBs framework is shown schematically in Figure 4 as a tree. The roots and trunk of the ‘9DBs tree’ (DB1–DB4) represent the early phases of WaRM system development, marking steady progress towards ‘universal’ collection and preventing uncontrolled dumping and open burning; 95+% performance against the SDG indicators 11.6.1 for collection and controlled recovery and disposal corresponds to emerging from DB4 at the top of the tree trunk into the new target baseline of DB5. Here, WaRM systems consolidate (with SDG 11.6.1 performance edging upwards) and begin to transition beyond a ‘basic’ level of facility control towards ESM or ‘full’ control, 95+% ESM compliance achieved in DB6 and DB7, and ‘basic’ mixed waste collection towards the ‘improved’ and ‘full’ service levels of collecting at least two or three source-separated waste fractions to facilitate the 3Rs, which become the focus in DB8 and DB9 (Figure 2). DB Zero sits on the top of the tree, representing the ultimate aspiration of a ‘zero waste’ circular economy.
The DBs are described briefly in turn in the following sub-sections. We highlight for each the commonalities in terms of waste collection, disposal and the 3Rs, and the priorities for system development. We also identify for each DB a critical pressure point for transformational change, aligned to the institutional functions set out in Figure 3, which gives insight into how...

**Key to the Development Bands (DBs)***

| DB  | Description                           |
|-----|---------------------------------------|
| DB1 | New Beginnings                        |
| DB2 | Early Movement                        |
| DB3 | Service Extension                     |
| DB4 | Consolidating Control                 |
| DB5 | The Target Baseline                   |
| DB6 | Market Oriented Systems               |
| DB7 | High Recovery Systems                 |
| DB8 | Policy Driven by Fiscal Mechanisms    |
| DB9 | Policy Driven by Technical Standards  |
| DB0 | Circular Economy                      |

**Figure 3.** Institutional functions, which need to be fulfilled for waste and resource management (WaRM) systems to work well. Adapted from Soos et al. (2013, 2017), Wilson et al. (2000) and Whiteman, (2010) (Graphics: Ecuson Studio).

MSWM: municipal solid waste management; SWM: solid waste management; WaRM: waste and resource management.

**Figure 4.** The 9DBs tree. The roots and trunk represent early development bands in WaRM system development (DB1–DB4). The top of the trunk, emerging from DB4 into the new target baseline DB5, marks meeting SDG indicator 11.6.1, and achieving ‘universal’ (95+% ) waste collection and controlled recovery or disposal. DB6→DB8 and DB7→DB9 represent two distinct historical routes through the ‘leafy upper branches’, with universal [95+%] full control (ESM) in recovery and disposal achieved in DB6 and DB7, and a focus on the 3Rs in DB8 and DB9. DB Zero sits on the top of the tree, representing the ultimate aspiration of a ‘zero waste’ circular economy. A key to the DBs is provided in Table 1. Figure© Andrew Whiteman (Graphics: Ecuson Studio).

3Rs: reduce, reuse, recycle; DB: development band. ESM: environmentally sound management; SDG: sustainable development goal. WaRM: waste and resource management.
specific institutional interventions at a given time can catalyse WaRM system development. We then compare and contrast the 9DBs, providing a summary table as an aide memoire, including locational examples, and looking at comparative performance indicators and costs.

The early DBs: the roots and trunk of the tree

**DB1 new beginnings.** In DB1, most households receive no waste collection service, so have to self-manage their waste. Anything with a value will be reused or recycled at home. Residual waste is typically disposed in neighbouring open spaces, drains, waterways or openly burnt. The priority is to protect public health by removing waste from populated areas. The key pressure point is to help establish operators, in particular collection service providers who also recover items with a market value; interventions often work best when they are driven by the community themselves.

**DB2 early movement.** DB2 is where some waste collection services have become established, often focused in the central business district and more prosperous residential areas of cities. The focus is on local government stepping in to coordinate or manage expansion of collection service coverage. Some capital budget is provided to purchase and replace vehicles and equipment, and operationally the units may hire labour for street cleaning services. Disposal sites have become established and may even have been officially designated; however, little if any budget is allocated and disposal operations remain largely uncontrolled. An active informal recycling sector (IRS) operates independently of the municipality. The priority is still to control the risks to public health from accumulating waste. The key pressure point is the formation, establishment and capacity building of local government waste/street cleaning/public health units, distinguishing the responsibility for ensuring service provision (an emerging client/employer function) from the task of service delivery (operator function).

**DB3 service extension.** The priority in DB3 is on further expanding collection services and introducing or improving control over disposal facilities. Collection service deficiencies continue to be evident in low-income and slum neighbourhoods. The IRS has become more established, operating in parallel to or even in co-operation with formal collection services. Operational standards of disposal begin to take hold as budget is made available for human resources to manage, and mechanical equipment to be in frequent use at, disposal sites. The priority is to improve both the levels and standards of collection, recovery and disposal (Figure 2). The key pressure point is to strengthen the planner function; strategic planning is required at national, regional and city levels, covering both the physical infrastructure and the governance frameworks, including ensuring that the institutional functions identified in Figure 3 are organisationally allocated.

**DB4 consolidating control.** DB4 is represented by the trunk of the 9DB tree and can be conceptualised as two parallel ‘tracks’. DB4a works towards meeting global waste target GW1 and SDG indicator 11.6.1, with 95% coverage of collection services and 95% controlled recovery and disposal. DB4 often sees costs rise sharply, as collection reaches more difficult to service urban, peri-urban and rural areas, and environmental standards of recovery and disposal increase; in this context, continuing to build on and integrate the services of the IRS is often important. The key pressure point is the revenue collector function, overcoming critical operational revenue bottlenecks by implementing the polluter pays principle and diversifying revenue sources.

The later DBs: The branches of the tree

**DB5: The target baseline.** Reaching DB5, figuratively speaking sitting at the top of the trunk of the 9DB tree (Figure 4), represents the important milestone of ‘universal’ (95%) collection and controlled disposal, meeting global waste targets GW1 and GW2/SDG indicator 11.6.1. For LMICs currently struggling through the lower DBs, DB5 represents a reachable target at least for urban areas; their primary aim must then be to ensure that this new baseline is financially sustainable in the medium- and long-term, while also consolidating their achievements by extending collection and controlled disposal to remaining pockets of service deficiency, including rural areas.

This contrasts with the high-income countries who regarded DB5 in the 1970s as a transitional state, focusing immediately on ramping up environmental standards for recovery and disposal facilities in a series of steps from ‘basic’ control (the entry point for DB5) through ‘improved’ to ‘full’ control or ESM (DB6 and DB7). Many countries currently in DB5 are relatively recent EU Member States who are working to improve the level of facility standards and collection services at the same time, so appear to be heading towards DB8 or DB9.

Current DB5 countries are a prime growth market for the WaRM service and technology supply sector. Unless checked, the costs of services can spiral upwards, sometimes with little visible result. The key pressure point is the financial regulator, ensuring that revenues entering the sector deliver quality services are not diverted for other purposes or used to generate excessive profit margins.

**DB6 and DB7** are two distinct approaches to achieving universal (95%) full control (ESM) of recovery and disposal and to maintaining and/or incrementally improving on that position. In DB6, Market Oriented Systems, the priority is to keep costs relatively low, so recovery and disposal are allowed to compete in an open market, provided that each meet the required technical and environmental standards. In practice, this likely means a significant dependence on landfill for disposal. Recycling also remains largely market-driven, operating in direct price competition with linear collect and dispose systems. Countries and cities choosing DB6 often have potential landfill space available near centres of...
waste generation, and a public who will accept new landfill sites (which is less likely if population density is high). The key pressure point is a strong and independent environmental regulator, key to ensuring that facilities are compliant with standards and service providers are operating across a level playing field. Common challenges include managing the transition when standards become more stringent, when investors in new facilities may be deterred if they face initial competition from existing facilities still allowed to operate to the old standards and preventing organised criminals from undercutting legitimate operators.

In DB7, High Recovery Systems, countries and cities make the choice to move away from disposal towards high rates of recovery. Motivations vary but may include some or all of the following: recovery requires less land and delivers higher economies of scale; suitable sites for disposal facilities near cities may be scarce or do not exist; there is strong public opposition to landfill; there is high market demand for products from recovery, for example electricity to feed into the grid, heat from district heating in cold climates or compost for agriculture in arid areas; recovery is perceived as environmentally preferable and/or higher on the waste hierarchy; rapid transformation of the WaRM recovery is perceived as environmentally preferable and/or higher on the waste hierarchy; rapid transformation of the WaRM sector to ‘modern’ practices is sought. Constraints to be overcome include higher investment and operating costs and sometimes vigorous public opposition to some technologies, particularly incineration. The key pressure point is the technical regulator function. Achieving ESM via recovery technologies depends on high technical policy standards backed up by availability of finance and a competent waste management industry sector.

DB8 and DB9 are two distinct approaches to address the 3Rs, improving collection service levels by separating wastes at source and thus enabling an increase in recycling rates, and beginning to target reduced waste generation. Experience suggests that stringent (i.e. both ambitious and binding) targets need to be set; these may be direct recycling targets; landfill diversion targets motivated also by reducing climate impacts; or even waste reduction targets. The two DBs differ in the mix of policy instruments used to meet the targets. In DB8, Policy Driven by Fiscal Mechanisms, reliance is placed primarily on, for example, landfill tax, landfill allowance trading schemes or recycling credits. Countries often move from DB6 to DB8, so continue to prefer market-based policy instruments to meet their new targets to divert waste from landfill to recycling. One key pressure point is the policy maker function.

In DB9, Policy Driven by Technical Standards, the focus is rather on mandating the changes required: for example by requiring separation at source, requiring recycling and banning landfill of particular MSW/materials streams from landfill and setting very high technical standards for both collection and recovery. Countries tend to move from DB7 to DB9. The key pressure point is the technical regulator, reflecting a preference to catalyse change by continually upgrading technical standards.

The distinction between DB8 and DB9 is based on the relative emphasis in the policy instruments chosen (i.e. fiscal mechanisms vs. bans and obligations); in practice, the mix of instruments will be specific to each location. However, current DB8 and DB9 countries still find it difficult to make substantial progress on waste prevention.

DB8 and DB9 represent the current status quo in terms of moving beyond ESM towards the 3Rs. The logical end point is DB Zero, the aspirational state of a truly Circular Economy, which sits proudly on top of the 9DBs tree. Unfortunately, there is as yet no clear consensus on what zero waste means in practice, and no city or country has yet achieved this aspiration; however, significant work is underway to map out and incentivise transformational change towards this future scenario. A critical pressure point is the change agent, which has already shown its importance in many countries as they move through earlier DBs.

Comparing the 9DBs

Table 1 summarises, compares and contrasts the DBs and draws out commonalities within each DB, using a standard pro forma; it is intended to be used as an aide memoir as well as providing some locational examples.

Various performance indicators for each DB are summarised in Column A of Table 1. DB1–DB4 are largely differentiated by their relative performance in relation to the SDG 11.6.1 indicators: (a) collection coverage and (b) controlled recovery and disposal. Collection coverage gradually increases from 0% to 30% in DB1 to 80% to 95% + in DB4a. Rates for management in a controlled facility lag somewhat behind, remaining at 0% in DB1, then up to 20% in DB2, 50% in DB3 and towards 95% + in DB4b. The boundaries between DBs are not rigid; for controlled disposal, the bottom of the range may stick at 0%, particularly if a city has just one or two official disposal sites. In DB5, the 11.6.1 indicators move beyond the 95% threshold for ‘universal’ coverage, but further progress towards 100% is often slow as service extension to rural areas and difficult to reach urban pockets can remain a challenge.

The rates for waste management in full control (ESM) facilities are typically very low up to DB3; begin to increase in DB4, particularly if regulations require standards based on ‘full’ rather than ‘basic’ levels of control (Figure 2); reach up to 50–70% + in DB5; with 95% + achieved in DB6/7. Recycling rates for MSW are more difficult to categorise between DBs. Informal recycling collectors can achieve rates of 10%–30% + in DB1–DB4, whereas the 1970–1980s baseline in the Global North (when in DB4–DB5) was <10%. DB8 and DB9 both show high recycling rates (up to 40%–60%).

As the level of WaRM performance increases through the DBs, so do the costs of service provision. Indicative data (with a nominal date of 2006 (UNEP and ISWA, 2015)) suggests WaRM service costs as low as US$20/tonne−1 (largely costs of primary waste collection and transport to a proximal place of disposal) in the early DBs, rising to perhaps US$50–100/tonne−1 (improved collection services, recovery systems, transfer and disposal beginning to meet environmental requirements) in DB4 and
Table 1. The nine development bands (9DBs). This table provides a brief pro forma summary of each DB as an aide memoire. Column A outlines WaRM system characteristics, focusing on indicators for collection coverage and management in a controlled or ESM facility, but also mentioning the reduce, reuse, recycle (3Rs). Column B shows commonalities in terms of challenges faced. Column C identifies critical developmental pressure points for transformational change, using the nine institutional functions defined in Figure 3. Column D shows some example locations.

| Development band (DB) | A. System characteristics | B. Common challenges | C. Pressure point | D. Example locations |
|-----------------------|---------------------------|----------------------|-------------------|---------------------|
| DB1 new beginnings    | Most waste self-managed, uncontrolled dumping and open burning the norm | Introduce basic collection systems | Operator | Many towns and cities in the least developed countries; areas recently affected by conflict or natural disaster; refugee camps; peri-urban and slum areas in cities in many LMICs |
|                       | Managed in a controlled facility: 0% Anything with value reused, repaired or recycled, at home or by informal sector | | | |
| DB2 early movement    | Collection coverage: 30%–60% Some collected wastes disposed at designated sites Managed in a controlled facility: up to 20% Active informal recycling | Expand collection coverage Introduce basic operational management practices at disposal sites | Municipal capacity to assume responsibility for service provision (i.e. client/employer function) | Many cities in LMICs, which are growing rapidly due to influx from rural areas. Includes many secondary cities |
| DB3 service extension | Collection coverage: 60%–80% Managed in a controlled facility: up to 50% Informal recycling often well established for a limited range of materials | Further expand collection coverage Introduce some engineered control and upgrade operational management practices at recovery and disposal sites | Planner | Many cities and megacities in LMICs |
| DB4 Consolidating Control DB4a: Universal Collection DB4b: Controlled Disposal | Collection coverage: 80%–95% Managed in a controlled facility: moving towards 95% As collection and disposal costs rise, diversion of waste from landfill by extending recycling moves up the municipality’s agenda | DB4a: Extend collection service coverage in cities to 95% DB4b: Extend controlled disposal in cities to 95-98%. Introduce gate fee or distinct line budget line for disposal – but avoid illegal dumping Build on existing informal recycling sector to enhance recovery system performance, for example by more separation at source | Revenue collector (Environmental regulator) | Diverse situations across the world, in cities of all different sizes, and in most continents Includes many small islands Residual pockets may persist for some time after a country progresses to the higher DBs |
| DB5 the target baseline | The new target baseline for meeting SDG 11.6.1 Collection coverage: 95% Managed in a controlled facility: 95% Managed in a full control (ESM) facility: → 50%–70% Increased focus on recycling – building on existing informal systems and increasing separation at source | Create a landing place for consolidation of achievements and preparation for next steps Expand collection service to rural areas and any unserved urban pockets Transition towards improved recovery and disposal standards as a step towards full control (ESM) Integrate recycling systems and extend separation at source Keep costs under control | Financial regulator | Most countries currently in higher DBs have spent a period in this transitional DB Current incumbents include many of the newer Member States of the European Union (EU) |

(Continued)
### Table 1. (Continued)

| Development band [DB] | A. System characteristics | B. Common challenges | C. Pressure point | D. Example locations |
|-----------------------|---------------------------|----------------------|------------------|---------------------|
| **DB6** market oriented systems | Managed in a full control (ESM) facility: → 95+ % High standards set for each technology Recycling, recovery and landfill compete in an open market so landfilling rates are often high and recycling rates low to moderate | Ensure and maintain full control standards for facilities Manage the transition when standards increase Prevent organised criminals from undercutting legitimate operators Public acceptance of new landfill sites | Environmental regulator | Some western and southern EU countries passed through DB6 in the 1980s–1990s North American and Australasian states/provinces have either passed through or still sit in DB6 |
| **DB7** high recovery systems | Managed in a full control (ESM) facility: → 95+ % High standards set for each technology Recovery (particularly waste-to-energy) favoured over landfill Recycling rates often low to moderate | First ramping up, then maintaining facility standards Sustaining high investment and operating costs Public acceptance of new waste-to-energy facilities | Technical regulator | Some central and northern EU countries passed through DB7 in the 1980s–1990s Some east Asian countries still sit in DB7 |
| **DB8** policy driven by fiscal mechanisms | Improved or full level of collection service with 2 or 3 separate fractions: → 95+ % stringent targets to divert waste from landfill Stringent recovery/recycling targets Reliance primarily on economic instruments | Use of fiscal mechanisms such as landfill tax, landfill allowance trading schemes and recycling credits to reach policy targets Instigation of initiatives on waste prevention | Policymaker (Change agent) | Countries tend to move to DB8 from DB6 Some countries in western and southern Europe Some states/provinces in North America and Australasia |
| **DB9** policy driven by technical standards | Improved or full level of collection service with 2 or 3 separate fractions: → 95+ % stringent targets to divert waste from landfill Stringent recovery/recycling targets Primary focus on mandating the required changes Set very high technical standards for both collection and recovery | Implement stricter technical requirements for separation at source, banning landfill or requiring recycling of MSW components Upgrade recovery facilities to latest technical standards Instigation of initiatives on waste prevention | Technical regulator | Countries tend to move to DB9 from DB7 Some countries in northern and central Europe, and in east Asia |
| **DB zero circular economy** | ‘Zero waste’ | Transformational change in production and consumption practices Striving for waste generation to be as close as possible to zero Innovations in materials science with widespread uptake | Change agent | An aspirational goal with work in progress, so no current examples |

3Rs: DB: development band; ESM: environmentally sound management; EU: European Union; LMICs: low- and middle-income countries; MSW: municipal solid waste; SWM: solid waste management.
US$150–250 tonne⁻¹ or more (more complex integrated waste management systems) in DB8–DB9. Average waste generation per capita tends to increase with rising income levels as countries develop economically (UNEP and ISWA, 2015; Wilson et al., 2012), so the increase in per capita costs from the lower to the upper DBs can become exponential.

**Testing the 9DBs framework**

This section tests the 9DBs framework by using it to describe historical journeys of countries, which have already progressed into the ‘upper branches’ of the 9DBs tree (Figure 4).

The UK is the first example. Up to the 18th century, solid wastes were largely unmanaged, except for some informal 3Rs (DB1). From the 1790s to the mid-19th century, coal ash in urban household waste (‘dust’) was in demand by the brick industry and for agricultural applications. In response, each local council within London granted an exclusive franchise for a private contractor to collect waste (DB2), which was then separated in ‘dust-yards’ (Velis et al., 2012). Several cholera epidemics from the early 1830s led to the first Public Health Act in 1848, which gave local authorities power to provide a waste collection service (DB3). A combination of the 1875 Public Health Act, which required householders to keep their waste in a ‘dustbin’ and obliged local authorities to empty those weekly; and the 1888 Local Government Act, which created larger authorities better able to collect revenue; led to increasing waste collection coverage (DB4a), largely reaching 99+% in urban areas by ~1900, and gradually extending also to rural areas. However, collected waste was largely disposed of in uncontrolled or semi-controlled dump-sites, which were often on fire; progress through DB4b to achieve 99+% controlled disposal was not completed until after the 1974 Control of Pollution Act.

The detail differs, but the early evolution of WaRM systems was broadly similar in other western, central and northern European countries, in the US and Canada, and in Japan, Australia and New Zealand. Having reached the top of the trunk of the WaRM tree around the 1970s, most of these countries spent a period in DB5, beginning the move from basic controlled recovery and disposal to full control (ESM), while working in parallel to extend collection to remaining rural areas. As technical standards for landfill and incineration were ramped up, their paths then began to diverge. Some countries, including the UK and most states in the US, were content to rely mainly on landfill (DB6), whereas others focused during this period (1970s–1990s) on recovery (DB7), with combined heat and power schemes in northern and central Europe where winters are cold and (for some) land is scarce.

Many US states continue to rely on market forces, combined with strict environmental standards, to determine the mix of recycling, recovery and disposal options (DB6); an abundance of land in many locations means that landfill predominates. The EU in contrast introduced targets in 1999 requiring Member States to divert waste from landfill to reduce methane emissions and thus mitigate climate impacts, and also established and gradually increased recycling targets. Quality standards for both recycled materials and for compost/digestate destined for use in agriculture necessitated a move beyond the ‘basic’ service level of mixed waste collection towards the ‘full’ service level of collecting three or more source-separated fractions. The UK chose to implement the new policy primarily using fiscal mechanisms (DB8); while several EU Member States had already moved away from landfill and focused rather on tightening technical standards and imposing bans and obligations (DB9). As new Member States have joined the EU, they have received both technical and financial assistance to achieve full controlled disposal (DB4b) and reach DB5 and to transition rapidly from basic to full levels of both facility control and collection service, ostensibly heading towards DB8 or 9. The EU’s Circular Economy Action Plan (European Commission, 2020) is a step on the path from DB8 and DB9 towards the ultimate objective of DB Zero.

China’s WaRM sector has evolved through a series of historical developments. The baseline system in the 1960s epitomised circular economy. State-owned municipal resource recovery companies achieved high recycling rates for a huge range of source separated materials (Furedy, 1990), whereas residual MSW was mainly organic materials and coal ash, which was collected and transported by municipal waste departments to transfer points in neighbouring agricultural areas from which it was received by farmers and composted for use on land. Urban collection rates were high (DB4a), as were levels of recovery – if this could have been categorised as ‘controlled’, then parts of the country were arguably among the first to reach the top of the trunk of the tree (DB4/5). However, by the mid-1980s, this system was unravelling; market reforms removed ‘subsidies’ from the State resource recovery companies with informal recyclers partly taking their place (Furedy, 1993); changes in consumption and waste composition made the MSW more contaminated and less degradable and new subsidies for artificial fertilisers slashed demand for compost (Furedy, 1989). So, while urban collection coverage remained high (putting cities towards the top of DB4a), rural transfer points became uncontrolled disposal sites and the rate of controlled recovery and disposal plummeted, leaving WaRM sector practices in DB3 or low DB4b.

In response, China introduced national standards for both landfill sites and recovery (incineration) in the 1990s, ramping up standards in a series of steps (Zhang et al., 2010). From the 2000s, the situation began to turn around with specific policy focus being placed on modernising the WaRM sector, including marketisation of the recovery sector, and consequent emergence of a strong domestic WaRM industry. In the 2010s, China surpassed DB4b, transitioned rapidly through DB5 due to a considerable tightening of environmental regulation and control on waste recovery and disposal facilities; and since became established within DB7 thanks to a sustained focus on technology adaptation and innovation. Very recently, policy attention has shifted to recycling, with separate collection of MSW fractions now mandatory in major cities (Wu et al., 2021); China is
implementing policy instruments that are reflective of a transition towards DB9.

The final example of Bahrain is typical of Gulf States. An international company was contracted to modernise waste collection and street cleaning services in the 1970s, leading to a transition from DB2/3 towards the top of DB4a. Uncontrolled disposal sites were replaced by a single centralised controlled landfill, which opened in 1987, moving the country’s WaRM sector to the top of DB4b, and into DB5, where it has since remained (Al Sabbagh et al., 2012). More recently, the government has sought to build a modern recovery facility, which could indicate a direction towards DB7.

Applying the 9DBs to low- and middle-income countries

Having tested the 9DBs framework against the past journeys of higher income countries, this section seeks to explore how it can be applied to facilitate the current journeys of LMICs, which are still negotiating the roots and trunk of the WaRM tree in Figure 4, aiming to emerge into the ‘leafier upper branches’.

In our view, urgent and priority focus must be on the more than two to three billion people living without access to waste collection and controlled recovery and disposal, essentially those countries, cities and regions within DB1–DB4. Meeting the SDG 11.6.1 indicator of universal collection and management in controlled facilities, and thus reaching the new baseline target of DB5, is fundamental to addressing the urgent challenges of marine plastics, open-burning and pollution.

Meeting this enormous challenge requires accurate targeting of development interventions. There is a strong need to identify areas of focus reform and investment in the DB1–DB4 WaRM systems. With the help of the 9DBs conceptual framework, we are able to highlight critical pressure points in terms of the institutional roles and responsibilities (Figure 3) that should be considered by WaRM practitioners while working in countries/cities within each DB.

Extending collection

Extending waste collection service coverage is central to DB1–DB4. In section ‘DB1 new beginnings’, the critical pressure point is to establish operators, which often means mobilising communities to establish collection services through social entrepreneurship, with emphasis on providing sustainable livelihoods. The lead can be taken by local CBOs or NGOs, sometimes catalysed by international NGOs or development agencies (Wilson et al., 2017). Additional income can be generated from separation of materials for informal recycling, selling into either an established secondary material market or a very local one (Lenkiewicz and Webster, 2017). Innovative approaches can be taken to bundle MSW collection with other complementary urban environmental services, such as sanitation and faecal sludge management.

In section ‘DB2 early movement’, the municipality begins to accept responsibility for ensuring the provision of waste collection services, often delivering services directly to the central business district and some more formal residential areas. Key interventions are to build the capacity of the WaRM function within the municipality, with focus on the client/employer function, opening up opportunities for the private and community sector to deliver services within a stable, fair and dynamic marketplace.

The city of Bo in Sierra Leone provides a case study of appropriate development interventions to progress from DB1 through DB2 (Table 2). Collection services had to be restarted from a low baseline when the civil war ended in 2002. Responsibility for WaRM was consolidated within one department with its own budget and revenue generating powers. Management capacity was developed to engage the community in planning service extensions, to deliver services directly and to act as ‘client’ for a series of public–private–community partnership initiatives. These include waste collection micro-enterprises run by formerly unemployed youths and small ‘waste-to-wealth’ businesses manufacturing recycled products for the local market. Bo, Sierra Leone also illustrates another potential route to capacity building, via knowledge exchange with a ‘twin’ city, in this case Warwick in the UK.

Expanding the focus to controlled disposal

In DB1, the key priority is to get waste out from under foot; uncontrolled or burning is prevalent. In DB2, collected waste often goes to designated disposal facilities; these are generally established outside the urban area, but can quickly become surrounded by people as the city grows and a recycling economy forms around the disposal site. In DB3 Service Extension, attention shifts to a dual focus: bringing disposal under control, either by upgrading existing sites (Rushbrook, 1999, 2001), or developing new recovery and disposal facilities; alongside further extending waste collection, with particular attention to peri-urban and low-income/slum settlements.

This requires a detailed understanding of the current baseline situation and forecasting of future population growth, rates of migration into the city from rural areas and changes in both waste generation per capita and waste composition. The city needs to identify how services are to be delivered, and to identify and reserve sites for both recovery and disposal facilities, and also for transfer of waste into larger vehicles if required by long transport distances. It needs to know how much budget is needed to support these efforts year on year. In short, the city needs to develop a strategic plan for WaRM.

The critical pressure point for development intervention in DB3 is thus the planning function. This can be interpreted broadly to include putting in place the necessary policy/legal/institutional frameworks for WaRM sector development at a national/state level, as well as more traditional local/regional
planning to upgrade services and infrastructure. Without a strategic plan in place, in a rapidly developing city context, it is unlikely that demand for services/infrastructure will be forecasted correctly or budgeted for adequately. The result is almost universally a shortfall in investment and operational financing, which will generally result in recovery and disposal services being either underfunded- or completely unfunded.

### Table 2. Case study: applying the 9DBs conceptual framework to city of Bo, Sierra Leone.

| Case study | City of Bo, Sierra Leone |
|------------|-------------------------|
| Geographical/contextual | Second largest city in Sierra Leone, West Africa. Civil war ended in 2002 |
| Baseline position of WaRM | As in 2007 |
| Population | 2004 census: 167,000. 2020 estimate: ~200,000 |
| Waste generation | 2013 data: Household waste 75 tonnes day\(^{-1}\), 0.37 kg (capita day)\(^{-1}\). Total MSW 120 tonnes day\(^{-1}\). 2005 waste composition: 75% organic (kitchen + garden) |
| Collection coverage | Perhaps 10%–20%. Bo City Council (BCC) had two trucks and 20 casual labourers; only central business district (CBD) serviced. Widespread dumping and burning of uncollected waste contributed to flooding and disease, for example malaria and Lassa fever |
| Controlled disposal | 0%. BCC ran one designated dumpsite – very poor access, little on-site control |
| Reuse, recycling, recovery | Widespread reuse (e.g. animal feed). Informal recycling focused on metals |
| Inclusivity | Household wastes mainly self-managed by women and children. Limited services provided by the city. Some informal sector collection for recycling |
| Financial sustainability | City spent ~30% of its total budget on WaRM but struggled to provide a service |
| National framework | Ministry of Health & Sanitation responsible for policy; Ministry of Youth & Sports for services; powers delegated back to elected local government in 2004. Policy focus: extend collection, protect public health, clear drains and prevent flooding |
| Local institutions | WaRM responsibility spread over several BCC departments, little capacity |
| Where did it fit in the DBs? | The civil war set SWM back to ‘square 1’, within DB1. The city struggled to restore more widespread collection and move up through DB1 |
| History of development interventions | UK Aid funded technical assistance (TA) from 2007 through long-standing ‘twinning’ of Bo with Warwick. UNDP TA 2008–2011. On-going UK Aid TA: German development NGO Welthungerhilfe (WHH) on the ground since 2014 |
| What were the interventions? | Focused first on establishing operator models to collect wastes from unserved areas and to recover value, then rolling out those services across the city and strengthening the waste management functions within BCC |

- **Development of operators**: Early work helped BCC to upgrade in-house collection services by providing skips across the city: 2013 collection coverage ~30%–40%. BCC also instituted basic controls at a new dumpsite with better access
- Later work developed the community NGO ‘Klin Bo Services’, training youth groups to set up and run small waste collection enterprises, earning money from user fees and separating saleable materials. Each group equipped with a motorised three-wheeler and wheelbarrows to access unserved areas. Also developed small ‘waste-to-wealth’ businesses, including composting and charcoal production from organic wastes; ecobricks, paving stones, baskets and handbags from plastics; and cooking pots or clothes hangers from aluminium cans

- **Building municipal capacity**: Consolidated WaRM responsibilities within one department; gave BCC own revenue generating powers, from household and commercial waste collections, septic tank revenue and gate fees from landfills; developed strong municipal by-laws. Developed management capacity to deliver services directly, to act as ‘client’ for the various public–private–community partnership initiatives and to engage the community in service planning

- **Outcomes and movement on DB scale**: Bo has moved from <20% collection coverage and piles of waste accumulating along the streets (DB1) to being the cleanest city in Sierra Leone. Low-cost waste collection is now available to everyone who is able and willing to pay; participation rates are ~50% (DB2). About 200 previously unemployed youths now earn a livelihood from waste collection or making new products from recycled materials

- **Sources of information** ([Greedy, 2012]; [Abarca and Thurn, 2013]; [Flett, 2014]. GWMO Case Study 7 [UNEP and ISWA, 2015]. Personal communication, 2020, with Oliver Priestley-Leach [WHH])

BCC: Bo City Council; CBD: central business district; DB: development band; GWMO: global waste management outlook; NGO: non-governmental organisation; SWM: solid waste management; TA: technical assistance; WaRM: waste and resource management; WHH: Welthungerhilfe.
How to cover escalating costs?

In DB1, any community-based or informal services for waste collection and/or recycling must cover their operating costs from a combination of user fees for the collection service, income from the sale of recovered materials, and if made available, municipal budget. Users may be willing to pay a small fee when they can see the benefit, which is usually in terms of keeping their immediate neighbourhood clean, as for example in Bo (Table 2).

In DB2, a significant proportion of the municipality’s budget may go to SWM, of which 90–95% is typically directed to collection and street sweeping. Labour costs are low, so low-tech, high-labour solutions are most common. Limited budget is available for investment; the priority is on collection vehicles and equipment, which need to work reliably under local conditions (e.g. dense/wet waste, restricted access, unmade roads and high ambient temperatures). Hand-, animal- or cycle-carts, a tractor and trailer or a simple tipper-truck may be more appropriate than a modern refuse collection vehicle (RCV) with hydraulic compaction; modernisation does not have to mean motorisation (Coffey and Coad, 2010).

By the time DB3 is reached, the cost per tonne is beginning to rise, and costs of disposal begin to be budgeted for. In section ‘DB4 consolidating control’, the critical issue becomes how to pay for universal collection and increased facility standards, necessitating a strengthening and diversification of the revenue collector function. There are many mechanisms for revenue collection; most assume that the costs are paid ultimately by citizens and businesses, for example through direct charges, or other utility bills, or local or national taxes (UNEP and ISWA, 2015). The revenue collection function is commonly undertaken by or on behalf of the municipality, though some private operators may charge the user directly for services.

It is becoming increasingly questioned why the municipality, and the public, should be expected to pay all the costs when much MSW comprises single-use packaging and other end-of-life products; extended producer responsibility (EPR) is increasingly used in developing as well as developed countries to pass some or all costs back to the producer and supply chain (Rodic et al., 2015).

Project STOP in Muncar, Indonesia provides a case study of how a small city can move rapidly from DB1/2 to DB4a (Table 3). The interventions address the critical pressure points for all four DBs, but a particular focus is on improving revenue generation. Much effort is going into changing and then normalising people’s behaviours to present waste for collection, to sort materials for recycling at source and to pay a small fee; mid-way through the project, collection coverage had increased from ~20% (DB1) to 66% (DB3), with fee collection rates from those receiving a service already at 76%.

In DB1, uncontrolled disposal to the environment is, by definition, ‘free’. In DB2, waste can generally be delivered to the designated disposal site free of charge, to encourage its use rather than ‘wild’ dumping. So, the decision, generally at some point in DB3 or even DB4, to put a price on disposal, by charging a gate fee for every tonne of waste delivered, is an important milestone (Scheinberg, 2011).

To avoid illegal disposal (fly-tipping) becoming an issue when disposal costs are first introduced, effective enforcement is important – which highlights the crucial role of an independent and adequately resourced environmental regulator. The ability of the environmental regulator to pursue cases on non-compliance, in particular non-compliance of disposal site operations, is a ‘tipping point’ between the lower and higher DBs. The city/municipality should not be exempt from the environmental standards of disposal. The crucial role of the environmental regulator has become evident in DB4 and will continue to be strongly relevant in all of the upper DBs.

Many cities in DB3 and DB4 struggle to afford the operating costs for their existing SWM systems. So, it is a challenge to finance the investment needed to extend collection and upgrade facility standards; inappropriate investment decisions can easily paralyse system development. One evaluation tool uses the ‘PentA’ rule of thumb: any selected technology should be institutionally appropriate, technically applicable, legally achievable, financially affordable, and environmentally acceptable (Gower-Jackson et al., 2018; Pilusa & McCarthy, 2016). Several decision-makers’ guides are available (GIZ, 2017; Liu and Nishiyama, 2020; UNEP, 2019; USEPA, 2020); there is consensus that relatively sophisticated and expensive recovery facilities should not be considered until the basics of a waste management system are in place, that is when a system has successfully reached the new target baseline (DB5).

Evolution of recycling and recovery

Reuse, recycling and recovery predates formal waste management; if a market exists for materials thrown away by the affluent, then people from more economically marginalised groups will take that opportunity to earn a livelihood. If the market price is high enough, then some informal recyclers will go door to door, buying clean source-separated materials such as newspapers, plastic bottles or old shoes from richer households (or their domestic helpers). Such itinerant waste buyers sit alongside the waste pickers who pick recyclable materials from mixed waste, for example put out for collection or at disposal sites, as part of the IRS (Wilson et al., 2006). In DB1 and DB2, recycling is a completely private sector, market-based activity, with the only revenue coming from selling into the materials value chains. But waste collectors often supplement their income by picking materials for recycling, and itinerant buyers ‘count’ towards collection coverage for SDG indicator 11.6.1 (a), so the SWM and recycling systems overlap. Interventions can usefully identify, and help local entrepreneurs meet, local market opportunities; one example is provided by Bo (Table 2) and a toolkit is available (Lenkiewicz and Webster, 2017; Wilson & Webster, 2018).

In DB3 and DB4, income levels rise and the proportion of recyclable materials in MSW increases. The IRS can provide livelihoods for large numbers of people and achieve significant recycling rates (Linzner and Lange, 2013). But tensions can arise as collection and disposal costs increase in the formal SWM system; both the city and private waste contractors may view the recycled materials as a lost revenue stream, instead of...
Table 3. Case study: applying the 9DBs conceptual framework to project STOP in Muncar, Indonesia.

| Case study | Project STOP in Muncar, Indonesia |
|------------|----------------------------------|
| Geographical/contextual | Muncar is a sub-district of Banyuwangi regency on the east coast of Java, Indonesia’s most populous island. Economy is based on fishing and agriculture |
| Baseline position | As in April 2018 baseline study |
| Population | 2018 Population: 134,780 with 40,485 households |
| Waste generation | 0.37 kg (capita day$^{-1}$), 4.7 tonnes day$^{-1}$. 75% organic, 13% plastic |
| Collection coverage | ~20%, which was significantly lower than the 39% national average and 45% in similar cities. 80% of wastes in Muncar leaked to the environment: about 20% buried or dumped on land, 20% open burned and 40% dumped in water |
| Controlled disposal | Across Indonesia: of the waste that is collected, around 25% is recycled, 50% goes to managed disposal sites and 25% to dumpsites |
| Reuse, recycling, recovery | Informal pickers collect ~6 tonnes recyclables day$^{-1}$. Sent 300 km to Surabaya, East Java. Indonesia has 2.0–3.7 million pickers, some organised into cooperatives |
| Inclusivity | Uncollected waste is managed mainly by women at the household level. Waste collection responsibility of the village government. Recycling collection entirely informal sector |
| Financial sustainability | A major constraint. In principle, funded largely from national, regency or village budgets, but waste not a high priority. Waste budgets limited and hard-to-spend; little capital funding and restrictions on operating spend. Local politicians reluctant to set waste fees at a level to make universal collection sustainable, improve worker productivity or enforce ethics and discipline |
| National framework | First national waste policy 2007, new National SWM Policy and Strategy launched 2017. Responsibility spread across multiple ministries and local governments |
| Local institutions | Responsibility for waste collection is at village level (10 villages in Muncar sub-district). SWM staff are political appointees, generally without technical expertise, and can be replaced suddenly. Inter-village resentment limits cooperation on larger disposal facilities |
| Development interventions | Indonesian government has prioritised SWM. Adopted ambitious plan in 2018 to cut weight of plastics entering the oceans by 70% by 2025. Project STOP, founded by Borealis and SYSTEMIQ, aims to help meeting that target. Muncar first of three pilot cities in East Java and Bali [April 2018–December 2021] Baseline studies included waste characterisation, local attitudes and behaviours towards waste, an assessment of the local governance and legislative environment and opportunities for recycling end-markets |
| Operators: | developing village or sub-district level local, autonomous non-profit waste collection bodies (called a BUMDES). Capital finance, along with technical support, made available for new services. Acknowledges existing informal recycling networks without disrupting them Building municipal capacity: developing autonomous, financially secure and technically capable municipal Solid Waste Management units within the sub-district government. Focus includes the client function, managing the operators to ensure services delivered, and policy engagement at the regency and national level. Support on stakeholder engagement to facilitate behaviour change in local communities to: present waste for collection, separate at source and pay a small fee |
| Planning: | supporting development of a regency-wide strategic waste plan, of which STOP expansion is a major part |
| Revenue generation: | Ensuring long-term financial sustainability is a key focus. Revenue from the sub-district budget is important, but during COVID-19, this has been diverted elsewhere. Collection fees at US$0.70 household month$^{-1}$ are designed to be affordable to all. Material sales also provide additional revenue (although these are typically low value as informal recyclers have generally removed higher value materials). The 3-year programme also aims to engage international premium markets for plastics diverted from the oceans and financial support from packaging and product producers (EPR) |
| Outcomes and movement on DB scale | The aim of Project STOP is to shift from the current DB1/2 to reach DB4a by end of 2021, extending collection to most of the population and eliminating leakage of waste into the environment. Achievements mid-way through [September 2020] include establishing BUMDES in the four largest villages, increasing collection coverage to 66% [DB3], fee collection rate 76% and 85 new full-time jobs created |
| Sources of information | [Danielson et al., 2020; Stuchtey et al., 2019; SYSTEMIQ, 2020]. Personal communication with Joi Danielson, SYSTEMIQ |

BUMDES: autonomous non-profit waste collection bodies; DB: development band; EPR: extended producer responsibility; SWM: solid waste management.
Recognising that the IRS handles perhaps as much as 10%–30% of total MSW at no direct cost to the city, saving them US$ millions (UNEP and ISWA, 2015). So, rather than replacing the IRS with formal recovery systems, a better approach can be to work towards the inclusion of the IRS alongside the formal SWM system: both a review of the barriers and success factors (Aparacana, 2017) and a number of tools to facilitate this (Jaligot et al., 2016; Scheinberg and Savain, 2015; University of Leeds, 2016; Velis et al., 2012) are available. There are also opportunities for direct cooperation between producers, who need to take responsibility for their products and packaging when they become waste, and the informal recycling sector who could collect them for recycling, thus preventing their leakage to the environment.

Within DB4, and particularly in countries which have reached the new baseline of ‘universal’ (95+%) collection (DB5), achieving just a ‘basic’ level of collection service (DB5), is no longer sufficient. The focus shifts rather to separate collection, encouraging householders to separate waste at source, into two fractions (‘improved’ level of service) or three or more fractions (‘full’ service). Such differentiated collection reduces cross-contamination and facilitates higher quality recycling of both dry materials and organics. It makes good sense to prepare for this transition before reaching the new baseline in DB5, by building on the existing local recycling system, which is often the IRS. This point is reinforced by the earlier observation, that in some countries itinerant waste buyers have been paying householders and businesses for separated materials for generations (‘full’ service).

**Reflections on the 9DBs framework**

The 9DBs conceptual framework classifies WaRM systems into nine system types or ‘DBs’ with recognisable commonalities. Within each DB, one can identify system characteristics, common challenges and critical developmental pressure points. Although the level of WaRM development often varies within and between regions/cities, it is possible to identify a ‘centre of gravity’ that roughly correlates to one of the DBs.

The 9DBs framework is useful when designing development interventions, governance reforms and investment strategies, particularly in LMICs, which are still negotiating the ‘roots’ and ‘trunk’ of the ‘9DBs tree’ (DB1–DB4); locating the present position within the DB framework helps to scope future initiatives to move the centre of gravity ‘upwards’. The early focus needs to be on extending collection (DB1 and DB2), with a subsequent parallel focus on management in controlled facilities, which includes both ‘formal’ disposal and ‘informal’ recycling or other recovery (DB3 and DB4). The critical pressure points include: in DB1, establishing inclusive operators for service delivery; DB2, municipal capacity to assume responsibility for service provision (the client/employer function); DB3, planning of WaRM services and infrastructure and DB4, ensuring sufficient revenue for financial sustainability. Such governance/institutional reforms are key to most development interventions; technological solutions alone are not sufficient.

The costs, either per tonne of waste or per household, increase significantly as WaRM systems progress through the DBs. Emerging into DB5 by extending collection (global waste target GW1) to, and eliminating uncontrolled disposal and open burning (GW2) from, 95+% of the population, thereby largely achieving SDG indicators 11.6.1, represents both a major achievement and a challenging target for all LMICs. For the least developed countries, the financial costs of achieving DB5 are locally unaffordable, but the economic benefits to the global community in terms of climate change mitigation and adaptation and reducing plastics entering the oceans are huge. The first GWMO set the target date as 2020 (UNEP and ISWA, 2015); the updated GWMO2 calls for a coordinated global effort to help all LMICs to reach this new baseline of substantial SDG 11.6.1 performance, corresponding to DB5, by 2030 (UNEP and ISWA, 2021).

Part of this global effort will involve an increased focus of both official development assistance and climate finance on SWM and WaRM. However, it is also critical that the ‘producers’, including the transnational fast-moving consumer goods companies (FCMGs) who put products and packaging on the market in every country, take full responsibility for the resulting solid wastes – particularly in those countries and locations where, for example the plastic packaging will currently often be open burned or leak into the ocean. Establishing a global regime for EPR, which applies wherever products are sold and which channels the funding into MSWM services, could positively tip the balance and catalyse the large-scale roll out of MSW collection services for all, one of the greatest challenges for WaRM sector practitioners.

The upper bands of the 9DBs are based on empirical observation; most countries who have so far reached this part of the tree have been (relatively) high income. So, although DB5 has always been a place for consolidation of the ‘basic’ service level for waste collection and control level for management facilities, it has primarily been viewed as a transitional development stage. The early occupants of DB5 worked quickly to raise facility control levels and move into DB6 or DB7. Only later did they turn attention to raising collection service levels beyond the basic level of universal collection of mixed waste to focus on several separated waste streams, leading to DB8 and DB9 evolving as higher DBs. The more recent Member States of the EU who currently occupy DB5 are working to improve facility standards and collection services at the same time, so appear to be leapfrogging towards DB8 or DB9.

Nuance and local context are important when determining interventions: good baseline data are required on both physical and governance aspects. Improving WaRM systems is a dynamic journey involving many steps, both to establish firm ‘roots’ and ‘trunk’ for the ‘9DBs tree’ through DB1 to DB4, arriving in DB5 once 95+% performance against SDG indicators 11.6.1 is achieved and then moving through the ‘leafy upper branches’. As the journey progresses, situations change and so do technical solutions. For instance, the village level waste systems of...
Indonesia may have been appropriate for a low income, largely agrarian society in DB2, but not for an emerging middle income, rapidly industrializing nation aspiring to DB5 and beyond (Table 3). China has moved rapidly from DB4a to DB4b, DB5, DB7 and recently towards DB9, implementing technological solutions that were unthinkable even a generation ago.

**Opportunity to reshape the roadmap**

The world has set the target that all LMICs should extend MSW collection to all and manage all wastes in controlled recovery or disposal facilities (meeting SDG 11.6.1), thus reaching DB5, the new target baseline for WaRM systems. These prospective new arrivals in DB5 will have different perceptions and priorities to the high-income countries who passed through DB5 some 40–50 years earlier, and indeed the new EU Member States who largely occupy DB5 now face different challenges and constraints to their predecessors. The prevailing social and economic context may mean that immediate ‘progress’ to higher DBs is not affordable, so that DB5 needs to become a comfortable landing place, a desirable destination rather than just a transitional stage.

For LMICs newly arriving in DB5, a new paradigm is needed to reshape the existing DB road map. A priority of such countries will be to consolidate the financial sustainability, both of their new baseline of basic service and control levels and of improved levels moving forward. How best can that be done? Existing routes ‘upwards’, either via DB6 → DB8 or DB7 → DB9, have typically been accompanied by rising waste quantities and escalating costs. Can a more sustainable new route be devised, perhaps aiming direct for DB Zero at the top of the tree? What groundwork can be done in the developmental stages DB1–DB4 to help countries/cities to reach DB5 with one eye already fixed on DB Zero? We believe these are the key questions being posed regularly as the economic, social and cultural dynamics change. It enables an intended ‘programme’ or ‘project’ to be designed and sense checked, helping to determine whether interventions are effectively targeted and sufficiently comprehensive. It can help the WaRM development practitioner to unlock a diversity of different systems types, which can then be tailored to local needs and realities.

The 9DBs framework brings clarity to discussions on waste and development. It emphasises the diversity of global WaRM systems, explains how systems have developed over time and identifies pressure points that help trigger change. It allows us to shine a light on the complexity of WaRM systems and identify areas where efforts need to be focused in order to unlock the status quo and allow reforms and development interventions to take root and flourish. It also reinforces the conclusion from previous work that ‘no one size fits all’ (Scheinberg et al., 2010; UNEP and ISWA, 2015). There is no one governance structure or technology that can ‘solve’ waste; WaRM systems cannot simply be translated from country to country or even city to city; solutions need to be both tailored to local needs and realities and reappraised regularly as the economic, social and cultural dynamics change.

We believe that the 9DBs can facilitate the design of smarter development interventions in all WaRM systems. It is helpful both for countries, regions and cities aiming to establish universal basic collection services, and controlled recovery and disposal systems (meeting SDG indicator 11.6.1, reaching DB5), as well as those that are charting a path towards a DB Zero circular economy.

Ultimately, this is a call for us to get smarter about how we support those struggling with the basics of waste collection, recovery and disposal. The focus of global efforts must clearly be to support the rapid transition of countries in DBs 1–4, with interventions aiming to shift their ‘epicentres’ upwards, both to safeguard local public health and the quality of the living and natural environment and to mitigate significantly the global challenges of climate change and ocean plastics.

**Conclusions**

The 9DBs framework is a first attempt to formulate a conceptual framework and global theory of waste and development. It provides an overview of the ‘big picture’: where does this or that country, region or city fit into the overall spectrum of WaRM sector development? It gives nuance and depth to the debate on appropriate waste collection, recovery and disposal systems and the governance frameworks under which they function, allowing deeper contextual analysis.

The 9DBs conceptual framework is an important addition to the WaRM practitioners’ toolkit, filling a key gap by focusing on the initial framing of the problem at the early scoping or prioritisation phase. It enables an intended ‘programme’ or ‘project’ to be designed and sense checked, helping to determine whether interventions are effectively targeted and sufficiently comprehensive. It can help the WaRM development practitioner to unlock a diversity of different systems types, which can then be tailored to local needs and realities.

The 9DBs framework brings clarity to discussions on waste and development. It emphasises the diversity of global WaRM systems, explains how systems have developed over time and identifies pressure points that help trigger change. It allows us to shine a light on the complexity of WaRM systems and identify areas where efforts need to be focused in order to unlock the status quo and allow reforms and development interventions to take root and flourish. It also reinforces the conclusion from previous work that ‘no one size fits all’ (Scheinberg et al., 2010; UNEP and ISWA, 2015). There is no one governance structure or technology that can ‘solve’ waste; WaRM systems cannot simply be translated from country to country or even city to city; solutions need to be both tailored to local needs and realities and reappraised regularly as the economic, social and cultural dynamics change.
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