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A BLUEPRINT FOR CIRCULAR CITIES:

Policies, Systems, and Guidelines for Solid Waste Management in the Rapidly Urbanising Mekong Region

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Cover: Worker separates waste in Da Lat, Vietnam. © michaklootwijk/ AdobeStock.com
Backcover: Local traders buying and selling produce from wooden boats. © Heli video/AdobeStock.com

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Acronyms

CSO	Civil Society Organisation
EPR	Extended Producer Responsibility
EUR	Euro (currency)
GMS	Greater Mekong Sub-region
GDP	Gross Domestic Product
ISWM	Integrated Solid Waste Management
MRF	Materials Recovery Facility
NGO	Non-Governmental Organisation
PET	Polyethylene Terephthalate
PPP	Public-Private Partnership
RDF	Refuse-Derived Fuel
SDGs	Sustainable Development Goals
SMART	Specific, Measurable, Achievable, Relevant, Time-bound
SWOT	Strengths, Weaknesses, Opportunities, and Threats
SWM	Solid Waste Management
SWMP	Solid Waste Management Plan
TPD	Tonnes per Day
US$	United States Dollar
WtE	Waste-to-Energy

Note: *Unless specified, all photos are from the author.*

01 INTRODUCTION

Fisherman fishing in Mekong River.

The Urban Mekong Corridor Initiative

The Greater Mekong Sub-region (GMS) represents a naturally interconnected economic region woven together by the Mekong River, one of the longest transboundary rivers in Asia. It has six member countries: Cambodia, China, the Lao People's Democratic Republic (PDR), Myanmar, Thailand, and Vietnam. The river is an important channel for transportation, tourism, and biodiversity and a source of energy. It sustains vital sectors, such as aquaculture and agriculture. These interconnected elements mean the Mekong is not just a geographical entity, but also a complex ecosystem critical to the well-being of the entire region.

While the GMS remains one of the least urbanised areas in the world, the number of people migrating to cities is rising rapidly, with an urbanisation growth rate exceeding the global average. The Lower Mekong Basin (encompassing Cambodia, Lao PDR, Thailand, and Vietnam) is home to nearly 70 million people. This region is projected to experience significant population growth, with estimates suggesting it will reach 110 million by 2050.

Urbanisation is producing substantial economic advantages for the region. Cities and towns are evolving into drivers of economic growth and hubs of culture and innovation. Most employment growth is also happening in towns and cities, underscoring the increasingly pivotal role urban centres will play in national economic development over the next two decades.

Much of this economic growth, however, is unevenly distributed. Towns and regions with inadequate infrastructure and limited investment persistently experience high poverty rates, slow growth, and substantial in- and out-migration to larger cities and neighbouring nations. Informal employment and housing are prevalent, with limited access to public services – a situation that increases the vulnerability of migrants and residents to exploitation and displacement.

The Urban Mekong Corridor Initiative (UMCI) links rapidly urbanising towns and cities to promote inclusive green development, comprehensive economic planning, and environmental sustainability. By leveraging key urban, regional, and financial partnerships, the initiative aims to foster economic and social equity collaboration while ensuring long-term environmental resilience.

> "In order to address the adverse impacts of climate change, partnerships between cities along the Mekong Basin will be crucial and will require capacity building, knowledge sharing, and networking among partners."
>
> — H.E. Mr. Atsaphangthong Siphandone, Governor of Vientiane Capital, at the first UMCI Dialogue, February 2024

> "Lao PDR is committed to environmental stewardship and its role in promoting a collaborative approach to addressing the complex challenges of urbanisation in the Mekong Corridor, particularly on waste management."
>
> — H.E Lao PDR Vice Minister Luangxaysana, at the first UMCI Dialogue, February 2024

1 Mekong River Commission (n.d.), Mekong Basin (mrcmekong.org).

2 https://www.citiesalliance.org/urban-mekong-corridor-initiative.

More than ten cities joined the first UMCI Dialogue in Vientiane in February 2024, where they prioritised discussions and solutions for solid waste management (SWM).

For cities along the Mekong River, SWM is a shared, significant challenge. Waste pollution not only affects local environments, but also has transboundary impacts – polluting the Mekong River and extending into the South China Sea, affecting several ASEAN coastal countries.

Success hinges on applying innovative approaches to waste management and fostering behavioural change within local communities.

Any SWM planning must account for rapid urban population growth, driven by significant rural-to-urban migration, alongside shifting consumption patterns and economic expansion.

Population and economic growth present opportunities, but their associated challenges, such as increased consumption and waste generation, must be effectively managed to ensure sustainable outcomes.

Figure 1:
The Urban Mekong Corridor Initiative Focus Area

Purpose of this Guide

This guide was developed by experts specialising in the Mekong Corridor and is adapted to the realities of its cities.

This blueprint serves as a dedicated guide for cities along the Mekong River Corridor to support their planning, decision-making, and discussions with development partners. It is not intended to be a technical manual that delves into the intricate aspects of SWM. Instead, it offers a comprehensive reference to help local governments and communities understand the broader system requirements. By providing an overview of the various elements of the SWM process chain, this blueprint ensures that a wide range of stakeholders can understand the key concepts and challenges.

Developed by experienced solid waste practitioners, the blueprint draws on global knowledge and direct experience working in the Mekong region. While global lessons can be valuable, it is crucial to acknowledge the Mekong Corridor's unique conditions, challenges, and opportunities, particularly concerning climate, the environment, biodiversity, culture, local populations, government institutions, legislation, and overall capacity. Cities can learn from global best practices, but SWM solutions, infrastructure, and services must be tailored to the local context. This approach ensures that strategies are effective, operations can be implemented efficiently, and that the overall system is sustainable in the long term.

The guide begins with a brief introduction to SWM that includes an outline of the waste management challenges in the Mekong River Corridor, followed by an overview of the need to shift from linear-based waste management practices (collect and dispose) to those that are built on the principles of the circular economy. This shift emphasises resource efficiency, waste minimisation, and the continuous circulation of materials.

Following the introduction, the blueprint provides a comprehensive overview of the requirements of the SWM system, addressing critical considerations such as legislative frameworks, governance, and the roles of various stakeholders. The subsequent sections focus on operations across the five core stages of the SWM supply chain: waste generation, collection, sorting, processing, and disposal. These sections provide insights into the necessary infrastructure and services required to establish an integrated and sustainable waste management system tailored to the needs of a particular city.

Housing, Mekong Delta, Vietnam.
© J-F Perigois/AdobeStock.com

An Introduction to Solid Waste Management

Solid waste management encompasses the comprehensive process of handling waste and post-consumer materials to mitigate their impact on human health and the environment while enhancing resource recovery. This system involves five phases that cover the logistics and management of waste, including:

1. **Waste generation.** All SWM systems start with waste generation. Everyone generates waste. It is important to capture the waste at the point of generation so that it enters the SWM system and does not get littered or dumped into the environment.

2. **Collection.** There are multiple ways to collect and separate waste, such as household collection, drop-off centres, and deposit or refund programmes. Waste can be collected from the place it was generated, or the generator of the waste can bring it to a collection point.

3. **Sorting and separating.** The most efficient and effective approach for separating recyclables from disposal waste is using 'source-separation' rather than sorting mixed waste after collection. Requiring waste generators to separate dry recyclables and organic wastes can help provide higher-quality material streams and reduce contamination. Further sorting of these materials is usually undertaken in a materials recovery facility, where individual material streams (e.g., packaging materials, electronic waste, and construction and demolition waste) are separated.

4. **Processing.** Rather than disposing of waste, many materials and products have the potential for reuse, recycling, or reprocessing, shifting from the concept of waste to resources. These materials may include synthetic materials such as plastics, which can be chemically or mechanically recycled into new plastic products. Organic wastes, such as food waste, can be composted or used in anaerobic digestion with energy capture.

5. **Disposal.** The final management of waste that cannot be processed, reused, or recycled involves disposal methods such as landfilling, which buries waste in designated areas to manage and contain it, or incineration, which burns waste at high temperatures to reduce its volume and occasionally generate energy.

Woman in mask transporting a cart.
© babble/AdobeStock.com

Figure 2:
The Five Phases of SWM

Traditional SWM used a linear waste collection and disposal model, losing valuable resources with limited benefits. Modern SWM adopts a holistic approach that focuses on waste prevention, resource recovery, and transforming waste into resources, aiming to reduce environmental, social, and economic impacts.

Integrated Solid Waste Management (ISWM) aligns with the circular economy, which designs out waste, keeps resources in use longer, and maximises their value throughout their lifecycle. This approach promotes a sustainable, resource-efficient economy, contrasting with the linear model.

The waste hierarchy helps to prioritise strategies to minimise waste and conserve resources. The government can take various actions based on the waste hierarchy. In addition to local government action, private businesses should be encouraged to engage in initiatives across the waste hierarchy.

Figure 3:
The Waste Hierarchy

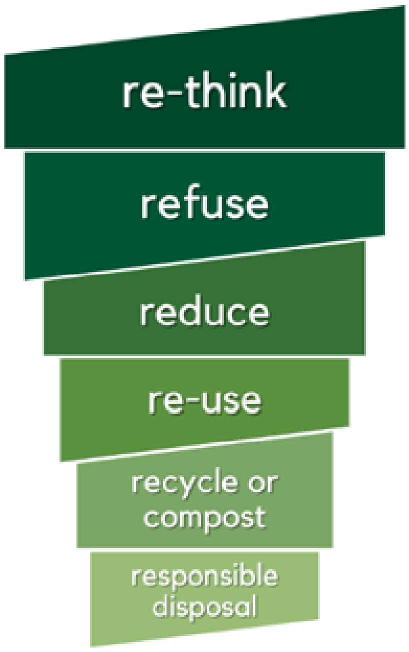


Table 1:
The Waste Hierarchy

Step	Description	Examples for Local Governments
Re-think	Consider how to rethink the current system to use less raw materials and create less waste.	❍ Promote community sharing, loan, and rental schemes. ❍ Implement green procurement policies. ❍ Incentivise eco-design to reduce raw material use and support repair, reuse, and recycling.
Refuse	Say no to products that are not essential.	❍ Avoid giving freebies at events or for marketing. ❍ Provide authority documents online; print only for accessibility needs. ❍ Promote 'refill' and 'bring your own' initiatives.
Reduce	Source reduction is the easiest and cheapest way to cut landfill waste by minimising waste and toxicity during design, production, or use.	❍ Create event guides to reduce waste. ❍ Educate on menu planning and food waste. ❍ Support community repair/refurbishment programmes. ❍ Ensure the authority repairs and refurbishes its equipment.
Reuse	Reuse refers to using products more than once for the same purpose. It reduces waste generation and saves money.	❍ Support community redistribution of unused food and products to charities. ❍ Donate unwanted authority equipment for reuse.
Recycle and Compost	Recycling is the overarching term to describe the process of removing materials from the waste stream and using them as raw materials to create new products (or turn organic waste into soil enrichment products).	❍ Funding resource recovery infrastructure and supporting pilot projects. ❍ Setting targets and issuing waste operator standards. ❍ Introducing disposal taxes/levies and restricting non-recyclable products. ❍ Legislating extended producer responsibility and container return schemes. ❍ Requiring recycled content in new products. ❍ Raising education and awareness.
Responsible Disposal	Disposing of residual waste in controlled environments.	❍ Improving the management of open dumpsites. ❍ Enforcing bans on dumping and burning waste. ❍ Providing waste collection services. ❍ Seeking funding for engineered landfills that have environmental controls such as lining, leachate management, and landfill gas capture.

Solid Waste Management Challenges in the Mekong River Corridor

The Mekong Corridor faces significant SWM challenges due to governance and policy issues, inadequate infrastructure, and rapid urbanisation. Growing waste volumes and complexity, driven by urban migration, economic growth, and changing consumption patterns, are increasing the costs of SWM services. Indirect costs of improper waste management – such as environmental cleanup, flooding from clogged drains, public health impacts, biodiversity loss, and reduced tourism – are often overlooked, further burdening local governments. Fragmented legislation and poor urban planning hinder progress, while private investment is limited due to risks and policy uncertainty, leading to reliance on international development funds. Operational costs remain a challenge due to low revenue and insufficient government subsidies.

Figure 4:
Burning Waste at Kov Bunsen Secondary School, Kratie, Cambodia

Existing SWM systems primarily follow a linear approach of collection and disposal, with limited integration of circular economy principles. This outdated linear model restricts potential revenue streams and hampers the efficient use of resources.

Local governments often have insufficient budgets for SWM, relying mainly on inadequate collection fees. As a result, many waste services face capacity issues, poorly maintained equipment, and frequent collection disruptions. The focus on waste disposal rather than resource recovery limits the potential for economic growth and environmental sustainability.

Service coverage is often limited to urban areas with low participation rates. Semi-urban and rural regions lack formal waste collection, leading to frequent dumping or burning, which causes environmental, social, and health impacts. Even in areas with access to services, improper disposal persists due to weak enforcement. Public awareness of the health risks and pollution caused by poor waste management remains low. However, many countries benefit from active non-government organisations (NGOs) and civil society organisations (CSOs) that can help raise awareness and drive change in these areas.

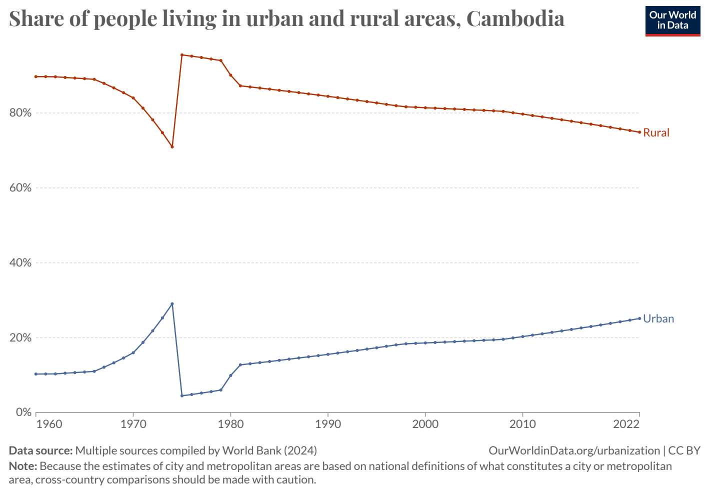
Open dumpsites remain the primary disposal method where formal services exist. These lack environmental controls and often resort to burning to reduce waste volume and recover metals, an approach that poses ongoing risks to human health and the environment. New engineered landfills, funded internationally, are costly to operate, and many local governments are unaware of the long-term financial commitments required. These landfills are often far from urban areas, with few transfer stations to improve transportation efficiency. Waste may not be compacted without sufficient budgets and revenue, leading to landfills filling up prematurely and reverting to dumpsite conditions.

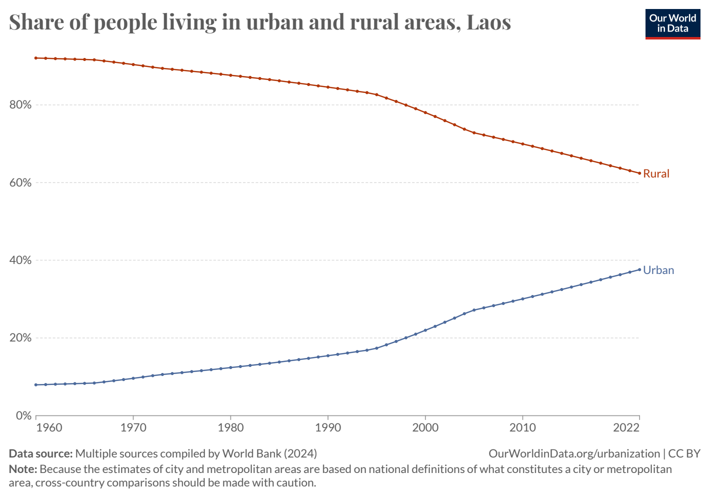
Recycling efforts for both dry recyclables and organics are limited. The informal sector, including waste pickers, landfill scavengers, and collection workers seeking extra income, play key roles in recovering materials; however, they face hazardous conditions, including exposure to accidents, infectious waste, and sharp objects. Child labour is also common. Many Mekong Corridor countries have minimal recycling infrastructure, with existing plants relying on manual processes and outdated technology. The sector is poorly regulated, leading to pollution and unsafe working conditions. There is also dependence on waste exports, but domestic recycling solutions will be needed as countries such as Thailand impose import bans.

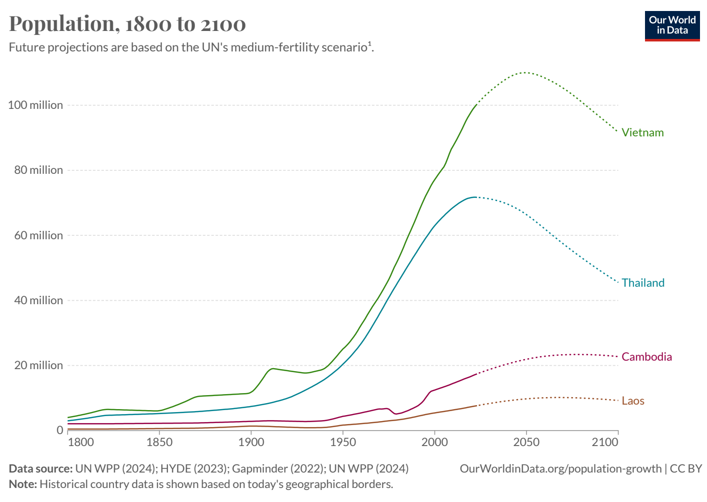
Figure 5:
Dumpsite in Stung Treng, Cambodia

Figure 6:
New Landfill in Kratie, Cambodia

Figure 7:
Population and Urbanisation Trends in the Mekong Corridor Region







Overall, the Mekong River Corridor's SWM challenges are multifaceted and urgent, driven by a combination of governance and policy issues, rapid urbanisation (as shown in Figure 7), inadequate infrastructure, and rising socioeconomic and environmental pressures. The increasing complexity of waste streams, coupled with a predominantly linear waste management approach, exacerbates the financial and operational difficulties faced by the region. Fragmented legislation, poor urban planning, and limited private sector investment further complicate efforts to implement effective and sustainable SWM practices.

The reliance on international development funds and insufficient local budgets result in inadequate service coverage and poor infrastructure maintenance. Additionally, the prevalence of open dumpsites, a lack of formal collection schemes for recyclables, limited recycling infrastructure, and hazardous conditions for informal and formal sector workers highlight the critical need for comprehensive reforms. Addressing these challenges requires a concerted effort to integrate circular economy principles, enhance public awareness, strengthen enforcement, and develop sustainable, long-term solutions.

Figure 8:
Summary of Waste Challenges in the Mekong Corridor Region

Removing waste in PhnomPenh, Cambodia
© Cities Alliance.

02

THE CIRCULAR ECONOMY AND WASTE

Waterlily harvest, Mekong Delta, Vietnam.

An Introduction to the Circular Economy

All cities and towns should adopt principles of a circular economy in their SWM systems to ensure long-term environmental, social, and financial sustainability. A circular economy aims to keep materials and products in use for as long as possible, contrasting with the linear extraction, production, and disposal model, which has failed sustainability by draining local resources.

A circular economy reduces material consumption by redesigning products to be less resource-intensive and easier to repair and reuse, while recovering "waste" as valuable resources for new materials and products. The circular economy is built on three core principles: eliminating waste and pollution, maintaining products and materials at their highest value, and regenerating natural systems to restore environmental health. This model shifts to renewable energy sources and sustainable materials, aiming to decouple economic activity from finite resource depletion.

Figure 9:
The Circular Economy

Source: The Ellen MacArthur Foundation, 2024.

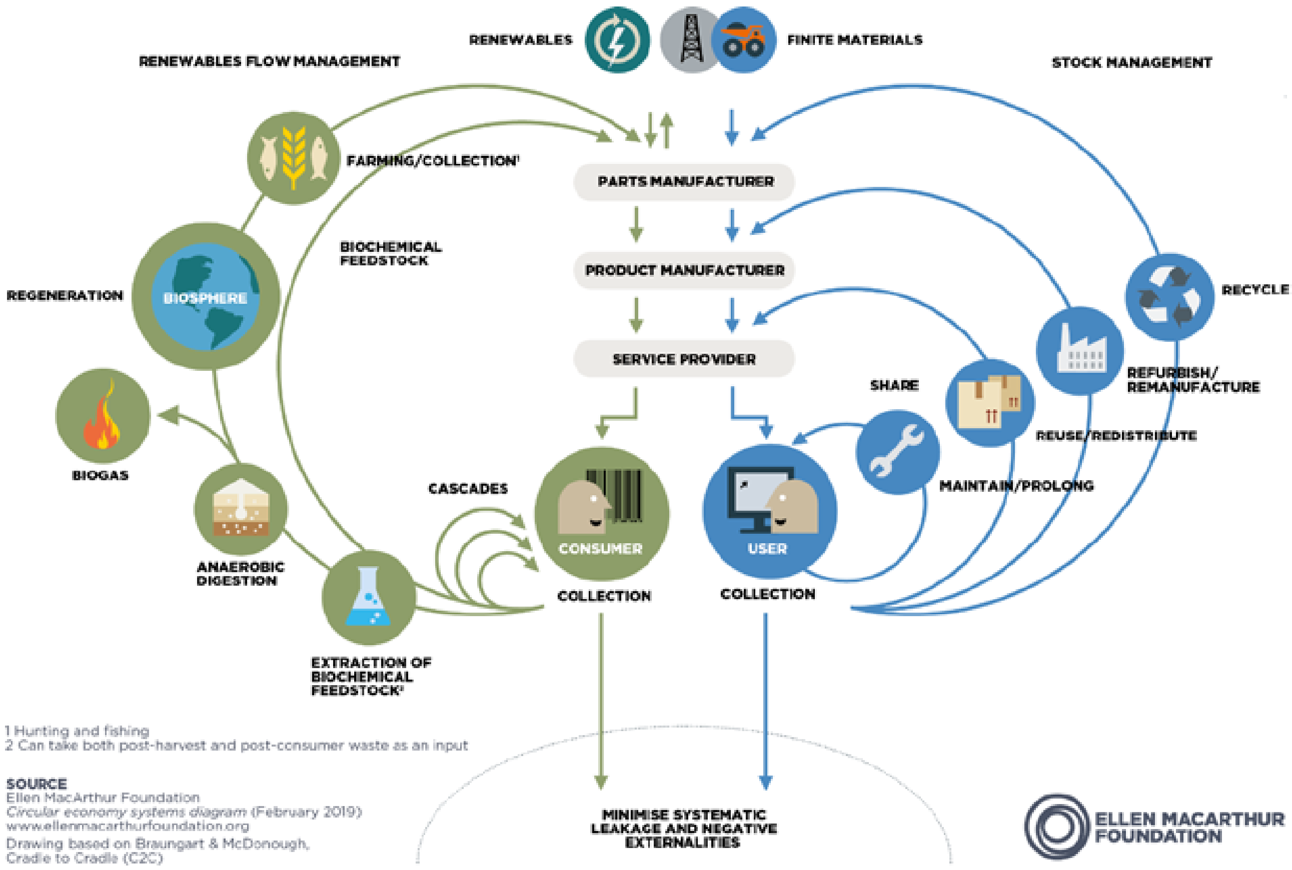
In a circular economy, resources are cycled through the system efficiently, reducing pressure on finite resources and fostering innovation in product design and manufacturing – making items more durable, repairable, and reusable. It operates across two cycles (as shown in Figure 10):

- **Biological Cycle:** Organic materials (e.g., food and natural fibres) are returned safely to the environment through composting and anaerobic digestion, regenerating natural systems.
- **Technical Cycle:** Non-biodegradable materials (e.g., metals, plastics) are kept in use as long as possible through reuse, repair, remanufacturing, and recycling, minimising waste and resource extraction.

The circular economy offers numerous economic, environmental, and social benefits, including long-term cost savings, local job creation, and enhanced innovation. It also mitigates climate change impacts by reducing harmful waste and lowering resource extraction.

When materials are reused or recycled instead of sent to landfills, they are no longer considered waste, eliminating the need for new raw material extraction and reducing environmental damage from mining and deforestation. This process also minimises energy demands related to raw material extraction and processing, lowering greenhouse gas emissions and preserving ecosystems.

Figure 10:
The Circular Economy Butterfly Diagram



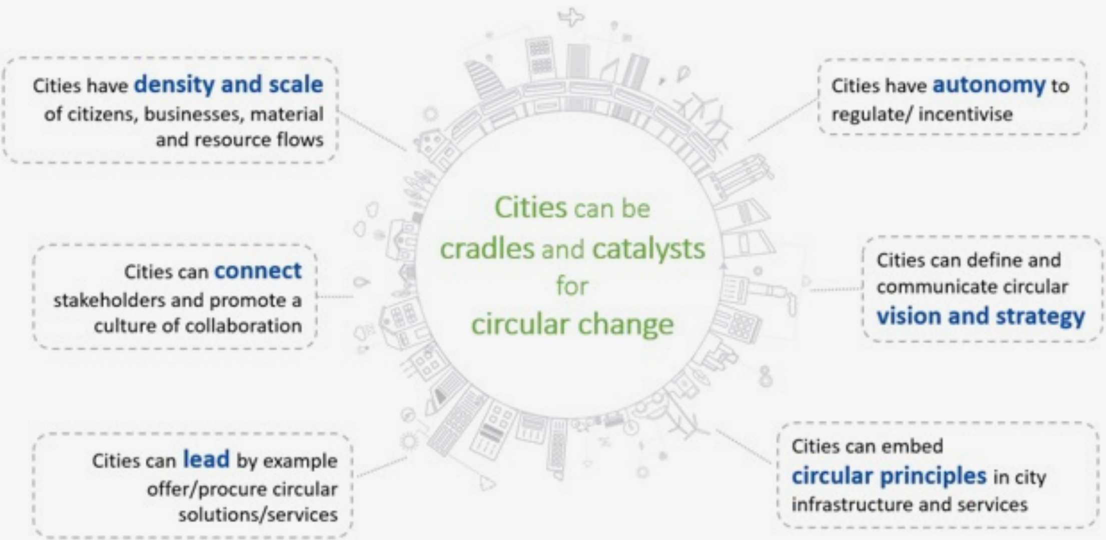
Source: The Ellen MacArthur Foundation, 2013.

Box 1:
The Circular Economy and Cities

Many cities in the Mekong River Corridor face challenges from rapid urbanisation, including resource consumption, waste, pollution, greenhouse gas emissions, water use, flooding, inefficient transport systems, and pressure on green spaces. However, their concentration of resources, capital, data, and talent positions them as potential innovation hubs that can support circular business models, such as sharing platforms and product-as-a-service models.

A circular city embraces circular economy principles, improving air quality with zero-emission vehi-cles and reducing congestion through public transport. Increased walking and cycling benefit local businesses and health, while urban land is repurposed for green spaces, housing, and recreation. Better waste management leads to cleaner water bodies, and efficient waste systems reduce littering and illegal dumping. Infrastructure supports durable, modular buildings made from low-carbon mate-rials, and products are designed for repair, reuse, or recycling. Renewable energy powers the city, shifting ownership models to sharing or leasing, while fostering a second-hand market and repair services.

Transitioning to a circular city requires manageable steps – focusing on urban systems such as food, buildings, and products – tailored to the city's primary activities. For example, a city with textile pro-duction could prioritise circular practices in that sector, while one with high plastic pollution could tar-get plastic waste. By addressing these systems in phases, cities can gradually promote sustainable urban development.

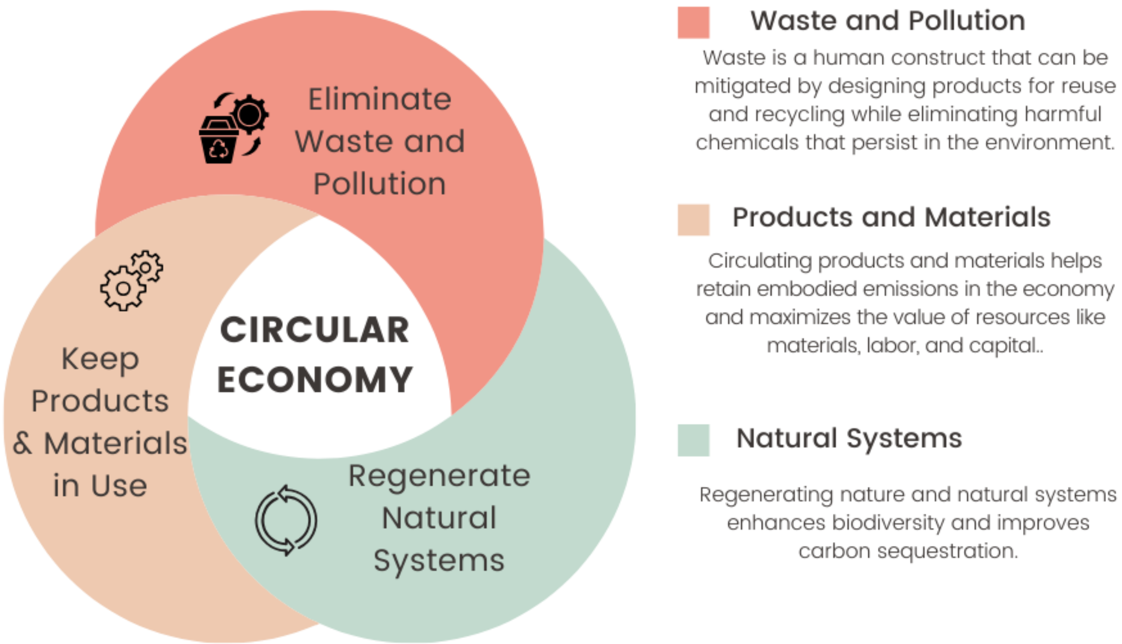


Source: European Investment Bank, 2021. The 15 Circular Steps for Cities.

Circular Economic Principles in Waste

The circular economy provides a fresh approach to SWM by focusing on sustainability and how to best use resources. Its main ideas are to eliminate waste and pollution, keep products and materials in use for as long as possible, and help nature recover. By following these principles, the circular economy aims to create a system where resources are reused instead of thrown away, which reduces environmental harm and reliance on limited materials. This shift promotes efficient use of resources, encourages innovation, and strengthens communities, leading to sustainable growth and a healthier environment.

Figure 11:
Principles of the Circular Economy



Source: Based on the Ellen MacArthur Foundation, 2024.

Case Study: Can Tho, Vietnam

Can Tho, Vietnam.
© CravenA/AdobeStock.com

Can Tho launched a project called For a Trash-Free Mekong River that exemplifies an innovative approach to waste management and environmental preservation. Centred around the Cai Rang floating market, the initiative tackles the challenge of managing the one ton of garbage produced daily from trading and tourism activities. Through the collaborative efforts of the Green Development Support Centre (GreenHub), the Centre for Research in Resources and Rural Development (RECERD), government, and local communities, the project aims to significantly reduce waste in the Mekong River, enhancing the living conditions of over 150,000 residents in the Binh Thuy and Cai Rang districts.

Key achievements include the construction of waste classification models at the source, promotion of circular economy practices, and extensive trash collection activities on the Hau River. Notably, the initiative has introduced organic waste composting techniques, such as the Banana Circle, reducing landfill reliance and promoting sustainable organic farming practices.

This waste management strategy aligns with the Mekong Delta's broader regional planning vision for 2030 and beyond. It emphasises the 3Rs of waste with the ultimate goal of achieving zero landfill use. By prioritising modern waste treatment technologies, including waste-to-energy (WtE) production, Can Tho and the Mekong Delta region are on a path toward sustainable urban development and environmental conservation.

In addition to highlighting Can Tho's commitment to tackling waste and promoting nature-based solutions, the city's experience serves as a model for sustainable urban management in riverine and deltaic environments worldwide.

Vietnamese floating market.
©herzform/ AdobeStock.com

The Biological Cycle

The biological cycle in a circular economy focuses on returning organic materials to regenerate ecosystems. Natural, biodegradable products can be composted or decomposed, enriching the soil and supporting natural cycles, while reducing waste and enhancing ecosystem health.

Food and garden waste constitute 40 to 70 per cent of municipal waste, yet dry recyclables often overshadow organic waste management in the Mekong River Corridor. Given the volume of organic waste, effective management solutions are essential. Transporting and compacting organic waste in landfills is costly, and anaerobic conditions produce methane, a potent greenhouse gas. Organic waste also causes nuisances like odours and pests, requiring frequent collection.

Food production demands vast resources, and food waste is a growing concern in urban areas in the Mekong River Corridor. Traditional markets, restaurants, and households significantly contribute to this issue. Globally, 25–30 per cent of food produced is lost or wasted, accounting for an estimated 8–10 per cent of total man-made greenhouse gas emissions.

Addressing food waste in the Mekong River Corridor is crucial for reducing environmental impacts, improving waste management efficiency, transforming waste into valuable resources, and enhancing food security. Solutions require infrastructure development, including composting facilities, biodigesters, and dedicated collection services, with initiatives ranging from home composting to municipal processing facilities.

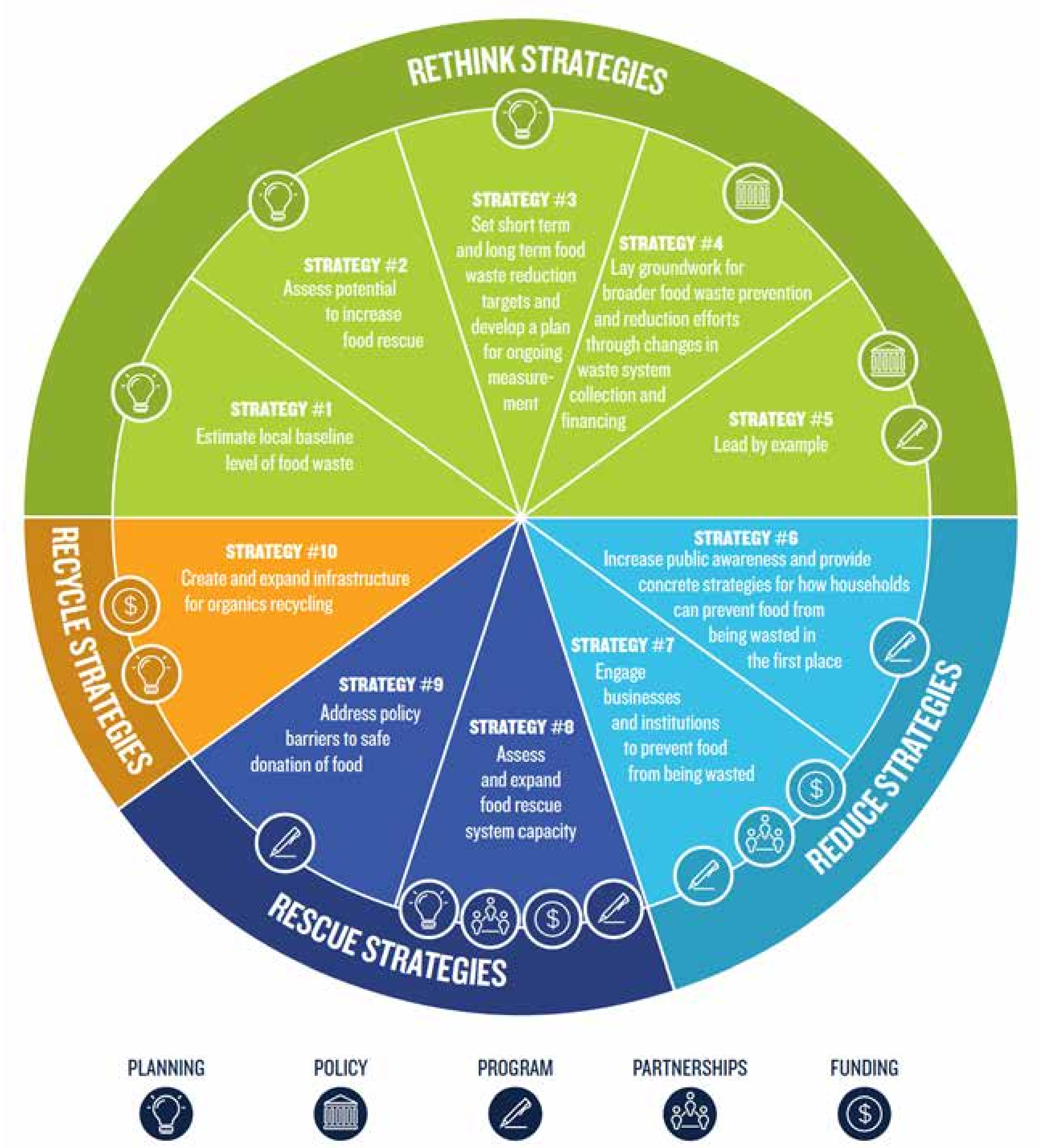
Preventing food waste involves understanding the cultural and social dynamics of consumption. Household practices, particularly among mothers, often lead to over-purchasing due to societal pressures. Solutions must address these motivations and engage families, especially women, with strategies like meal planning and portion control that respect local customs.

If food waste were a country, it would be the third-largest emitter of greenhouse gases, behind only China and the USA.[3]

The C40 Knowledge Hub provides a practical toolkit for cities to implement food waste reduction initiatives, including a four-step approach that focuses on boosting food rescue, preventing waste, and diverting excess food for alternative uses such as animal feed.

3 WRAP. Action on Food Waste. https://www.wrap.ngo/taking-action/food-drink/actions/action-on-food-waste.

Figure 12:
Strategies for Food Waste



Source: C40 Knowledge Hub

Case Study: Vientiane, Lao PDR

Vientiane, the capital city of Lao PDR, is at the forefront of addressing its SWM challenges to enhance the quality of its urban environment. With a population of 948,477 across nine districts, the city generates an average of 450–500 tons of solid waste per day that is managed by one public and nine private companies. This waste is transported to an open dumping landfill 32 km from the city centre. The landfill has been operational since 2009 and covers an area of 70 hectares.

The composition of waste represents a significant challenge, with organic waste constituting 62 per cent and plastic waste 20 per cent. This highlights the urgency for sustainable waste management practices to mitigate environmental impacts.

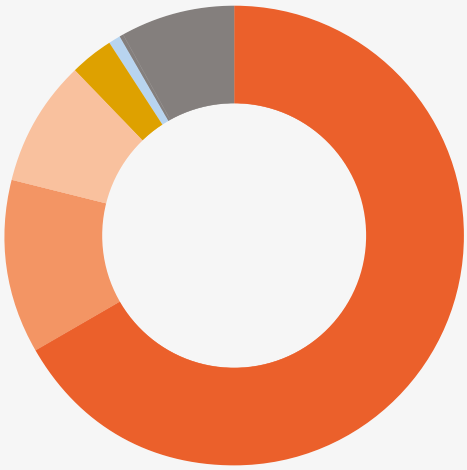
Vientiane's approach includes a robust waste collection service that covers 74 per cent of the service area, emphasising the critical need for comprehensive coverage and efficient waste processing.

Vientiane's Sustainable Solid Waste Management Strategy and Action Plan for 2021–2030 outlines ambitious goals to tackle these challenges head-on. Key strategies include ensuring 100 per cent waste collection rates for all citizens by 2030, maximising waste-to-resource opportunities through source separation, and increasing waste treatment capacity with mechanical and biological treatment facilities.

The city has also embraced technological solutions such as the Vientiane Waste Management Application to facilitate household and business services, including an Express and Payment service. This application is part of Vientiane's vision to become a model city where waste management is not just about disposal, but also about resource recovery and integration of informal waste pickers into the formal system.

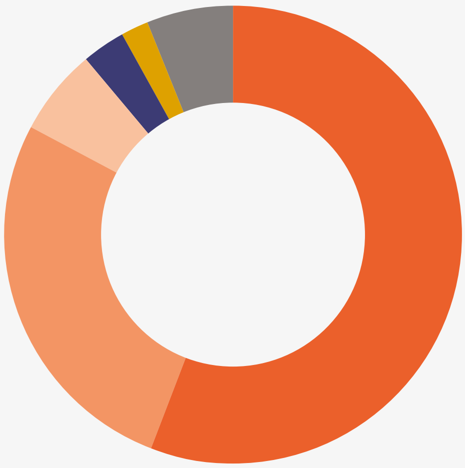
By 2030, Vientiane aims to be recognised for its commitment to waste-to-resource initiatives. The city envisions a future where source separation is a civic duty, per capita waste generation rates are significantly reduced, and the informal waste sector is formally integrated to ensure social protection schemes for waste pickers.

Composition of municipal solid waste in Vientiane (%)



- Organic Waste (67%)
- Plastic (12%)
- Paper and Cardboard (9%)
- Glass (3%)
- Cans (1%)
- Other Waste (8%)

Waste composition at the landfill in Vientiane (%)



- Organic Waste (56%)
- Plastic (27%)
- Paper and Cardboard (6%)
- Textile (3%)
- Glass (2%)
- Other Waste(6%)

Composting

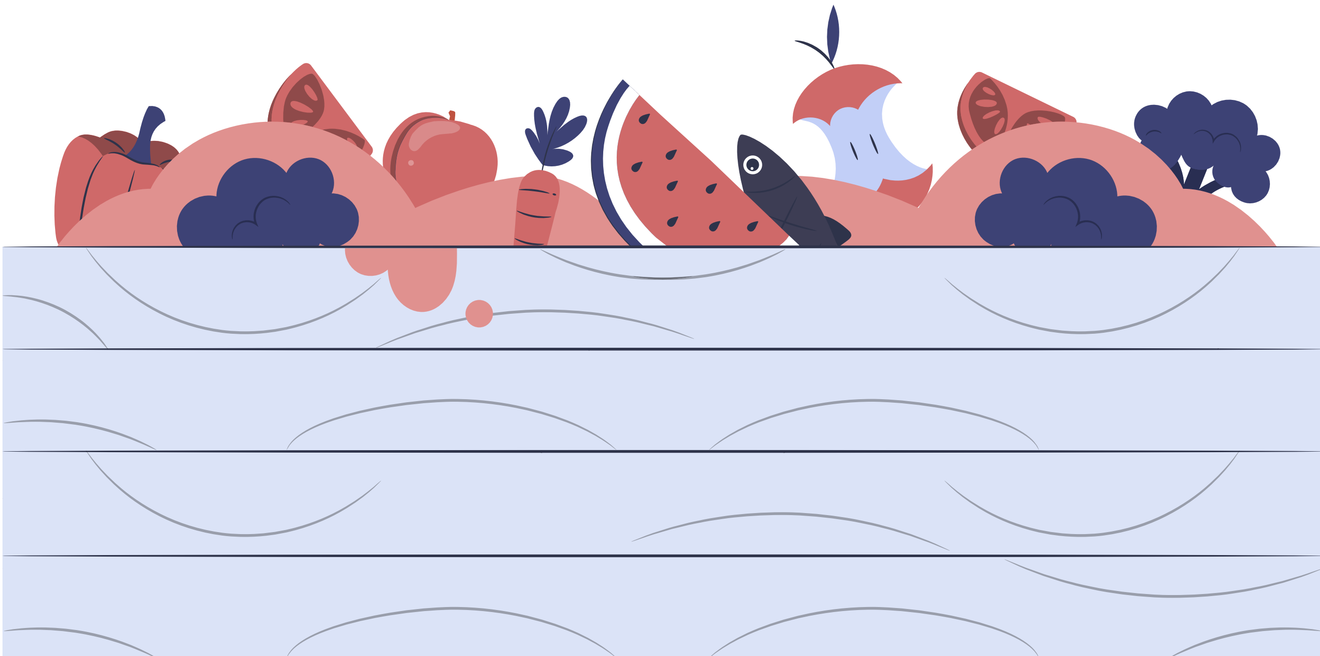
Composting is a natural process that transforms organic waste into nutrient-rich fertiliser. Suitable materials for composting include leaves, paper, fire ashes from natural wood, and food scraps. This process can occur on various scales, ranging from small backyard composting to community systems and large industrial facilities serving entire cities.

Successful composting hinges on creating an optimal environment for beneficial microorganisms, such as bacteria and fungi, as well as worms and insects. There are several composting methods, including windrow composting, which involves creating long, narrow piles of organic material that are regularly turned. Static pile composting involves loosely stacking organic waste and allowing it to decompose without turning. In-vessel composting involves containing materials within a controlled environment for more efficient processing.

Additionally, innovative approaches such as using black soldier fly larvae can enhance composting efforts. These larvae can efficiently break down organic waste while producing high-protein livestock feed. Integrating these methods reduces waste, enriches soil health, and supports sustainable agricultural practices.

Figure 13:
Home and Central Composting at the Village Level

Source: The Asia Foundation 2024.



Biodigesters

Anaerobic digestion uses microorganisms to break down organic material, producing biogas (mainly methane and carbon dioxide) and digestate, a liquid or solid byproduct that can enrich soil. Biogas is a renewable energy source that reduces dependence on fossil fuels.

Biodigesters range from small home units, which convert food waste into biogas for cooking and liquid fertiliser, to large commercial facilities that handle greater waste volumes, including animal processing waste. These facilities generate energy from biogas, often feeding electricity into the grid, while producing nutrient-rich digestate for agriculture. While these facilities require infrastructure and collection systems investment, the benefits can be significant, especially when strategically located close to organic waste sources to minimise transportation emissions. This process cuts waste, promotes renewable energy, and reduces methane emissions from landfills.

Figure 14:
Home Biodigester in Laos

Box 2:
Transforming Organic Waste with Black Soldier Fly Larvae

GrubFeeds, a Phnom Penh-based company, is transforming organic waste into sustainable animal feed using black soldier fly larvae. By processing waste from wet markets and food byproducts, they produce black soldier fly larvae, meal, oil, and frass, a natural fertiliser. This approach not only helps meet the global demand for protein but also significantly reduces greenhouse gas emissions, particularly methane, aligning with Cambodia's carbon neutrality goals. The use of black soldier fly larvae diverts waste from landfills and offers an eco-friendly alternative to traditional feed ingredients such as soybean meal and fishmeal, which are both under pressure from overfishing and environmental challenges.

The process begins by feeding organic waste to the black soldier fly larvae, which rapidly grow as they consume it. Once matured, the larvae are harvested, dried, and processed into high-protein meal and oil for animal feed.

The frass, or larvae excrement, is used as a biofertiliser to improve soil health. This closed-loop system reduces waste, enhances feed security, and supports sustainable agriculture.

GrubFeeds' decentralised model empowers local farmers to rear black soldier fly larvae on-site, converting agricultural waste into valuable products. By buying back the larvae, GrubFeeds provides farmers with a steady income while reducing dependence on resource-intensive feed ingredients and supporting sustainable agricultural practices.

Source: The Phnom Penh Post, https://www.phnompenhpost.com/creativity-innovation/waste-to-feed-local-startup-tackles-carbon-emissions-and-boosts-food-security

Support from the Local Government in the Biological Cycle

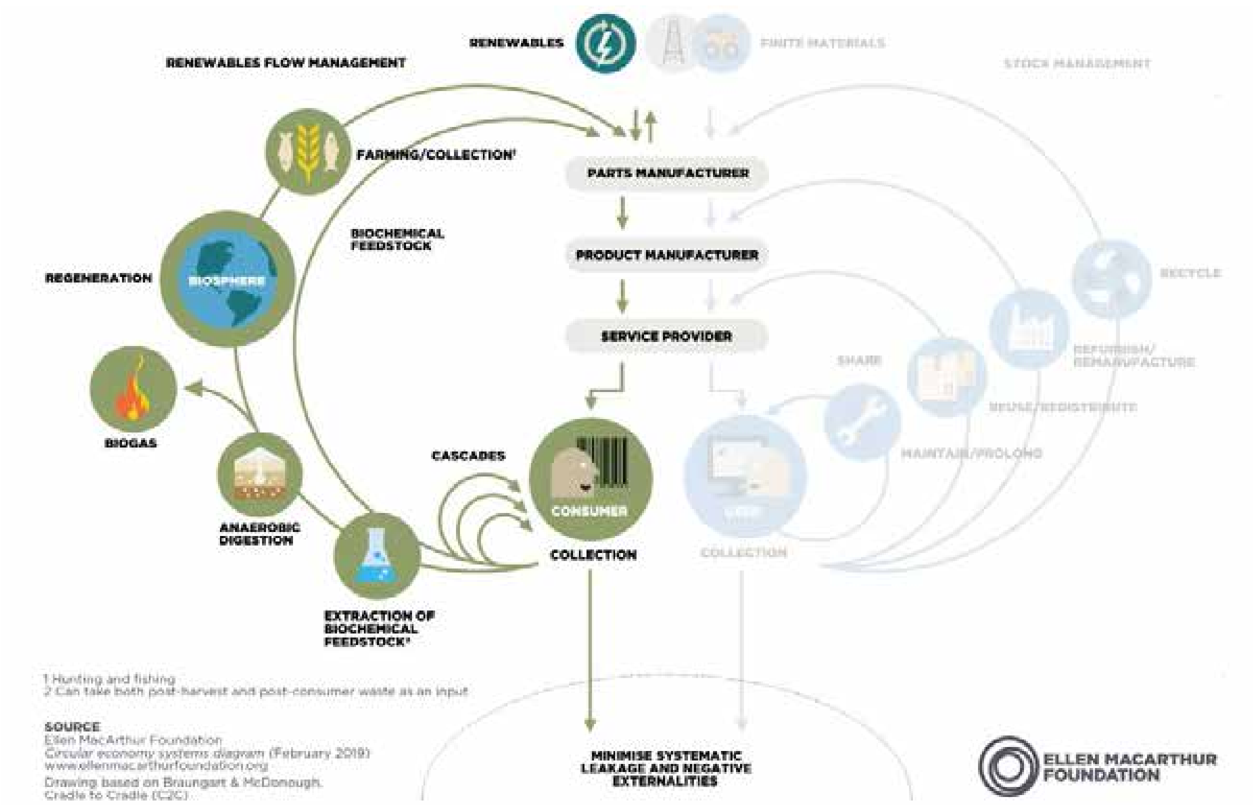
The local government can support the biological cycle to reduce landfill waste and boost sustainability by:

- **Subsidising Home Composting and Biogas.** Offering financial aid for compost bins and biogas units, and educational workshops to help households manage organic waste.
- **Setting Up Community Composting**. Creating community composting sites for households and businesses to process waste, using the compost for green spaces and food gardens.
- **Establishing Organic Waste Collection.** Organising waste collection systems for industrial composting or biogas facilities.
- **Promoting Anaerobic Digestion.** Supporting anaerobic digestion facilities to turn waste into biogas and fertilizer, enhancing energy capture and sustainability.

Summary of the Biological Cycle

The biological cycle is a crucial element of the circular economy, emphasising the transformation of organic waste into valuable resources. This process fosters sustainability within local communities by promoting the recovery of nutrients and enhancing soil health. By effectively managing organic waste through methods such as composting and anaerobic digestion, communities can reduce environmental impacts, support local agriculture, and create opportunities for economic growth, ultimately turning waste into a resource rather than a burden.

Figure 15:
The Biological Cycle in the Circular Economy



Source: The Ellen MacArthur Foundation, 2013.

The Technical Cycle

The technical cycle in the circular economy focuses on using, reusing, and recycling non-biodegradable materials. This cycle aims to keep valuable resources in circulation by designing durable, repairable, and recyclable products, reducing waste and resource extraction. The priority is on "inner loops," which involve sharing, maintaining, repairing, and reusing products before resorting to recycling.

- **Maintenance and Repair.** Maintenance and repair extend product lifespan, but some manufacturers practice "planned obsolescence," making repairs difficult. Governments can support the "right to repair" by removing barriers to repair information and parts. Cities also promote Repair Cafes, where volunteers help repair items, reducing waste and fostering community skill-sharing.
- **Reusing/Redistributing.** Reusing keeps products in their original form, maximising their use. Sharing within communities reduces the need to buy new items. Initiatives like food redistribution, common in parts of the Mekong River Corridor, reduce food waste and address hunger. Local governments can also donate excess building materials from city projects, promoting resource efficiency and minimising waste.
- **Refurbishing/Remanufacturing.** Refurbishing restores products to like-new condition through disassembly, cleaning, and replacing parts. Often applied to high-value goods like vehicles or electronics, this process extends product life, conserves raw materials, and creates jobs. Governments can support this by offering incentives and policies that encourage remanufacturing, backed by warranties.
- **Recycling.** Recycling is the final step when products can no longer be reused or repaired, preserving the value of raw materials. Successful recycling depends on efficient collection, separation, and storage systems, tailored to local needs. Community education is essential for proper waste segregation, which enhances recycling effectiveness.

Box 3:
Waste Recycling Banks

Waste recycling banks are community systems where people drop off recyclables such as plastics, paper, and metals, which are then sold to recycling companies. These systems are useful in areas without formal collection services. Participants may receive incentives, like money or credits, or benefits may go to the community, such as schools or places of worship. Individual incentives require more administration, while community benefits simplify management.

Recycling banks have separate bins for different materials and are often placed in schools or community hubs. Bins should be colourful and designed to contain waste effectively. Awareness campaigns are crucial to encourage waste segregation at the source.

Waste recycling banks have been introduced successfully in many Southeast Asian cities, including in Cambodia, Laos, Thailand, and Vietnam.

Source: Indorama Ventures.

Support from the Government in the Technical Cycle

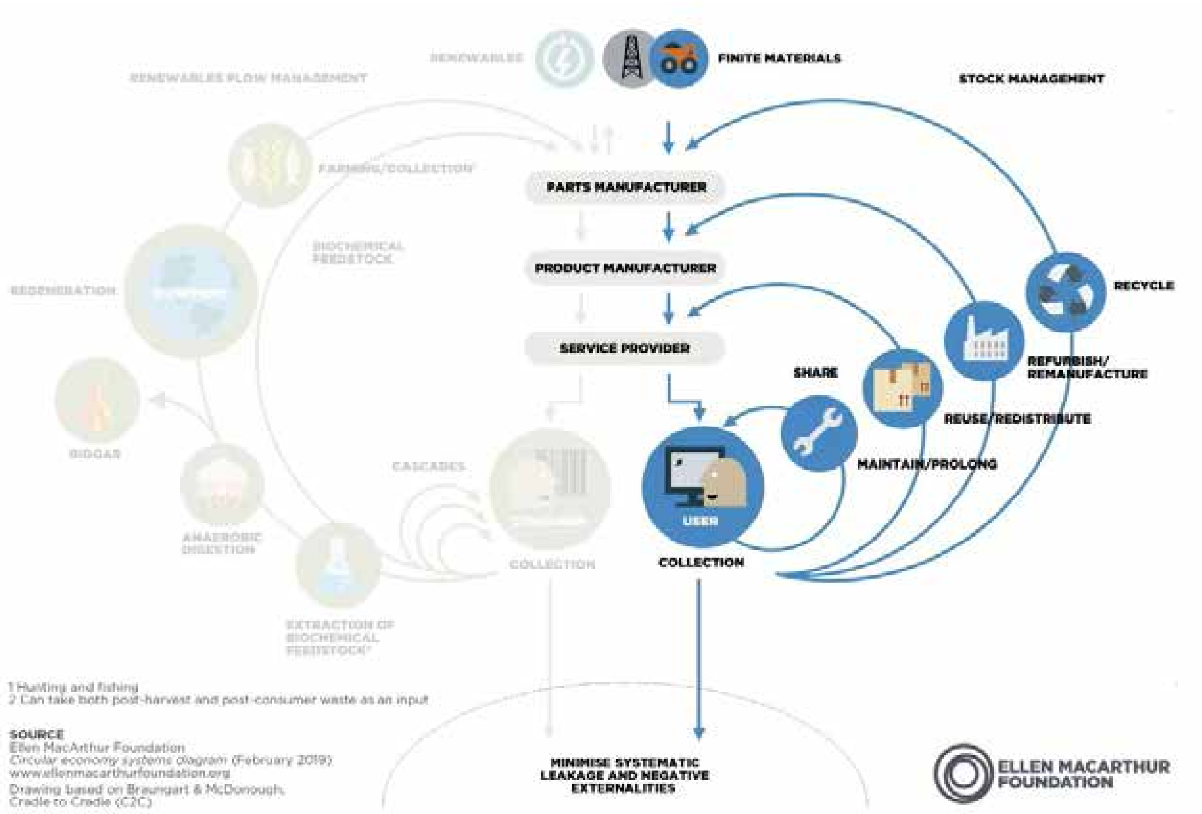
Governments can enhance the technical cycle to boost resource efficiency and reduce waste through key actions:

- **Regulatory Frameworks.** Implement eco-design policies and "right to repair" laws for better repair, reuse, and recycling access.
- **Incentives and Subsidies.** Provide financial incentives, like tax breaks, to promote remanufacturing, refurbishing, and recycling.
- **Extended Producer Responsibility (EPR).** Hold manufacturers responsible for product lifecycle management through take-back programmes.
- **Infrastructure Investment.** Fund recycling technologies and resource recovery facilities to improve recycling rates.
- **Public Awareness.** Run education campaigns on recycling and the environmental impact of waste.
- **Green Public Procurement.** Prioritise purchasing goods made from recycled materials or designed for easy recycling.

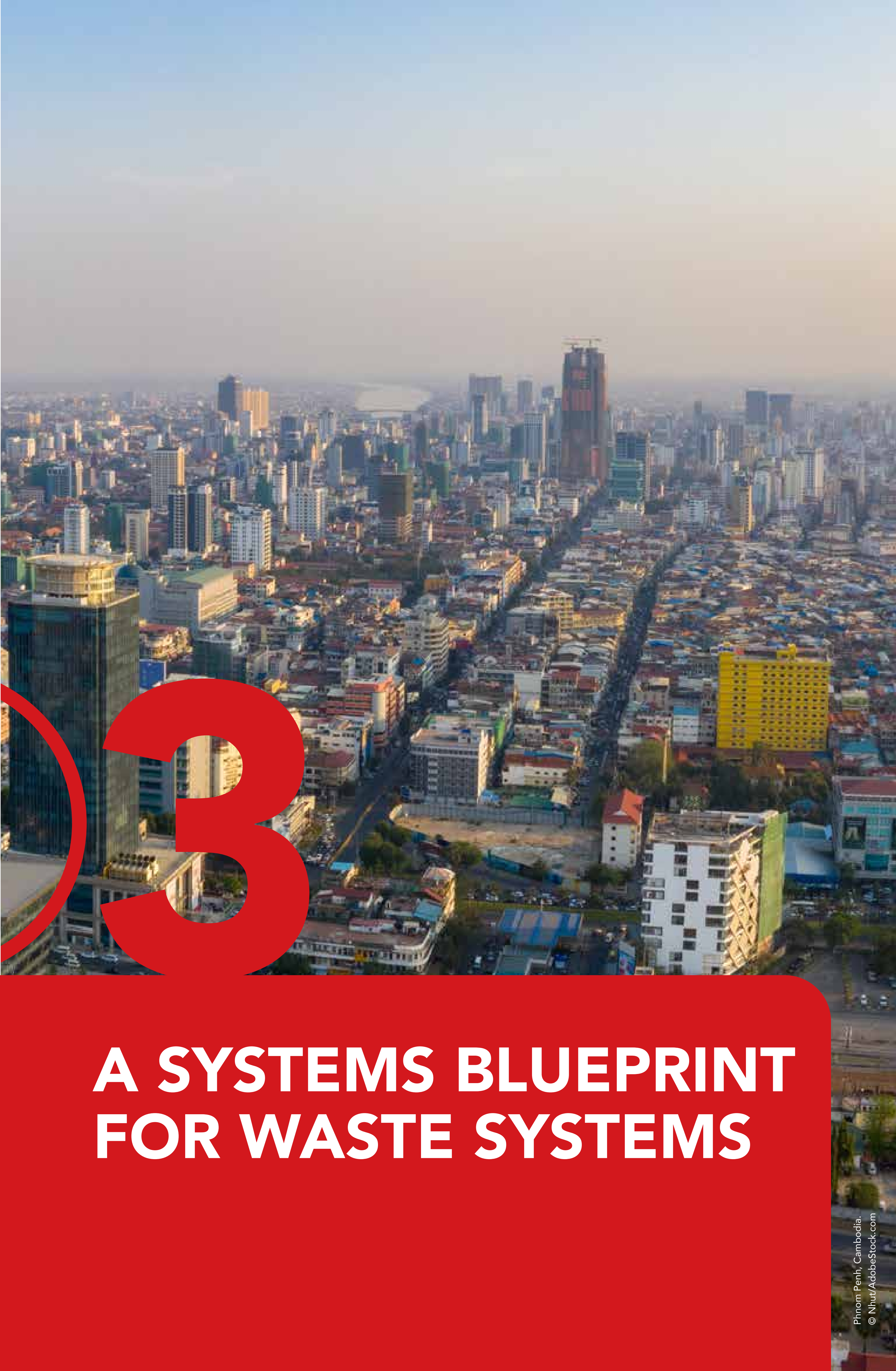
Summary of the Technical Cycle

The technical cycle in the circular economy is focused on maximising the lifespan and value of non-biodegradable materials through repair, reuse, remanufacture, and, finally, recycling. By designing durable, easy-to-repair, and recyclable products, the technical cycle reduces the need for virgin materials and minimises waste.

Figure 16:
The Technical Cycle in the Circular Economy



Source: The Ellen MacArthur Foundation, 2013.



Phnom Penh, Cambodia.
© Nhut/AdobeStock.com

3

A SYSTEMS BLUEPRINT FOR WASTE SYSTEMS

The Need for a Systems Perspective

In recent years, development partners have provided essential financial and technical support to improve SWM in cities along the Mekong River Corridor. This support is crucial, as many countries in the region have underdeveloped SWM sectors with limited capacity and funding for infrastructure and services. A key challenge is determining where to allocate investments most effectively and identifying the necessary infrastructure and services for long-term sustainability.

Development funds often target specific parts of the waste supply chain, such as landfills. While landfills are essential, focusing investments solely on one area will not ensure success. Landfills are costly to operate, and local governments face budget constraints. Therefore, boosting revenue streams from other parts of the system is crucial, such as recycling and composting.

An integrated approach is essential to effectively addressing the entire waste management system. In many countries, SWM has struggled due to attempts to make efficiency gains in one area at the expense of others. For instance, reducing the costs of waste collection by gathering commingled (mixed) waste might appear cost-effective initially, but this approach shifts the burden of sorting to other parts of the supply chain, increasing operational costs at materials recovery facilities (MRFs). This imbalance can lead to inefficiencies that undermine the overall system.

> "I see great potential for cities along the Mekong Basin to reduce waste and improve wastewater and waste management via integrated urban planning approaches as well as tackling climate change mitigation and adaptation, ecosystem preservation, and restoration and circular economy."
>
> — H. E. Mr. Atsaphangthong Siphandone, Governor of Vientiane Capital, at the first UMCI Dialogue, February 2024

A more holistic approach, focusing on reducing waste generation, increasing recycling rates, and optimising resource recovery throughout the entire supply chain, can create a more resilient and sustainable SWM system. Development partners should ensure their support covers a broad spectrum of activities, including infrastructure, capacity building, public awareness campaigns, and technical assistance, to enhance the performance of SWM systems in the region.

Figure 17:
A Systems Perspective for SWM

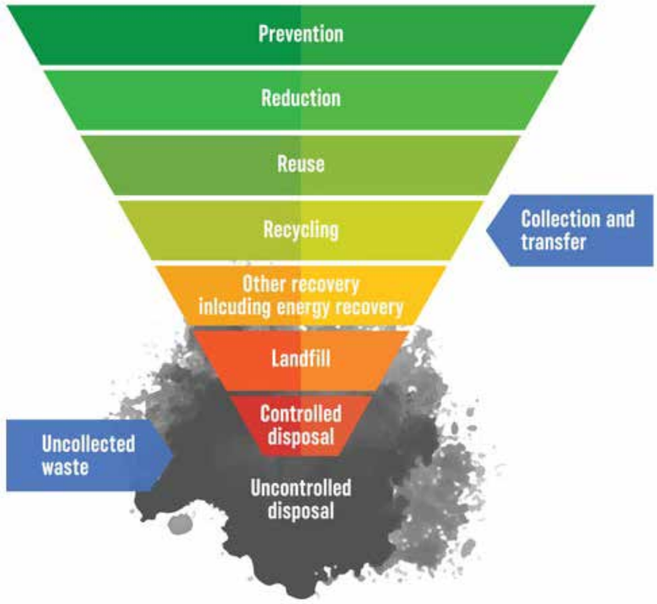
Waste Management Evolution: Global North Lessons, Global South Opportunities

The development of SWM in the Global North has evolved over the past 50 years from basic disposal to integrated systems. In the 1970s, the focus was on waste collection and disposal, but landfills were unregulated. The 1980s introduced engineered landfills, and by the 1990s, recycling programmes emerged, though many relied on exports to Asia. Following China's 2018 National Sword policy, the Global North shifted to domestic recycling solutions and is now moving toward circular economy principles, focusing on reuse, repair, and remanufacturing. Despite improvements, the Global North's journey towards sustainable waste management has been slow and linear, gradually addressing different aspects of the waste hierarchy over time.

In contrast, the Global South has an opportunity to adopt more effective, systems-based SWM approaches from the start. While addressing waste collection and disposal is crucial, focusing on reuse, recycling, and resource recovery early on can lead to environmental sustainability and financial viability. The Global South can create a cost-efficient, sustainable SWM model by prioritising revenue generation through material recovery and minimising disposal costs.

Solid waste management is closely tied to 12 of the 17 Sustainable Development Goals (SDGs), addressing issues such as sustainable consumption, health, clean water, and climate action. Improving SWM systems helps countries progress toward a green, circular economy and align with SDG targets. Key waste management concepts that guide policy development include pollution prevention, lifecycle management, the polluter pays principle, internalising environmental costs, and preventing free riders from ensuring fair and sustainable waste systems.

Figure 18:
Contemporary Version of the Waste Hierarchy



Source: Whiteman et al., 2021.

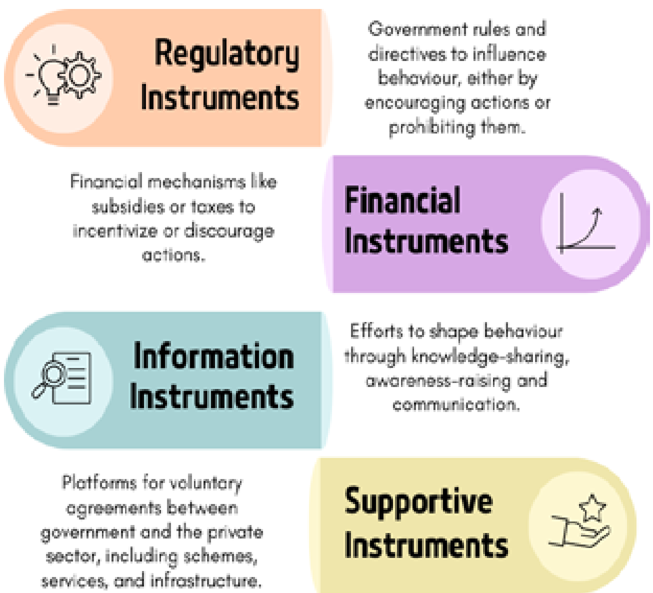
Legislation and Policy

Introduction

Solid waste management legislation operates at international, national, and local levels. National laws set frameworks and standards, while local laws focus on implementation and enforcement, making both essential for sustainable systems. Collaboration between government levels ensures effective regulatory compliance and policy alignment.

With their on-the-ground expertise, local governments should actively contribute to developing national legislation to ensure it is practical and regionally relevant. National governments should ensure that local policies align with broader regulatory standards and policies.

Figure 19:
Legislative Instruments



Governments should combine regulatory and non-regulatory approaches to support a circular economy, including financial and informational tools. Instruments should both encourage positive behaviour and have disincentives to discourage harmful practices. Achieving sustainable SWM may require refining existing national and local laws or establishing new ones to address emerging needs. Clear legislation defining roles, targets, and evaluation methods is crucial. Effective communication and awareness campaigns are also needed to promote positive behaviour and discourage harmful practices.

The following sections outline some of the main policy instruments.

Regulatory Instruments

Regulations can act as prohibitive measures to ban harmful actions or set standards for desired behaviours. They are essential in environmental management, especially where incentives are lacking. Compliance is enforced through fines and penalties, creating clear expectations among stakeholders. However, regulations often only encourage minimum standards, so providing adequate information, monitoring, and enforcement is key.

Product bans, like those on plastic bags, are common tools for reducing single-use plastics. Eighty countries, such as Thailand and Vietnam, have adopted such measures.[4] Bans on specific products, materials, or harmful substances can encourage recycling and reuse. A phased approach may help industries and consumers transition smoothly and can initially include voluntary bans. For bans to be effective, they must be part of broader strategies that promote sustainable alternatives, including education and innovation, and involve stakeholder collaboration. Proper enforcement remains challenging, especially in regions like the Mekong River Corridor.

Rubbish, plastic bottles, cans, and paper by the Mekong River in Luang Prabang, Lao PDR.
© Jordi/AdobeStock.com

Financial Instruments

Economic tools can incentivise or penalise actions through subsidies, loans, tax breaks, or disincentives like fees, taxes, and levies. These instruments internalise the costs of pollution, resource extraction, and disposal, promoting circular economy practices.

Figure 20:
Pay-as-you-throw Schemes

Sustainable **subsidies** encourage waste reduction and green technologies, while environmentally harmful subsidies should be phased out to support sustainability.

Higher **taxes** on environmentally harmful activities can stimulate job creation and innovation in circular business models, while reducing taxes in sectors like reuse, repair, and remanufacturing can further accelerate these efforts.

Waste levies on landfills and incineration make disposal costlier, encouraging reduction and the diversion of waste for activities such as recycling. Funds generated can support waste-reduction initiatives.

Fees like Pay-as-you-throw (PAYT) link waste charges to waste generation, promoting waste reduction and the segregation of recyclables.

Extended producer responsibility (EPR) mandates that producers handle the lifecycle of their products, incentivising eco-friendly designs and collection schemes for reuse, refurbishment, or recycling. Examples of initiatives include product take-back schemes, container-deposit schemes, and advance disposal fees.

Information Instruments

Information tools are vital for successful policy implementation. Education and awareness are key to the effectiveness of regulatory and economic measures. Clear, credible, evidence-based communication builds public trust and drives behaviour change in waste management. Efforts to change behaviour must be supported by accessible infrastructure to prevent loss of public trust, such as when sorted recyclables are mixed during collection. International studies[5] show that investing in education and awareness can yield significant value and cost savings across the supply chain by boosting public confidence and participation in waste management efforts while reducing littering and improper disposal.

4 Planet Patrol. Which Countries Have Banned Plastic Bags? https://planetpatrol.co/2021/06/which-countries-have-banned-plastic-bags/.

5 WRAP. 2015. Analysis of Recycling Performance and Waste Arisings in the UK 2012/13. https://www.wrap.ngo/resources/report/factors-influencing-recycling-performance

Sustained, culturally sensitive messaging encourages responsible waste practices and promotes environmental action as a societal norm. Gender-sensitive communication is essential, as women often lead household waste management and can influence sustainable behaviour. Tailored strategies that include both genders enhance engagement and participation. It is also important to consider the unique needs of rural citizens who have migrated to the city and vulnerable communities who may have different waste habits.

Social media now offers a cost-effective way to promote waste management initiatives, complementing traditional methods like public meetings and clean-up events. Education on sustainability in schools and communities is also crucial for building long-term engagement with waste systems and legislation.

Figure 21:
A Billboard on the Island of Koh Trung, Cambodia

Supportive Instruments

This policy area relies on collaboration among the private sector, government, civil society, and the informal waste sector to address broader environmental and social issues. Collaborative governance aligns goals across stakeholders, with the private sector contributing through business development and corporate social responsibility. Integrating the circular economy into areas like construction, transport, and urban planning fosters shared visions and supports priorities including growth, employment, and decarbonisation.

Governments can use collaboration to drive change without over-reliance on regulation, benefiting the environment and economy. Strategies include setting private sector goals, developing collaborative platforms, green public procurement, and promoting extended producer responsibility. Green Public Procurement (GPP) prioritises circular products and services, minimising environmental impacts and waste. As major consumers, governments can influence markets, encourage innovation, and lead by example through procurement policies focused on repair, reuse, and recycling.

Targeted support for youth, women, and vulnerable groups in waste labour markets is essential for an equitable transition to a circular economy. Examples include the initiative "Waste for Life" in the Philippines that empowers women in recycling, and Goonj[6] in India, which provides skill development for youth in waste management. Additionally, programmes in Thailand promote women's leadership in community waste management projects, fostering social inclusion and gender equality.

Collaborative platforms such as the ASEAN Circular Economy Platform[7] facilitate cooperation between sectors, foster knowledge exchange, and support sustainability efforts. These platforms enhance innovation and regional waste management solutions by connecting diverse stakeholders.

6 https://goonj.org/.
7 https://ce.acsdsd.org/.

City-Level SWM Strategies

An SWM Strategy is a strategic document designed to guide how a community manages its waste from generation to reprocessing and disposal. The strategy should include key components such as waste reduction and reuse, waste collection, transportation, segregation, recycling, reprocessing, and disposal. It outlines methods for handling different types of waste, reduces reliance on landfills, and encourages reduction, reuse and recycling. The SWM plan section also addresses financial and institutional responsibilities, ensuring long-term sustainability and community engagement through public awareness initiatives.

A Solid Waste Management Strategy can be developed through five steps:

Figure 22:
Five Steps to Developing an SWM Strategy

Stage 1. **Baseline Assessment.** Evaluate the current SWM system through research, identifying deficiencies, and aligning with policies and legislation. Assess waste flows, services, infrastructure, stakeholders, and finances while forecasting future waste generation. Review public practices and use SWOT analysis to capitalise on strengths and address weaknesses.

Stage 2. **Set the Strategic Direction.** Define the SWM system's vision, aims, and objectives over 10–15 years. Set SMART objectives and establish the scope of the strategy. Ensure the vision is specific, realistic, and aligned with broader city goals.

Stage 3. **Develop the Action Plan.** Outline specific actions needed to meet objectives by assigning responsibilities, timelines, budgets and other resources. Prioritise short-term, cost-effective actions and set milestones for long-term goals. Track progress and manage risks throughout implementation.

Stage 4. **Development and Endorsement of the Strategy.** Draft, review, and adopt the SWM strategy with stakeholder input. Ensure alignment with other city policies, secure community engagement, and update connected strategies for consistency.

Stage 5. **Implementation and Review.** Transition to action, building awareness, and securing support. Monitor performance through regular reviews, adapt to changes, and share results transparently. Treat the strategy as a living document, adjusting as needed.

Essential Data for Effective Waste Management

Effective waste management, including developing regulations and strategies, requires accurate measurement. Knowing the types, quantities, and sources of waste and how it is disposed of is crucial for supporting regulations such as waste licensing and extended producer responsibility. Regular data collection establishes a baseline to track trends and adjust policies. Many cities in the Mekong River Corridor lack reliable waste measurement systems, making tools like a weighbridge essential. Improving data quality, transparency, and sharing information fosters accountability, enhances decision-making, and drives progress toward sustainable waste management practices.

Figure 23:
Weighbridge at Vang Vieng Landfill, Lao PDR

Enforcement

In many parts of the Mekong Corridor, enforcement is challenging due to capacity issues and cultural sensitivities, especially when local officers must enforce regulations within their own communities. However, relying solely on awareness campaigns for behaviour change in waste management is often insufficient, making enforcement essential to ensure compliance. Effective enforcement includes penalties for non-compliance and mandatory participation in waste programmes, with some offenders encouraged to join waste collection schemes as a rehabilitative measure rather than facing fines. Combining awareness efforts with enforcement creates an accountable and structured system that encourages responsible waste management while discouraging harmful practices.

A designated government agency, or regulator, oversees compliance monitoring and enforcement, ensuring independence from policy or operational activities to prevent bias and fraud. The compliance programme should cover several elements, as detailed in Figure 24. A strong enforcement strategy is intelligence-led, risk-based, and focused on preventing harm. Monitoring should be both proactive and reactive. Proactive inspections are prioritised based on data, while reactive inspections respond to violations. Encouraging self-audits and providing accessible public reporting channels, such as hotlines or online forms, enhance compliance.

Inspections are essential for assessing compliance with environmental regulations. They gather information through interviews, record reviews, photographs, sample collections, and observing operations. Trained inspectors detect violations and enforce actions. If non-compliance is found, an investigation follows, leading to enforcement decisions. The goal is to document compliance, prevent harm, detect violations, and inform policy adjustments.

Figure 24:
Elements of a Strong Compliance Programme

Coordination Between Stakeholders

An effective and sustainable SWM system requires collaboration across various stakeholders, not just government efforts alone. Key players in SWM include:

- **Government.** Coordination between central and local governments is vital for effective SWM. In many Mekong River Corridor countries, SWM falls under the jurisdiction of local governments, as they better understand local conditions. Thus, national policies must consider local insights to ensure practical, aligned solutions. Similarly, local governments should consult with central authorities on service delivery challenges and opportunities while providing essential data for national reporting.

- **Private Sector.** The private sector plays a vital role in SWM by investing in infrastructure, delivering services, and innovating resource recovery. Public-private partnerships improve efficiency and reduce costs for local governments. Additionally, private companies advance recycling, waste-to-energy technologies, and circular economy initiatives, transforming waste into valuable resources.

- **Industry Bodies.** These organisations represent the interests of businesses and professionals within a specific sector. In waste management, these bodies play a crucial role in shaping policy, promoting best practices, capacity building, setting standards, and fostering collaboration between businesses, governments, and other stakeholders.

- **The Public.** As the primary waste generators, local communities, including households and businesses, play a crucial role in sustainable SWM. Progress in waste reduction and segregation at the source is essential for the efficient processing of recyclables and materials of value. This requirement makes public awareness and communication between the community, government, and private-sector waste companies critical.

- **Non-Government Organisations.** The SWM sector across the region typically has many NGOs, including those that seek to achieve zero waste, undertake litter clean-ups, support informal workers, or improve resource recovery. These NGOs can be valuable in complementing formal operations and supporting awareness-raising.

- **Civil Society Organisations (CSO) and National Bodies.** CSOs play a significant role in SWM by engaging communities, advocating for sustainable practices, and influencing policy. National organisations can act as a bridge between local governments, businesses, and residents to create more inclusive and effective waste management systems.

- **Research Institutions.** Universities and colleges play a vital role in SWM by conducting studies that inform policies and practices. By collaborating with government and industry, they provide data-driven insights that enhance sustainability and resource recovery while supporting capacity building and education initiatives in the waste sector.

- **Development Agencies.** International funding bodies and development agencies enhance SWM through financial support, technical expertise, and capacity building. They help implement sustainable practices and improve waste systems while assisting governments in effective policy development and community engagement for long-term sustainability.

Improving coordination across these stakeholders requires clear communication channels, well-defined roles, and joint planning. Regular meetings, task forces, data sharing, and technology can enhance transparency, collaboration, and project tracking. Capacity building and community engagement ensure broader buy-in, strengthening the overall SWM system.

Case Study: Nong Khai Province, Thailand

Nong Khai Province has embarked on an innovative journey to tackle the pressing issue of waste management. It has adopted a multi-faceted approach that emphasises household waste separation, the promotion of the circular economy, and the engagement of both the community and private sector in sustainable waste practices.

In Nong Khai Province, the daily production of solid waste amounts to approximately 490.63 tons. Of this, 67 per cent (328.77 tons) is managed effectively each day, showcasing the province's commitment to sustainable waste management practices. Specifically, 28.14 per cent of the waste is disposed of in accordance with academic and environmental principles, ensuring safe and environmentally friendly waste processing.

A significant portion of the waste, 38.87 per cent, is repurposed or reused, reflecting the province's robust efforts in promoting recycling and the circular economy. This approach mitigates environmental impact and underscores the community's active participation in sustainable waste management practices.

Initiatives and Achievements

Wet waste separation programme: To combat global warming, Nong Khai Province launched a programme encouraging households to separate wet waste. This initiative aligns with Thailand's Voluntary Greenhouse Gas Reduction standards and aims for universal household participation. As a result, 113,988 households have successfully adopted wet trash cans, significantly contributing to the province's environmental sustainability goals.

Recycle waste separation and circular economy: The province has focused on the separation of recyclable waste, urging residents to embrace the circular economy's principles of reduce, reuse, and recycle. This effort includes widespread campaigns to raise awareness and encourage community participation in waste reduction and recycling. A notable outcome of this initiative is the establishment of 38 waste banks across Nong Khai, which collectively amassed 7,124.69 tons of recyclable waste in 2023, translating to significant community income of THB 35,839,937.28.

Hazardous waste collection: Recognising the dangers of hazardous waste, Nong Khai has facilitated separate disposal mechanisms for such materials. Local administrative organisations have installed designated collection points in every village or community, leading to the safe disposal of 4,357.30 kg of hazardous waste in 2023.

Local volunteer network: To bolster its waste management efforts, the province has established a Local Volunteers that Save the World network, recruiting at least one volunteer per household to participate in activities aimed at preserving natural resources and the environment. This initiative has attracted 119,299 households, resulting in a robust volunteer force of 121,685 members dedicated to environmental preservation.

Waste management clusters: To streamline waste management operations, Nong Khai supports local government organisations in forming clusters, thus facilitating more efficient and effective waste handling processes.

Private sector engagement: Nong Khai actively encourages private investment in waste management solutions that are environmentally safe and sustainable. A pivotal achievement in this domain is the partnership with Nong Khai Na Yu Co., Ltd., which led to the establishment of a facility capable of processing 380 tons of waste per day into 6 MW of electricity. The facility commenced operations in December 2022. This project is addressing waste disposal needs and contributing to solving the country's energy challenges.

> "Nong Khai Province expects that it will help manage solid waste more efficiently and contribute to making people in the Mekong River Basin region have a good quality of life, balance, stability, and prosperity sustainably."
>
> — Jaratpong Kamdokrap, Chief of the Nong Khai provincial office for Local Administration, Thailand at the first UMCI Dialogue in February 2024

Nong Khai Province's comprehensive approach to waste management showcases the potential of integrated, community-engaged strategies in achieving sustainability goals. Through a combination of household participation, circular economy practices, hazardous waste management, volunteer networks, and public-private partnerships, Nong Khai sets a precedent for regions facing similar environmental challenges. Its experience exemplifies how localised initiatives can contribute significantly to global sustainability efforts, paving the way for a greener future.

Thai–Lao Friendship Bridge in Mukdahan, Thailand.

Public Private Partnerships

Public-private partnerships (PPPs) involve transferring control of services or goods from the public sector to the private sector, either fully or partially. PPPs typically occur when neither the public nor private sector can fully meet stakeholder goals independently, recognising that waste management requires collective societal contributions.

Due to differing objectives, private sector involvement should be seen as an opportunity, not a complete solution. The private sector prioritises profitability, while the government focuses on public good, cost savings, and service quality. Evaluating factors like cost recovery, efficiency, accountability, risk, and legislation is essential for assessing the private sector's role.

Many cities globally and regionally have engaged in PPPs to improve their waste management systems, covering areas such as waste collection, transportation, processing, and disposal and the construction or management of sanitary landfills. Often, specific parts of the waste management chain are contracted out, creating a mix of public and private service delivery. Local governments, however, retain oversight responsibilities and must ensure the capacity to manage contracts effectively. Revenue-sharing opportunities may also arise, requiring transparent oversight.

Beyond the private sector, waste management partnerships can include social enterprises, forming public-private-social partnerships. An example is Pune, India, where the city partnered with SWaCH,[8] a cooperative of waste pickers and urban poor, to improve solid waste management. Integrating the informal sector has been shown to reduce the burden on formal waste systems by lowering labour, transport, and landfill costs.

8 https://swachcoop.com/.

Girl riding bicycle in flood area.

Case Study: Phnom Penh, Cambodia

Phnom Penh, Cambodia.
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Phnom Penh faces significant challenges in managing solid waste. The Dangkor district landfill receives approximately 3,700 tons of municipal solid waste daily.

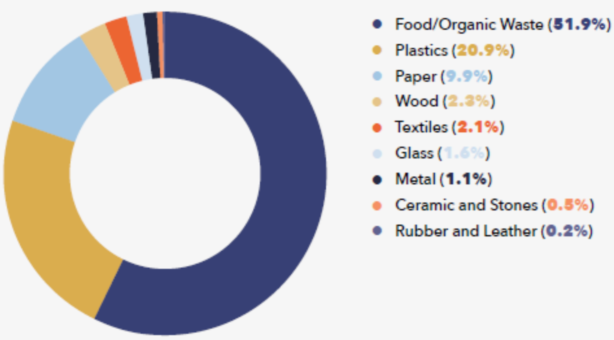
In a 2005 report, the Japan International Cooperation Agency (JICA) stated that about 73 per cent of all waste generated was recycled by the informal sector.

In late 2019, the Government of Cambodia reformed the municipal solid waste management system, establishing enterprises responsible for waste collection, transportation, and landfill management. This reform led to the division of the city into three zones, each awarded to different service providers through a competitive bidding process.

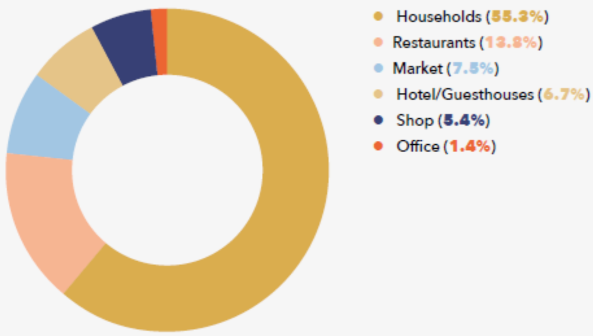
Since 1 July 2021, these new service providers have enhanced the quality of waste collection and transportation with modern equipment and regular collection schedules. As a result, waste volume transported to the Dangkor landfill increased from 2,700 to 3,700 tons per day. Additionally, the city is using innovative German technology to clean the Mekong, Tonle Sap, and Bassac rivers with a system that is capable of collecting 20 tons of garbage per day.

This case study reflects Phnom Penh's proactive approach to solid waste management, contributing to the city's vision of becoming a sustainable and prosperous urban centre by 2050.

Composition of municipal solid waste



Sources of municipal solid waste generated



The Informal Sector

The informal sector plays a vital role in waste management across the Mekong River Corridor, with many workers, particularly women from vulnerable backgrounds, engaged in low-paid, labour-intensive jobs with limited rights and protections. Distinct groups involved in informal waste collection include:

- **Street material pickers.** Collect recyclables from public spaces and streets, facing exposure to hazards, traffic, and challenging conditions.
- **Landfill pickers.** Work in dumpsites and landfills, extracting recyclables in harsh environments with poor safety conditions.
- **Recyclable collectors.** Self-employed individuals using carts or motorised vehicles to gather recyclables from households and businesses, selling them to junk shops.
- **Waste collectors.** Employed by formal waste services, but often informally scavenge for recyclables to earn additional income, highlighting the need for policies that address informal practices while ensuring fair compensation and safety.

The informal sector often leads to inefficient collection practices, low recycling rates, and material leakage. Street collectors may leave waste scattered, and collected recyclables are often contaminated, reducing their value. Informal workers, especially women, face unsafe working conditions, health risks, harassment, and limited access to resources.

Despite these challenges, the informal sector can reduce waste management costs by decreasing the volume of waste handled by formal systems. Integrating informal workers into formal waste management systems has proven beneficial, improving livelihoods and boosting recycling rates. Formalising this sector through cooperatives or social enterprises enhances working conditions, offers social protections, and provides training.

Such formalisation should be participatory, involving stakeholders to address the needs of informal workers regarding income, flexibility, and empowerment. Civil society organisations such as WIEGO (Women in Informal Employment: Globalizing and Organizing) and SDI (Slum Dwellers International) have vast experiences in this sector.

Figure 25:
Landfill Waste Pickers in Cambodia

The Public's Role in Integrated Solid Waste Management

The public, including households and businesses, plays a critical role in the success of integrated waste management systems. Community participation in waste collection and source-level segregation is essential for efficiency and effectiveness. Encouraging adherence to the '3Rs' (reduce, reuse, recycle) can significantly minimise landfill waste and reduce disposal costs. Waste segregation is often voluntary, making public awareness and convenience crucial. Research[9] by WRAP in the UK highlights several barriers to effective waste segregation, including:

- **Situational barriers.** Lack of space for storing segregated waste.
- **Behavioural barriers.** Busy lifestyles that hinder participation.
- **Knowledge barriers.** Uncertainty about what materials can be recycled.
- **Attitude barriers.** Limited perception of the benefits of recycling.

Education is key to overcoming these barriers. Awareness campaigns and communication tools such as guides, calendars, stickers, social media, and smartphone apps can effectively increase public participation. Well-designed educational initiatives and transparent communication can improve recycling rates, reduce improper disposal, and lower waste management costs for local authorities.

Enforcement mechanisms are also important for preventing improper disposal, such as illegal dumping and burning. By fostering accountability and providing clear guidelines, communities can significantly enhance their contribution to sustainable waste management.

9 WRAP. 2014. *Barriers to Recycling: A Review of Evidence since 2008.* https://www.healthandsafetybookstore.co.uk/members/WRAP_BarrierstoRecycling.pdf.

Case Study: Kampong Cham City, Cambodia

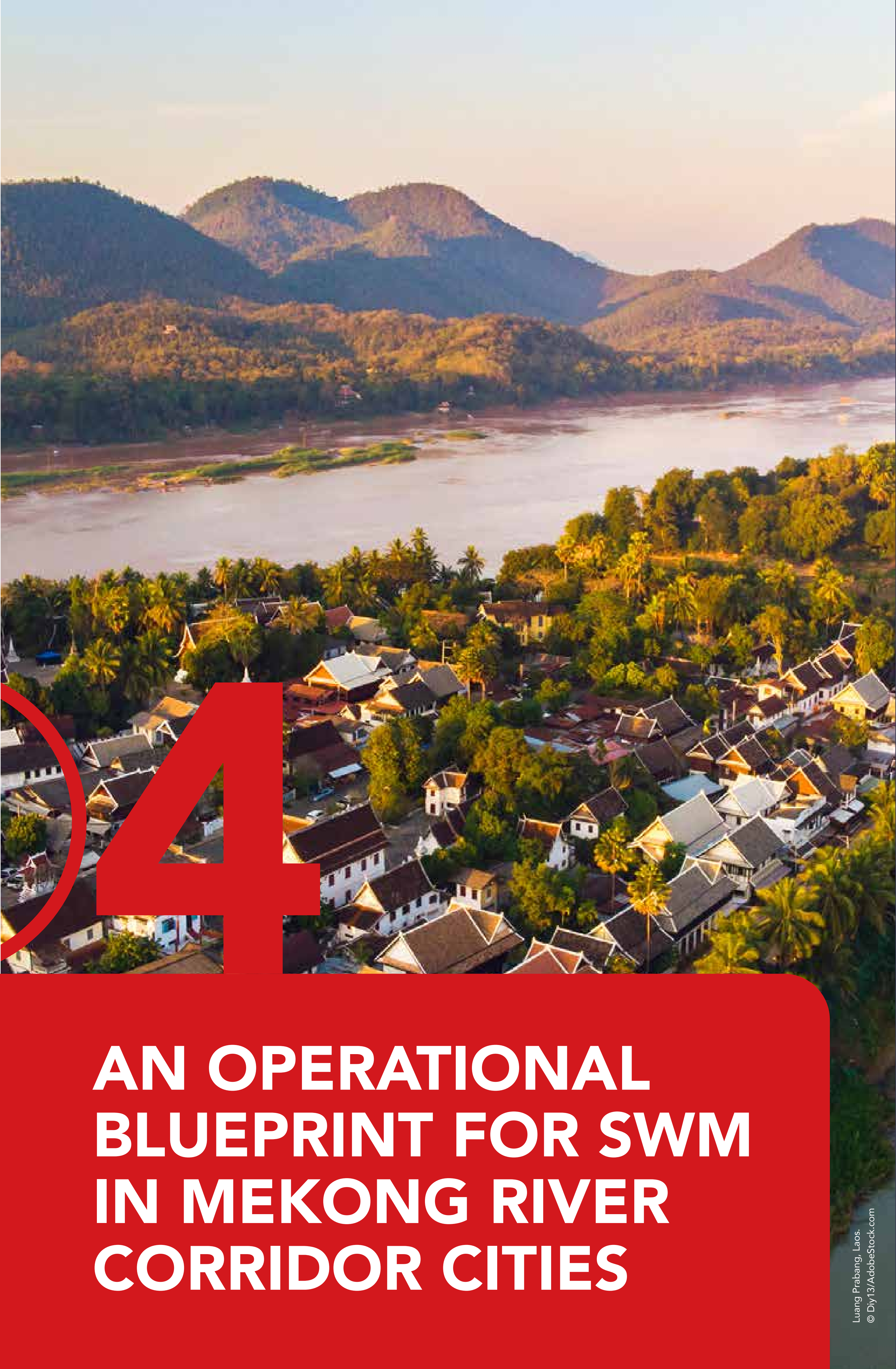
Kampong Cham City has partnered with the private sector (CINTRI) for solid waste collection and transportation since January 2023. The city generates 50 to 60 tons of garbage daily, and waste collection efforts are divided among home fundraising teams, CINTRI monitoring teams, and garbage weighing groups. Kampong Cham uses an official garbage collection app, SAMRAAM, and transports waste to a landfill 20 km from the city. Nonetheless, challenges remain in waste distribution, public education, and the introduction of modern landfill solutions.

Efforts are underway to improve waste management through radio broadcasts, educational campaigns, public bins, and fines for littering.

Partnerships with non-government organisations and civil society focus on plastic collection, youth involvement in waste management, setting garbage prices, and promoting waste storage.

Kampong Cham's approach to SWM illustrates a commitment to environmental sustainability and public health. Through collaboration with private and non-profit sectors, the city aims to enhance its waste collection services, promote recycling, and move towards more sustainable waste management practices, reflecting its broader vision for a cleaner, greener urban environment.

Kampong Cham, Cambodia.



4

AN OPERATIONAL BLUEPRINT FOR SWM IN MEKONG RIVER CORRIDOR CITIES

Luang Prabang, Laos.
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Improving the Waste Supply Chain

In addition to enhancing the overall waste management system, as detailed in the previous section, it is equally important to focus on improving each stage of the waste supply chain in Mekong River Corridor cities and towns. This chain can be broken down into five main stages: waste generation, collection, sorting, processing, and disposal. When developing these stages, it is essential to maintain the system's integrity as a whole, ensuring that any changes in one part consider the impacts on all other stages to keep the system efficient and effective.

Figure 26:
Main Stages of the SWM Supply Chain

While the capital costs for developing waste management infrastructure are often covered by international development funding, the biggest challenge for individual cities is the long-term operation of these facilities and services. SWM is still a relatively new and evolving discipline within the Mekong River Corridor, with a shortage of experienced professionals.

Increasingly, development projects include capacity building initiatives, and there is a growing focus on SWM in universities and technical colleges, but developing experience will take time.

The most pressing issue is financial sustainability. In the Global North, SWM is typically funded through taxes or local rates, with 20–50 per cent of local budgets allocated to waste management. In the Global South, SWM revenue primarily comes from household and business collection fees, which often barely cover collection costs – leaving other parts of the system underfunded.

Linear waste management approaches (take, make, dispose) are unsustainable, especially when focusing solely on disposal. Many landfills in the Mekong region struggle with insufficient budgets, leading to inadequate waste compaction and cover material use. As a result, these landfills often reach capacity prematurely, forcing waste into unlined areas and reverting to open dumpsite models, wasting initial investments.

The path to financial sustainability lies in adopting a circular economy approach, involving reducing waste at its source through prevention, reuse, remanufacturing, and recycling. Diverting waste from landfills creates revenue streams from selling recyclables and value-added processes like composting and biodigesters. Reducing disposal costs and extending landfill lifespan helps cities achieve long-term financial and environmental sustainability.


Luang Prabang, Laos

Stage 1: Waste Generation and Storage

Introduction to Issues and Opportunities

Waste Generation

SWM begins with waste generation, which happens wherever people live, work, or engage in daily activities. Factors influencing waste generation include household size, income, location, consumer behaviour, and awareness of sustainable practices. Larger families and wealthier households typically generate more waste. Some households may sell recyclables directly, but formal collection schemes are often lacking.

Types of Waste

Cities generate various types of waste, each requiring specific management strategies:

- **Municipal solid waste:** Everyday items like food scraps, packaging, and paper.
- **Organic waste:** Biodegradable materials such as food and garden waste.
- **Recyclable materials:** Items like paper, plastics, metals, and glass that can be reprocessed.
- **Hazardous waste:** Dangerous substances such as chemicals, e-waste, and batteries that need special handling.
- **Construction and demolition debris:** Waste from building activities.
- **Bulky waste:** Large items like furniture.
- **Special waste:** Items with specific disposal needs, such as tires or certain industrial byproducts.

Waste to Value

Capturing waste at the source is essential to ensure it enters the formal waste management system rather than being dumped or burned, which harms the environment. Collecting organic and recyclable materials at the point of generation enables resource recovery, diverts waste from disposal sites, and transforms waste into a valuable resource. Properly managed waste reduces pollution, produces high-quality recycling materials, protects ecosystems, and supports cleaner urban spaces, contributing to a circular economy.

At the waste generation stage, cities should focus on three key areas to improve the sustainability and effectiveness of services (Figure 27).

Figure 27:
Waste Generation Focus Areas

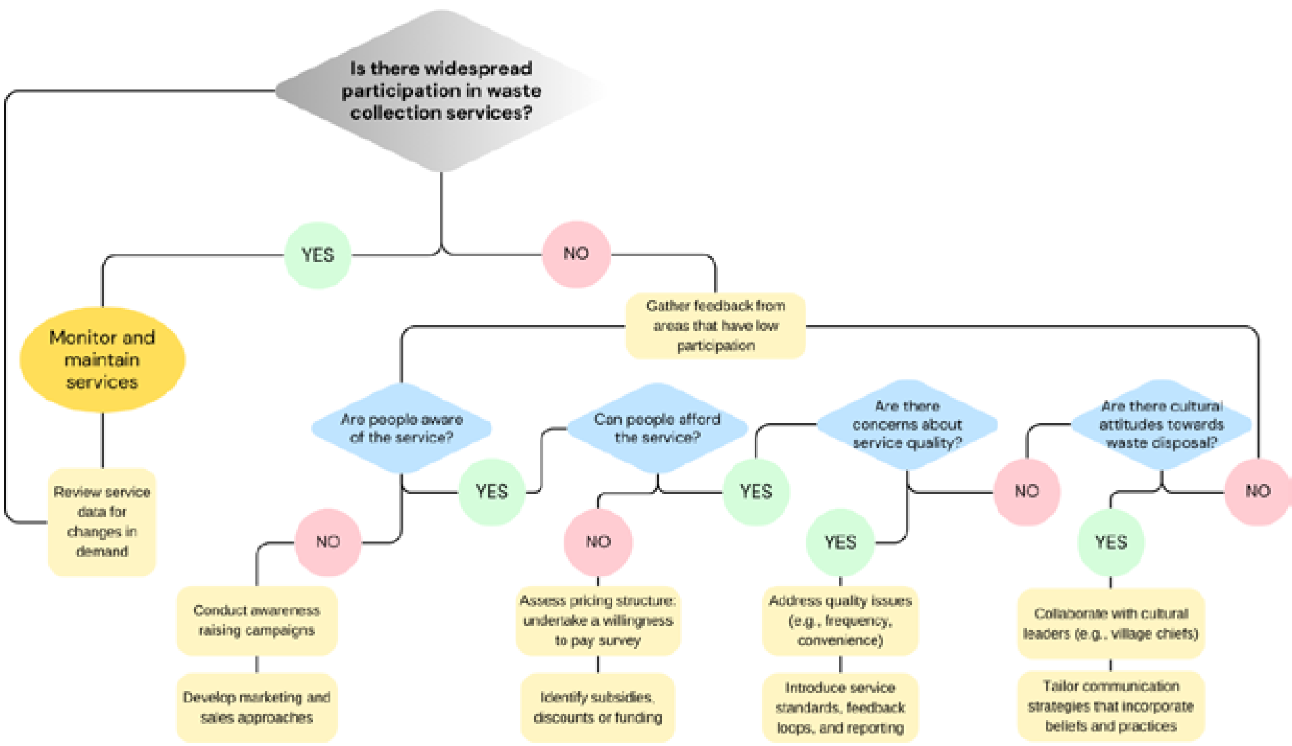
Improving Participation in Waste Collection

Introduction

Participation in waste collection schemes remains a significant challenge across the Mekong River Corridor, alongside limited service coverage (see the next section on waste collection). Even in areas where services exist, participation may be low due to a lack of awareness, affordability concerns, perceived poor service quality, or cultural habits. Many residents may have historically disposed of waste themselves and see no reason to change these practices. This mindset often leads to improper waste disposal through dumping or burning, negatively impacting the environment and human health.

The goal is to ensure widespread access to waste collection services, with a target of 70–80 per cent participation considered satisfactory and 80–90 per cent deemed exemplary. However, achieving these targets in very remote villages may be challenging.

Figure 28:
Assessing How to Improve Participation Rates



Ongoing monitoring and service maintenance are essential in areas with high participation rates. This should include user feedback and regular reviews of service data to ensure that waste collection services keep pace with changing demand and waste volumes.

Gathering feedback through surveys or focus groups is crucial if participation is low. Low participation may stem from various factors, not just cost-related issues; addressing these factors is key to improving engagement in waste collection schemes.

Awareness Raising and Marketing

Many communities lack awareness of the benefits of waste collection services and the harmful effects of improper disposal, such as dumping and burning. Public awareness campaigns and school education are essential to inform residents about the environmental and health risks of poor waste management and the advantages of formal collection services. These campaigns should be ongoing to drive lasting behaviour change and use various media, including community workshops, announcements, billboards, radio, videos, litter clean-ups, recycling events, and social media.

However, awareness alone may not prompt immediate behaviour change. Waste collection services should be marketed similarly to consumer goods, using professional sales strategies to boost participation. By emphasising the convenience and health benefits of formal waste collection and the risks associated with improper disposal, these marketing efforts can make waste collection more appealing to households. Highlighting reduced health risks and the potential economic impacts of pollution can further drive engagement in waste management schemes.

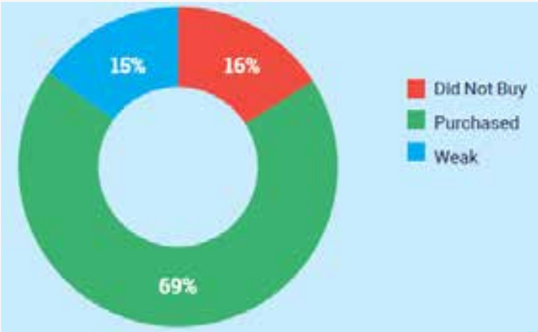
Box 4:
Market Opportunities for Household Waste Collection in Cambodia

IDE Global is a non-profit organisation focused on providing innovative solutions to address global water and sanitation challenges, emphasising sustainable business models and community engagement to improve access to essential services.

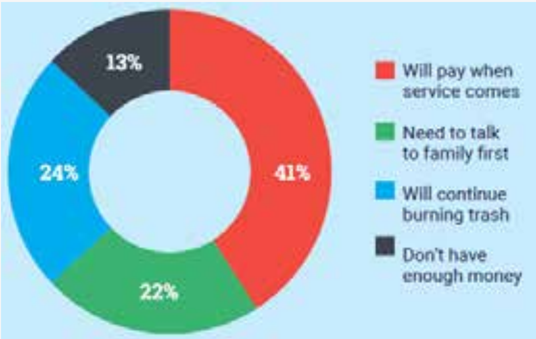
In Cambodia's Kampong Cham Province, IDE Global used a sales trial to assess consumer willingness to pay for waste collection services. Professional trained sales agents visited 274 households and presented on the convenience and benefits of signing up for the service.

The research found that 69 per cent of households were willing to pay $2.50 per month because of the sales presentations. A further 15 per cent were interested but did not have any money at the time of the presentation. Of the 85 households that were not interested in buying the service, only 13 per cent stated that this was because they could not afford it. Most of these respondents wanted to talk to family members or see the quality of the service before buying.

Percentage of household purchasing decisions:



Reasons for purchasing objections:



Source: IDE Global, 2024.

Affordability of Services

A common perception among local authorities, service providers, and waste management NGOs is that households are unwilling to pay for waste collection services. However, as detailed in Box 4, affordability is not always the primary issue. Households regularly pay for utilities such as electricity and water, but waste services are often seen differently, perhaps because they are newer, or people believe they can manage waste disposal themselves.

In many areas, low waste collection fees affect cost recovery. Willingness-to-pay surveys can help assess how much residents are willing to contribute, ensuring financial sustainability. These surveys should include diverse socio-economic groups. Offering discounts or subsidies for low-income households can increase participation but must be designed to ensure long-term sustainability unless supplemented by government or development funds.

Concerns About Service Quality

Service quality concerns in waste management often arise from inconsistent collection schedules, unpredictable pickups, mess left behind, and poor communication from service providers. Additionally, concerns about environmental impact and transparency in waste management practices can erode public trust, leading to demands for more accountability and sustainable approaches. Unreliability, lack of transparency, and poor responsiveness significantly undermine confidence in waste management services. Surveys often show that households and businesses are willing to pay collection fees if the services are reliable and meet reasonable quality standards.

Cultural Attitudes About Waste

Traditionally, communities returned organic waste to nature, supporting natural nutrient cycles. However, modern materials, particularly plastics, have disrupted these cycles and degraded soil quality. Many still follow traditional practices, fostering a "throwaway" culture that resists change. Some believe they can manage their own waste, which hinders more effective waste management strategies. Awareness campaigns must align with cultural beliefs and promote sustainable alternatives. By highlighting the environmental damage caused by current waste habits, communities can be encouraged to adopt more responsible practices, benefiting both the environment and overall quality of life.

Enforcement

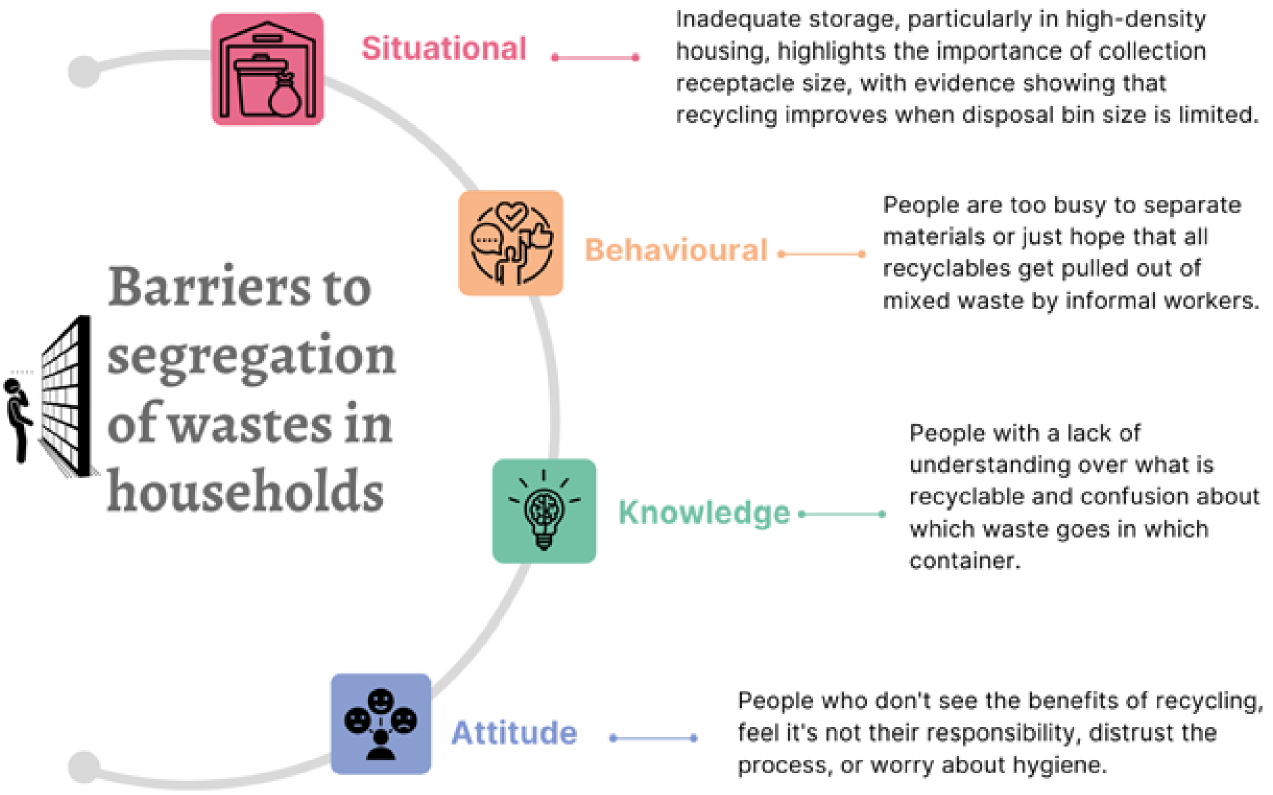
Some cities have waste management regulations, such as bans on illegal dumping and burning or waste collection and separation requirements. However, without proper enforcement, these rules fail to protect public health and the environment. Effective enforcement includes clear regulations, monitoring, inspections, and penalties.

Many cities struggle with enforcement due to limited resources or reluctance to act within close-knit communities. However, combining awareness campaigns with enforcement can be effective. For example, educating people about the health risks of burning waste, followed by patrols, can encourage compliance. Persistent offenders may need penalties, but first-time offenders could be encouraged to join waste schemes instead of paying fines, fostering compliance through education.

Encouraging Sustainability in Waste Generation

Circular economy-based waste systems prioritise sustainability by encouraging waste generators to reduce, reuse, and recycle. This approach requires education to raise awareness and the provision of tools to help households and businesses minimise waste. A key step is source segregation, where waste is divided into organic, recyclable, and non-recyclable categories. This improves collection efficiency, reduces landfill waste, and enhances material recovery for the circular economy. However, barriers to household waste separation may hinder progress (as shown in Figure 29).[10]

Figure 29:
Barriers to Segregation at Source in Households



Raising awareness alone will not improve segregation, as seen in many Mekong River Corridor cases where separated waste is subsequently mixed in collection trucks. Adequate infrastructure and services are essential, including separate collections for recyclables and convenient containers.

Launching awareness campaigns on segregating waste without supporting services can erode public trust. Therefore, aligning the timing of awareness efforts with the introduction of infrastructure and services is critical.

10 Adapted from: WRAP. 2008. Barriers to Recycling at Home.

Improving Storage at Households and Businesses

In many areas across the Mekong River Corridor, households and businesses are responsible for providing their own waste bins and containers. This approach leads to a wide range of container types, many of which are unsuitable for effective waste management. It is common to encounter over 15 different types of bins and bags on a single collection route. These inconsistencies create several challenges:

- **Unsanitary waste storage.** Poor-quality bins made from weak materials or without proper lids lead to pest infestations, odours, leachate leakage, and waste spillage, compromising hygiene and the appearance of urban areas.
- **Handling challenges.** Fragile, heavy, or small bins slow down collection, increase fuel and staff costs, and expose waste collection crews to risks from sharp, hazardous, or infectious waste.
- **Inconsistent segregation.** A lack of standardised containers results in poor waste separation, leading to contamination, lower recycling rates, and increased landfill waste.

Figure 30:
Challenges with Unsuitable Waste Containers

To improve waste management, containers and bags should match waste volumes and encourage recycling. They should be durable, eco-friendly (e.g., made from recyclable materials), easy to handle, and compatible with manual and mechanised collection systems. Containers should also maintain hygiene, be easy to clean, and prevent access by animals such as dogs, rats, and flies. Space outside households and businesses must also be considered to ensure the containers fit within the urban environment.

Providing standardised, government-issued, or subsidised bins that meet durability, size, and waste segregation requirements can enhance hygiene, improve operational efficiency, and support better waste segregation. Additionally, bins should be considered for drop-off points, public spaces, and events to ensure comprehensive waste management across all areas.

Figure 31:
Five Steps to Standardising Containers

Summary of Requirements for Waste Generation and Storage

The key infrastructure needed during the waste generation phase includes suitable containers for waste storage at households and businesses.

A mix of awareness campaigns, marketing strategies, and community engagement is essential to encourage participation in waste collection and promote source segregation.

Regular monitoring and maintenance of the system are critical to ensure long-term success and adaptability to changing needs.

Figure 32:
Summary Checklist for the Waste Generation Phase

1 PARTICIPATION
- Provide public awareness campaigns
- Develop marketing and sales
- Monitor and maintain services

2 SUSTAINABILITY
- Provide public awareness campaigns
- Identify barriers to waste segregation
- Introduce convenient infrastructure and services

3 STORAGE
- Assess waste and volumes
- Assess container requirements
- Pilot and rollout to the community

Stage 2: Waste Collection

Introduction to Issues and Opportunities

Waste Collection Access

In the Mekong River Corridor, waste collection services primarily focus on urban centres, leaving secondary cities, rural areas, and semi-urban zones underserved. This lack of coverage leads to widespread dumping and burning, harming the environment and public health. Expanding service coverage is crucial for pollution control. Decentralised collection schemes using smaller vehicles and local crews can help reach smaller villages and remote areas.

Waste Types

Formal waste collection systems generally focus on disposal waste, while the informal sector deals with dry recyclables. This results in excess waste in landfills, where informal workers operate in unsafe conditions, extracting heavily contaminated recyclables and contributing to low recycling rates. Organic waste, which releases methane, a potent greenhouse gas, is often neglected. Promoting source segregation and establishing separate collection systems can transform waste into valuable resources through recycling and composting.

Efficiency and Customer Service

Many waste collection schemes struggle with limited financial and human resources, making it difficult for small companies to remain viable. Poorly planned routes, high service costs, and infrequent collections result in excessive fuel consumption, lengthy collection times, and inefficient operations. The lack of standardised containers complicates waste handling, increases health risks, and slows the process. Additionally, using unsuitable or poorly maintained vehicles leads to frequent breakdowns, service interruptions, and negative customer perceptions. To improve efficiency and customer satisfaction, cities must invest in better route planning, appropriate vehicles, standardised containers, and sufficient budgets for vehicle maintenance, staff protective equipment, and communication systems.

At the waste collection stage, cities should focus on three key areas to be more effective, environmentally sustainable, and responsive to community needs (Figure 33).

Figure 33:
Waste Collection Focus Areas

Case Study: Mukdahan, Thailand


Mukdahan city, Thailand © RoBird/AdobeStock.com

Mukdahan Province has taken significant strides towards sustainable waste management and environmental conservation. The province's waste management strategy includes sanitary landfills, establishing recycling banks in all local government organisations, and promoting the separation of household waste to reduce global warming.

The establishment of eco-friendly bins in every household has been certified to reduce greenhouse gas emissions by the equivalent of 1,547.24 tons of carbon dioxide, amounting to THB 402,220. With the City Hall Recycling Waste Bank project, Mukdahan reduced greenhouse gases from the purchase of calculated waste by 55.221 tons of carbon dioxide equivalent (tonCO2eq) in 2023.

Efforts to reduce and sort solid waste in government agencies have been successful, leading to the reduction of greenhouse gases. Additionally, Mukdahan has been declared a Smart City with a focus on Smart Energy, highlighting the potential of wind power plants, which contribute to clean energy production.

Mukdahan's environmental initiatives align with Thailand's national policy towards achieving carbon neutrality by 2050 and net-zero emissions by 2065. The province's approach to environmental management encompasses the sustainable development of cities, protection, and restoration of natural resources, participatory environmental preservation, and the development of renewable energy sources.

Mukdahan's case study demonstrates a proactive and integrated approach to waste management and environmental sustainability. Through innovative practices, community involvement, and alignment with national and international environmental goals, Mukdahan is making significant progress towards becoming a model for sustainable urban and rural development in the region.


Damnoen Saduak floating market, Thailand. © Kalyakan/AdobeStock.com

Maximising Service Coverage

Maximising service coverage involves assessing geographic and waste collection areas to ensure collection services are available, tailored to needs, and accessible to all residents. Implementing decentralised collection methods can enhance accessibility while establishing clear payment structures, encouraging broader participation.

Waste Collection Areas

Different areas in a city, like those shown in Figure 34, produce various waste types. To ensure comprehensive coverage and maintain public hygiene and a clean environment, different collection approaches, as outlined in Table 2, should be considered for each area.

Figure 34:
Key Waste Collection Areas

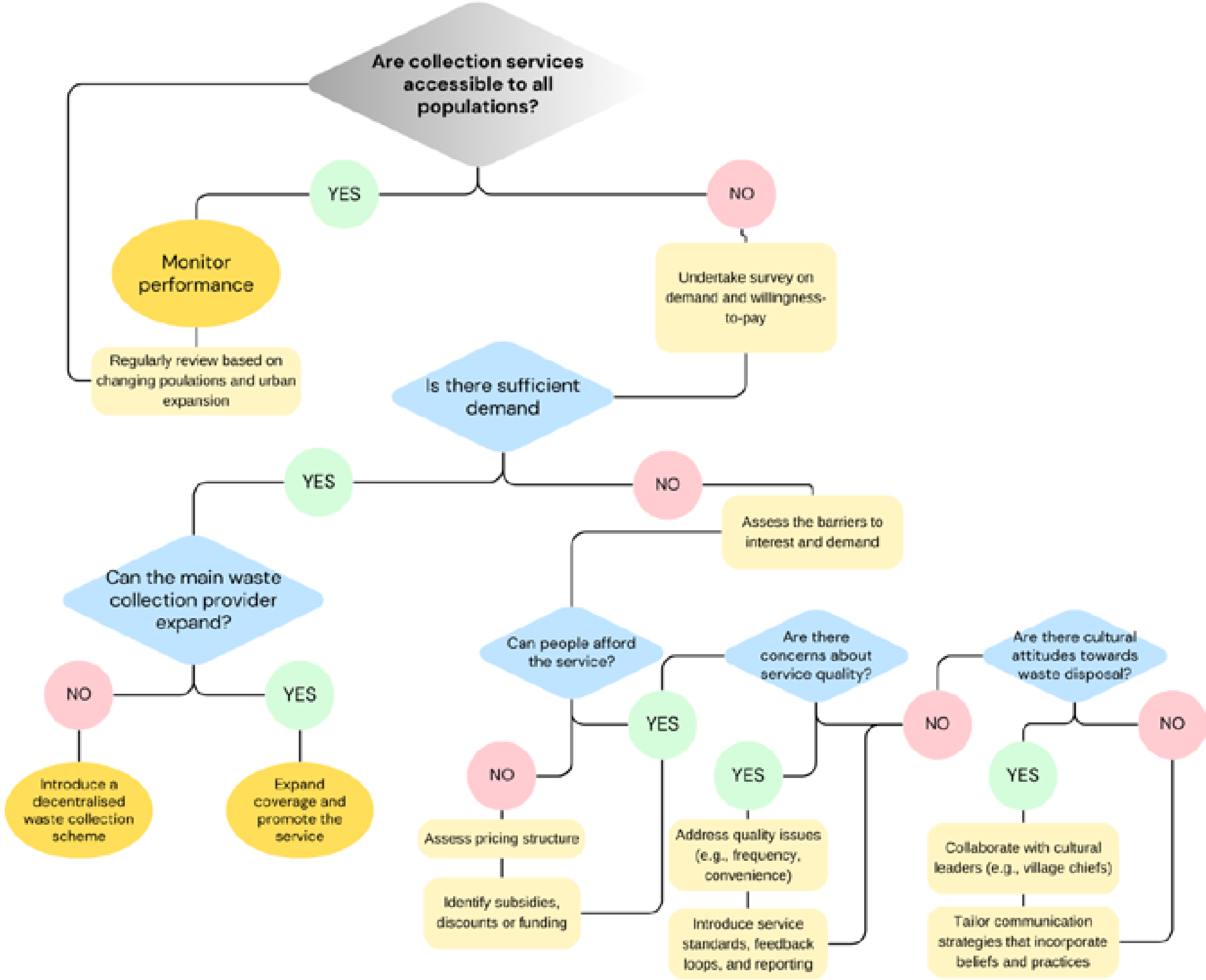
Damnoen Saduak floating market, Thailand.

Table 2:
Types of Waste and Collection Approaches

Area	Types of Waste	Collection Approach
Residential	Generate the largest volume of waste across all municipal waste types.	Collection must be fairly regular and reliable.
Commercial	Businesses and retail produce large amounts of packaging.	Prompt and consistent collections to prevent build-up of waste.
Markets	Generate packaging and food waste.	Require daily collections.
Hospitality Sector	Hotels, bars and restaurants produce large volumes of organics and recyclables from food and beverage products.	Frequent collection to avoid health and sanitation issues.
Tourist, Transport Sites and Public Spaces	Produce a range of wastes, particularly relating to on-the-go food and beverage products.	Regular collection and street cleaning to maintain a clean, appealing environment is critical for tourism.
Events	Generate large amounts of waste in a short time, especially recyclable food and beverage items.	Require temporary bins for waste and recyclables and immediate post-event cleanup.
Institutions	Schools, government buildings, and offices generate specific types of waste.	Provide options for the collection of recyclables, especially paper.
Hospitals & Health Clinics	Sharp, hazardous and infectious wastes.	Provide separate collections using strict protocols that take waste to suitable disposal sites.
Construction and Demolition	Bulky waste, much of which is reusable.	Specialised collection and sorting to encourage reuse.
Industrial	Industry-specific wastes, which may be hazardous.	Specialised handling and disposal methods, separate from municipal waste.

Assessment of Service Coverage

Figure 35:
Decision Tree: Waste Expansion and Improving Accessibility of Services



If waste collection services are limited, it is essential to identify unserved areas and assess demand through willingness-to-pay surveys. These surveys help gauge public interest and inform the design and pricing of services. If demand exists, evaluate whether current providers can manage the additional waste. If they can, expand services and promote participation through awareness campaigns.

If existing providers lack capacity, introduce new ones through competitive bidding, dividing the city into zones. This approach encourages competition, increases efficiency, and improves customer service. Multiple providers enable better performance tracking. If provider one fails, others can step in. Different providers can also address diverse areas, including urban and semi-urban zones.

Decentralised community-managed schemes can be effective in regions where traditional collection services are unfeasible due to poor road conditions or dispersed housing. These schemes utilise local labour, smaller vehicles, and transfer points while promoting recycling and organic waste diversion.

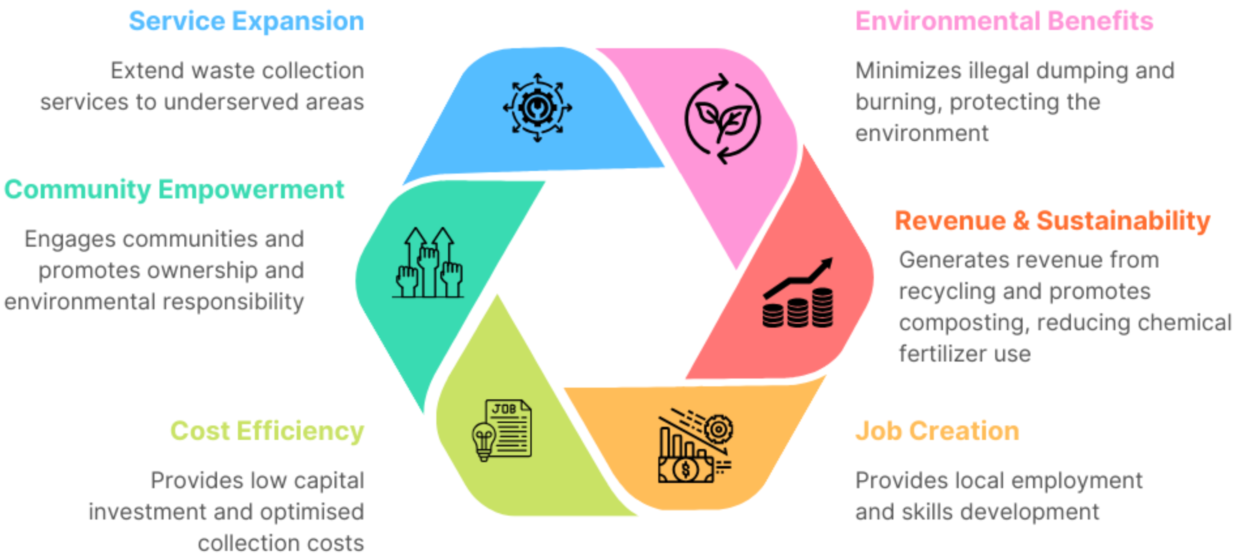
If demand from unserved areas is low, it is important to understand the reasons. If surveys show residents cannot afford the rates, consider adjusting prices, providing subsidies for low-income households, or offering incentives to encourage participation. Concerns about service quality may also lead to self-managed waste disposal through dumping and burning. Improving collection frequency, ensuring timely pickups, maintaining clean streets, and enhancing communication can increase service quality. Implementing service standards, feedback mechanisms, and regular reporting reassures the public that providers are committed to high-quality service.

Cultural attitudes towards waste management, where residents feel capable of handling their own waste, may also limit participation. Engaging community leaders and using targeted communication campaigns can highlight the negative impacts of improper waste practices and promote the benefits of formal collection schemes.

Decentralised Waste Collection

A decentralised waste collection scheme distributes SWM responsibilities to local entities rather than a central authority. Establishing a decentralised scheme in conjunction with the main waste collection service has many benefits.

Figure 36:
Benefits of Decentralised Waste Collection Schemes

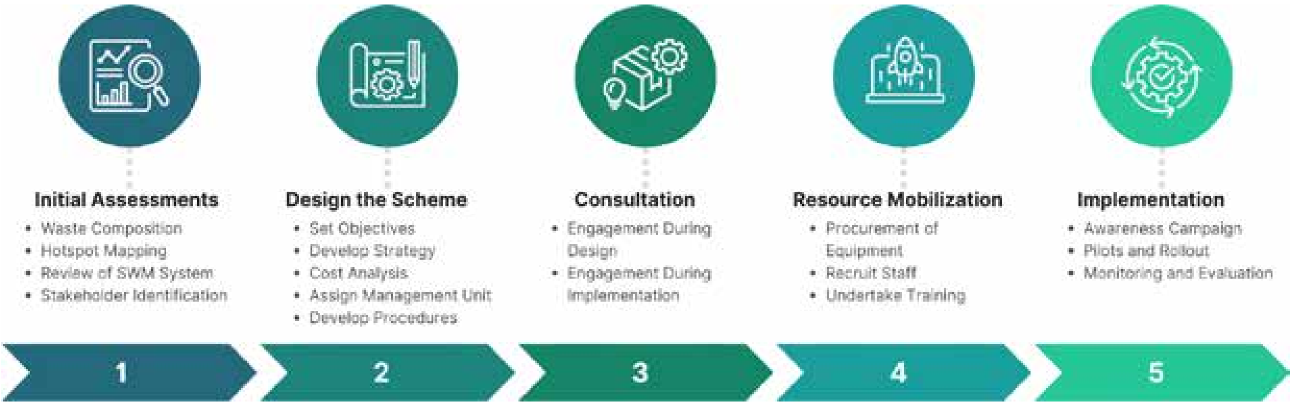


Each decentralised waste collection scheme will need to be customised to meet local conditions and objectives, incorporating the following key components:

- **Community engagement and education.** Initiatives will educate residents on waste management, recycling, and source segregation, encouraging participation in decision-making to foster ownership.
- **Administrative and operational support.** Local teams will oversee daily operations, including logistics and stakeholder coordination, while implementing systems to monitor and evaluate performance based on waste volumes and recycling rates.
- **Financial mechanisms.** Financial sustainability will rely on local government funding, community collection fees, and revenue from recycled materials, supported by effective budgeting and planning.
- **Local collection infrastructure and equipment.** The infrastructure will include collection bins, central drop-off points, recycling banks, composting facilities, and necessary transportation equipment, such as vehicles and protective gear for waste collection crews.

Decentralised waste collection schemes can be established in five key steps tailored to the scheme's size and local needs. These steps ensure effective implementation and sustainability by addressing community engagement, infrastructure development, and operational efficiency.

Figure 37:
Five Steps to Establishing a Decentralised Scheme



1. **Initial Assessments:** To implement an effective decentralised waste collection system, analyse waste composition using tools such as the UN-Habitat Waste Wise Cities Tool (WaCT).[11] The system must comply with national regulations and coordinate with main waste providers while establishing markets for recyclables. Stakeholder engagement from the public, private sector, and local government is essential. Conduct hotspot mapping to identify areas of improper waste disposal and guide targeted interventions.

2. **Scheme Design:** Set clear objectives for the decentralised scheme that align with national and local strategies, including scope, waste types, and target populations. Develop a collection strategy, including waste identification, collection frequency, and accessible storage. Conduct a cost analysis for financial sustainability and establish a management unit that can oversee operations and develop standard operating procedures (SOPs).

3. **Consultation:** Engage the community during design and implementation. Use surveys and focus groups for local insights and workshops to discuss collection methods. Collaborate with local authorities for alignment. Maintain communication and feedback channels during implementation, conduct pilot programs for testing, and provide training to enhance community understanding. Continuous monitoring and recognition of contributions will foster support.

4. **Resource Mobilisation:** Focus on procuring essential equipment and vehicles by assessing needs and sourcing locally within budget constraints. As shown in Figure 37, equipment may include collection vehicles, storage solutions, transfer containers, recycling banks, and compost units. Prioritise durability, environmental considerations, and user-friendliness during procurement. Promote gender inclusivity in staffing and implement comprehensive training covering operational procedures, health and safety, and customer service.

5. **Implementation:** Conduct awareness campaigns and training to engage residents effectively. Outline scheme objectives and proper waste management practices through workshops. Encourage participation with regular clean-ups and clear communication about fees. Use pilot programs to test participation rates and waste segregation accuracy before a full rollout. Continuous monitoring and tailored reporting will ensure the scheme meets community needs and promotes sustainability.

11 https://unhabitat.org/wwc-tool.

Figure 38:
Equipment Considerations for a Collection Scheme

Introducing Separate Waste Collections

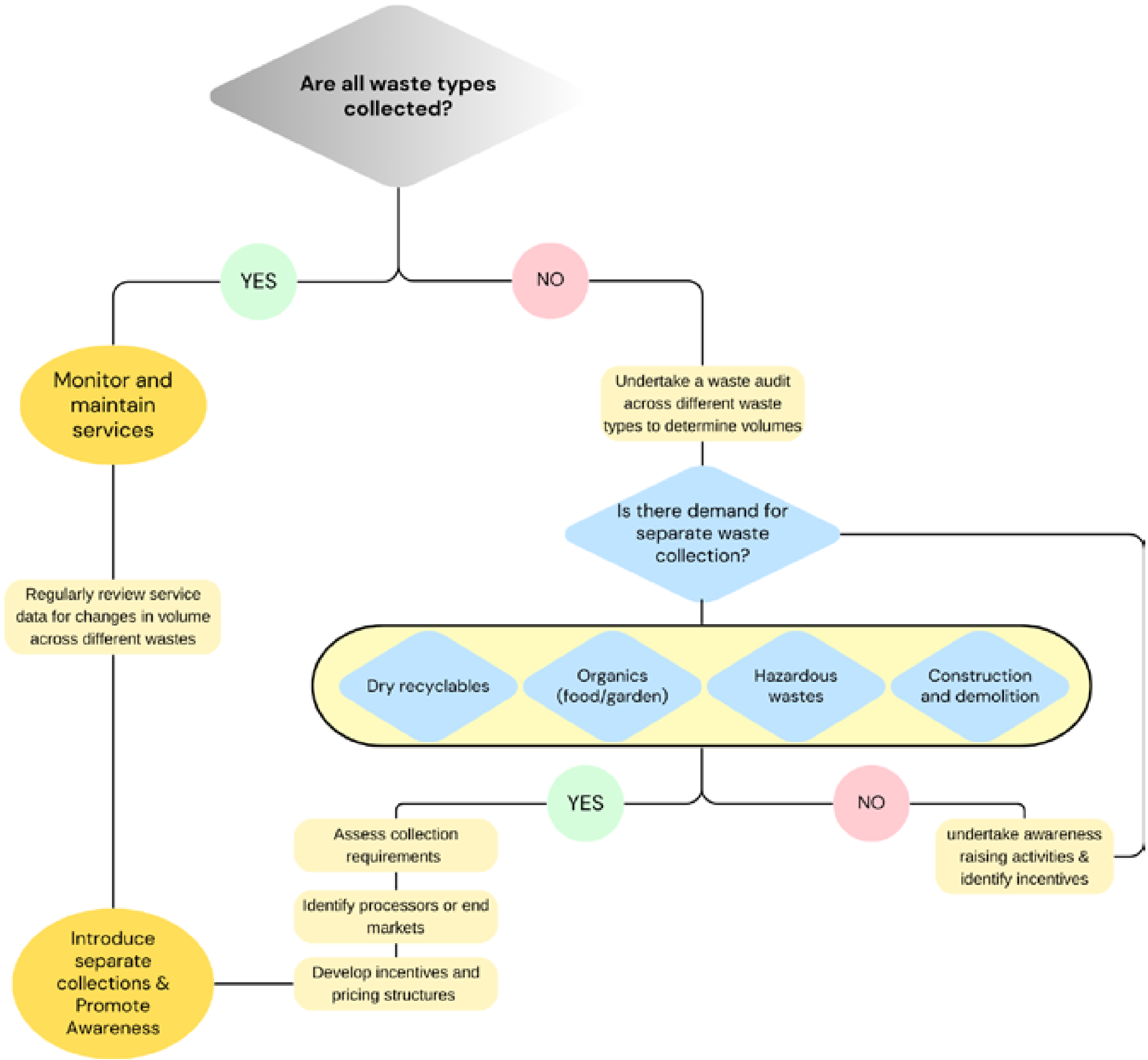
Implementing separate waste collection can significantly increase recycling rates, improve material quality, reduce contamination, and lower disposal and landfill management costs. It also generates revenue from recyclables and organic processing while enhancing the safety and livelihoods of informal workers.

Separate collection schemes can be cost-effective, as collection frequency can be tailored to waste types. For example, organic waste requires frequent pickups due to odour and pest issues, particularly in the hot climates of the Mekong River Corridor.

In contrast, as dry recyclables and organic waste are diverted from disposal, the volume of residual waste decreases, enabling less frequent collection of disposal waste.

While focusing on disposal waste, dry recyclables, and organic waste, Mekong River Corridor cities should also consider construction, demolition, and hazardous materials. Assessing expansion capacity is essential; a phased approach prioritising major waste generators can improve collection efficiency and implementation, allowing for customised methods based on waste types and generation locations.

Figure 39:
Decision Tree: Introducing Separate Waste Collections



Assessing the Demand and Benefits of Separate Collections

Assessing the demand and benefits of separate collections starts with evaluating the current waste collection system and the potential for introducing waste separation. This evaluation includes analysing waste composition, engaging the community to understand their needs, and reviewing existing infrastructure. Estimating environmental and economic benefits, such as increased recycling and reduced disposal costs, is also key. Pilot programmes can test feasibility and gather feedback. These steps help cities develop strategies to improve recycling and community involvement in waste management.

Figure 40:
Five Steps to Developing Separate Waste Collections

Assessments are required to evaluate the potential for introducing the separation of waste and new collections across different waste types, which may include:

- **Dry Recyclables:** This includes plastics, metals, glass, paper, and cardboard, primarily from packaging and food and beverage products. Typically, these are collected as mixed recyclables and separated from general waste by generators, but not by material type. Some countries require further sorting by type and colour. Initially focusing on mixed recyclables may simplify introduction of a new scheme. Success depends on a materials recovery facility to sort these materials into specific streams, such as clear PET bottles. The system's effectiveness also relies on the availability of buyers and end markets for the recyclables.
- **Organics:** Organic waste, mainly food scraps and garden waste, makes up the largest portion of municipal waste. Diverting organics from landfills reduces disposal costs and improves efficiency. Composting or anaerobic digestion can transform this waste into valuable products such as fertilisers or biogas. While commercial-scale facilities are still underdeveloped in many Mekong River Corridor cities, home composting can empower residents to manage organic waste sustainably.
- **Hazardous Wastes:** Hazardous materials such as electrical waste, batteries, chemical containers, and used oils are frequently mixed with municipal waste, leading to improper disposal. Hospitals also produce hazardous waste. Although some incinerators exist, fuel constraints often result in low temperature burning, causing air pollution. New landfills in the region are developing hazardous waste storage, incinerators, and separate landfill cells to enable safer collection and disposal.
- **Construction and Demolition (C&D) Waste:** This category includes heavy materials such as concrete, bricks, wood, metals, and glass. While disposal is costly, many materials can be reused or recycled. For instance, concrete and brick

can be crushed for aggregate, and metals can be recovered. Onsite separation, dedicated collection or drop-off facilities, and encouraging recycling and reuse in construction can enhance C&D waste management.

- **Bulky Waste:** Items such as furniture, mattresses, and large appliances that regular waste collection cannot handle often end up improperly discarded. Effective management requires dedicated collection services or drop-off points, potentially supported by extended producer responsibility schemes with scheduled collections. Many bulky items can be recycled, repurposed, or reused, and promoting donation or repair programmes can reduce landfill pressure and support the circular economy.

Encouraging Segregation at Source

Promoting source segregation requires a blend of education, incentives, and convenience. Public awareness campaigns, school programmes, and clear guidelines should emphasise the benefits of waste separation. Key strategies include:

- **Colour-coded bins:** Simplify segregation by using distinct bins for recyclables, organics, and general waste.

- **Frequent collection:** Ensure regular pickups for recyclables and organics to encourage consistent participation.

- **Incentives:** Offer rewards or reduced waste collection fees for those who separate waste properly.

- **Volume-based systems:** Pay-as-you-throw schemes link fees to waste volume or weight, motivating households to recycle more and send less waste to landfills.

Community involvement is critical. Engaging waste champions, cultural leaders, and peer influencers can foster a sense of ownership and boost compliance. Additionally, a system of warnings and penalties for non-compliance.

Equipment for Separate Collections

Collection Vehicles
Different waste types require specific vehicles for safe and efficient handling. Compactor trucks are ideal for general disposal waste, especially in high-density areas, as they maximise storage by compressing waste, reducing trips to disposal sites. Non-compactor trucks are preferred for dry recyclables and organic waste to preserve material integrity, which is crucial for reuse or composting. Specialised trucks for organic waste may feature leak-proof containers or temperature control for hygienic handling. To enhance sustainability, electric vehicles (EVs) can be used for waste collection, lowering fuel costs and greenhouse gas emissions and supporting long-term environmental goals.

Storage Containers
Tailored storage containers are essential for effective waste segregation. Organic waste containers should have secure lids to reduce odours and pests, while dry recyclable containers need clear labelling and ventilation to prevent moisture buildup. Disposal waste containers should be durable and hygienic. Larger containers are necessary for businesses generating higher volumes of waste, and specialised bulk containers benefit those with substantial organic or recyclable waste. Offering various container sizes can support a pay-as-you-throw system, which incentivises waste reduction by charging based on waste volume, aligning with sustainability goals and improving efficiency.

End Markets and Processors

The success of collecting dry recyclables and organic waste depends on the availability of nearby end markets and processing facilities to ensure cost-effective transportation.

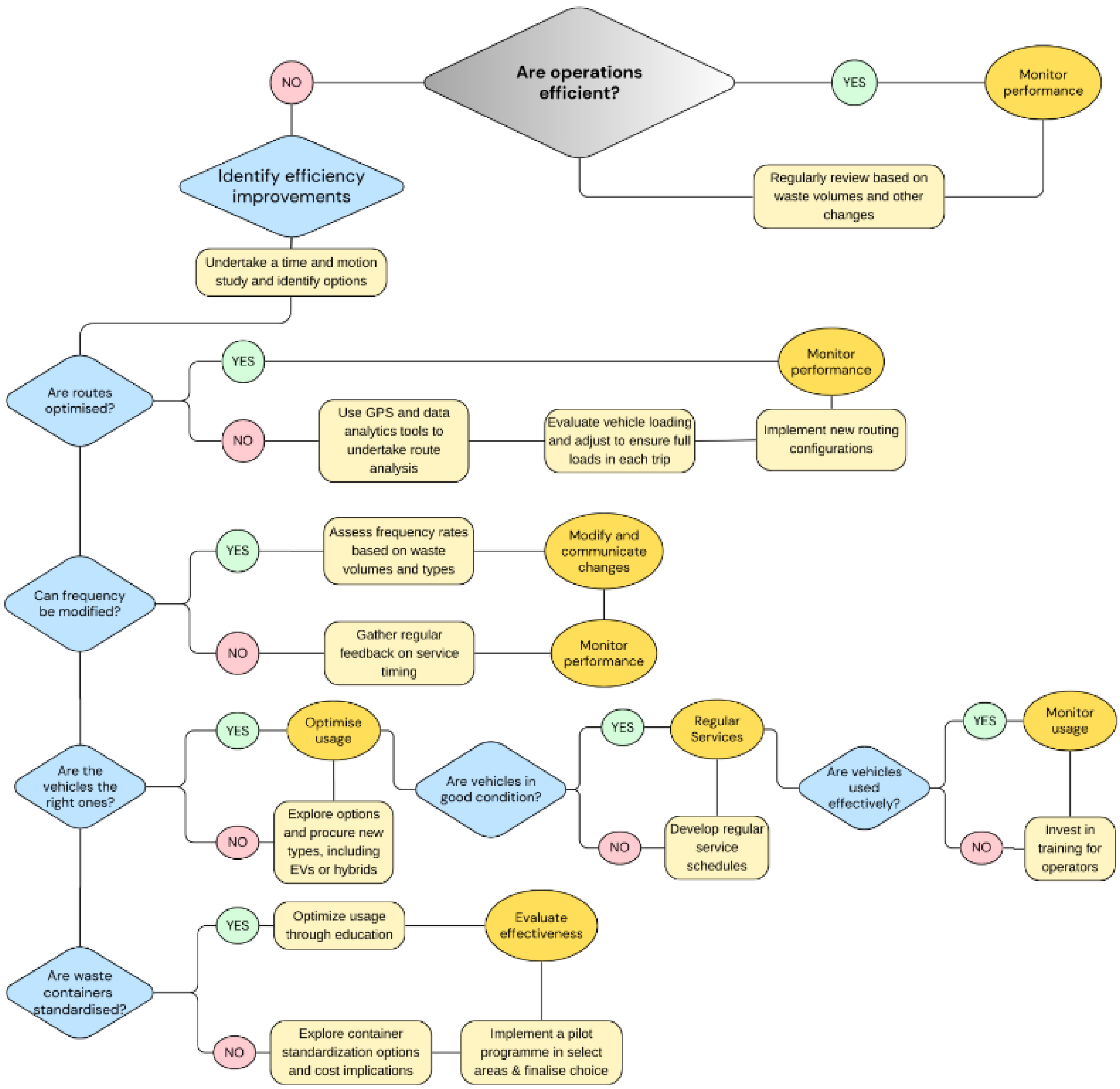
- Local processing is crucial for organic waste, typically through commercial composting facilities or biodigester plants. Due to its high density and weight, transporting organic waste over long distances is neither economically nor environmentally viable.

- Mixed dry recyclables require more complex processing at materials recovery facilities, where materials are sorted into specific streams like paper, plastics, metals, and glass. These materials are then transported to local, regional, or international markets, depending on their value and local recycling capacity. Efficient infrastructure and logistics are critical for moving materials through the supply chain. Further details on processing and transportation logistics are covered in the next section.

Improving Collection Efficiency and Quality

Operating waste collection services is expensive. Typical costs include management, administration, operations, and logistics. However, significant efficiency improvements can be achieved by optimising staff deployment, collection routes and fuel usage, and maintaining equipment. Continuous performance monitoring is essential to identify inefficiencies and implement cost-saving measures. Regularly reviewing and upgrading processes ensures that operational efficiencies are sustained and enhanced over time, contributing to a more cost-effective waste collection system.

Figure 41:
Decision Tree: Improving the Efficiency of Collections



Communications with Customers

Effective communication with customers is crucial for enhancing the quality of waste collection services. Clear and timely information regarding collection schedules, service changes, and recycling guidelines fosters trust and encourages community participation. By actively engaging with customers through feedback mechanisms, waste management providers can identify improvement areas and promptly address concerns. This proactive approach enhances service reliability and promotes responsible waste disposal practices, leading to a cleaner, more sustainable environment.

Route Optimisation

Waste collection systems in the Mekong River Corridor often face inefficiencies due to reliance on driver judgement and manual operations. This dependency can lead to inconsistent collections, missed pickups, and increased operational costs. Optimising routes is essential for minimising travel distances and maximising vehicle capacity, leading to cost reductions, increased efficiency, lower fuel consumption, and decreased carbon footprints while ensuring customer satisfaction.

Technology solutions such as Geographic Information Systems (GIS) and Global Positioning Systems (GPS) play a critical role in this optimisation. GIS aids route planning by modelling road conditions, while GPS allows real-time monitoring of trucks, enhancing operations and reducing unnecessary travel.

Implementing these technologies requires mapping municipal boundaries and training staff. GPS tracking improves customer service by ensuring timely collections and enabling quick responses to unscheduled pickups while promoting safer driving through real-time feedback. Advanced GPS features, along with smartphone apps for notifications and real-time tracking, further enhance service delivery.

Frequency of Collection

To plan the frequency of waste collection, the operator must assess waste generation rates, seasonal variations, and the types of waste. Developing separate collections for different waste types – particularly across disposal waste, dry recyclables, and organic wastes – permits the development of different schedules and frequencies (e.g., organics may need more frequent pickups). It is important to consider population density; urban and high-activity areas require more frequent collections, and this must be balanced with available infrastructure, storage capacity, and budget constraints.

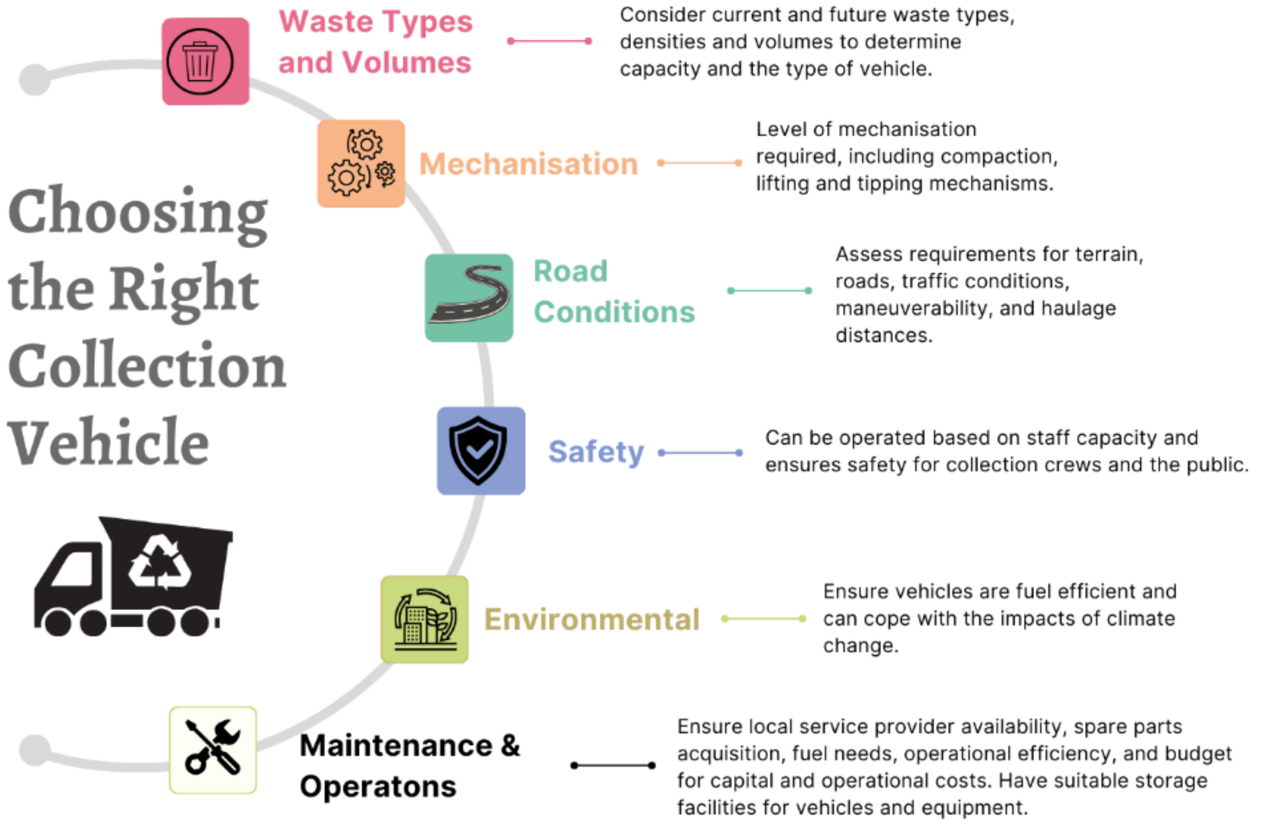
Environmental concerns like minimising fuel use and emissions also play a role. Engage the community to understand their needs and educate them on waste separation to reduce collection frequency. The use of technology is also key in this regard and the planning of frequency should be undertaken in conjunction with route optimisation. Pilot programmes and ongoing monitoring help adjust schedules for maximum efficiency and cost-effectiveness. It is important to gather regular feedback on waste volumes and socio-economic factors so that frequencies and schedules are kept current.

Collection Vehicles

The requirements for vehicles, equipment, and machinery in waste collection focus on cost-effectiveness and efficiency in handling household, commercial, and hazardous wastes. Effective logistics are essential for transporting, storing, and sorting these materials as they move to processing facilities or landfills. Due diligence, including equipment trials, ensures suitability and efficiency before large-scale purchases. Decisions regarding the selection of the vehicles, equipment, and machinery for SWM must be made by experts who thoroughly understand the technical, operational, and financial implications so that inappropriate equipment is not procured.

Each city is unique, and the selection of vehicles and equipment must be tailored to the specific conditions, including capacity (i.e., waste volumes), waste types (i.e., density), mechanisation requirements (i.e., compaction, lifting, and tipping), road conditions and terrain (i.e., dirt roads, steep terrain), safety (i.e., emergency stop buttons), environment (i.e., fuel type), maintenance (i.e., ability to service and get spare parts), and operations (i.e., efficiency).

Figure 42:
Considerations When Choosing a Collection Vehicle



Collection vehicles vary in type, including compactors that densify waste, open trucks, and multi-compartment trucks that enable crews to sort waste during collection. Specialised vehicles and equipment are also essential for handling hazardous and special wastes, featuring safety mechanisms and containment systems. Properly equipping the fleet to handle diverse waste types ensures compliance with safety regulations and minimises environmental and health risks.

Figure 43:
Compaction and Open Waste Collection Trucks

Compactor truck selection should be cautiously approached in many areas of the Mekong River Corridor. These trucks excel at compressing low-density waste, like packaging, to reduce volume. However, using them for high-density waste, such as food waste, can lead to issues due to the high moisture content, which decreases compaction efficiency and lowers carrying capacity. Furthermore, compaction mechanisms require regular maintenance to avoid breakdowns and are susceptible to environmental conditions. Open trucks may be more effective in such scenarios, as they can handle high-density materials without the limitations of compaction systems.

Box 5:
Electric Waste Collection Vehicles

Electric Waste Vehicles are becoming increasingly used in waste collection services. Electric waste collection trucks reduce emissions, contributing to better air quality and lower carbon footprints compared to traditional diesel or gasoline vehicles.

They also have the potential for lower operational costs, as they typically incur fewer fuel and maintenance expenses, and their quieter operation can reduce noise pollution in urban areas.

However, there is a need for extensive and reliable recharging infrastructure. Additionally, electric vehicles may have range limitations on a single charge, which can impact operational efficiency and require careful route planning. The initial cost of electric waste vehicles is also generally higher compared to conventional models.

To successfully integrate electric waste vehicles, it is essential to invest in robust charging infrastructure, develop technical expertise for maintenance and repair, and strategically plan routes to optimise vehicle use and minimise downtime.

Maintenance of Vehicles

Waste collection vehicles and equipment must be durable enough to handle challenging environments. Yet, they are often prone to breakdowns that result in service disruptions. When purchasing equipment, it is crucial to ensure that spare parts are readily available, and that local mechanics are familiar with the specific makes and models. Access to local parts and repair expertise minimises downtime due to mechanical failures, ensuring consistent service delivery and long-term operational efficiency.

Waste collection vehicles are often inefficient in fuel consumption, and poor maintenance exacerbates this problem. Prioritising preventive maintenance over reactive repairs is essential to reduce breakdowns and optimise operational efficiency. Regular servicing extends the lifespan of vehicles and equipment, improves fuel efficiency, lowers overall maintenance costs, and enhances reliability. A proactive maintenance schedule keeps equipment in optimal condition, while maintaining clean, well-presented vehicles projects a professional image. This appearance helps build public trust and confidence in the waste management service, reinforcing the company's commitment to quality and reliability.

Standardisation of Containers for Collection

Many cities in the Mekong River Corridor lack standardised waste containers for households and businesses, leading to inefficiencies in waste handling and increased exposure of collection crews to sharp, hazardous, and infectious waste. Currently, users often provide their own bags and containers, which vary in size, shape, and material, making collection inconsistent and unsafe.

Implementing standardised containers and enforcing their use can significantly improve waste management operations. Crews will be able to anticipate and handle containers more efficiently, reducing the time spent at each collection point. Standardised containers also help manage occupational hazards, as they are designed to minimise direct contact with waste and offer better protection against injuries.

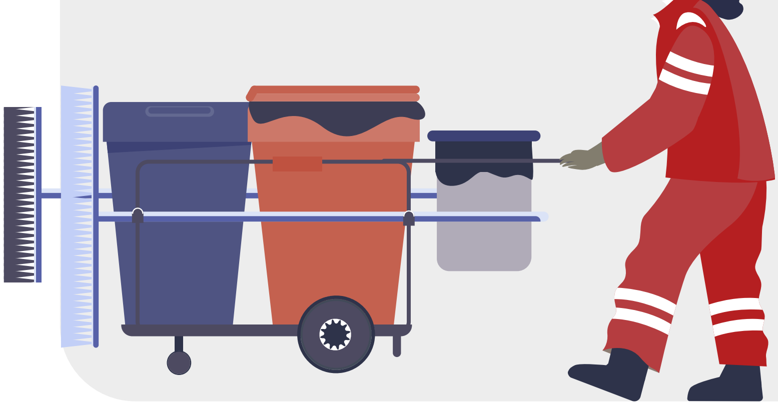
Staff and Capacity Building

Efficient waste collection services depend on a well-structured team, including management, administrative, and operational staff. Management roles typically involve fleet managers, safety officers, financial personnel, fee collectors, customer service representatives, and administrative support. Collection crews generally consist of a driver, who often acts as the supervisor, and at least two additional workers. It is essential to determine the appropriate number of workers per vehicle and clearly define their responsibilities to ensure timely collections. Understaffing or overloading can pose safety risks and increase costs, making effective communication between office and field staff vital, especially with multiple crews operating simultaneously in different areas.

Waste collection is physically demanding and exposes workers to hazards including sharp objects, hazardous waste, heavy loads, traffic, and machinery. Providing personal protective equipment (PPE) such as overalls, gloves, high-visibility clothing, masks, and safety boots is critical.

Proper training in waste handling, lifting techniques, machinery operation, and PPE usage is essential, along with the establishment of clear SOPs. To minimise accidents, collection vehicles should be equipped with safety features such as reversing alarms, cameras, seat belts, and warning signs. Many waste collection crews informally sort recyclables for additional income, which, while common, reduces overall efficiency. High staff turnover often results from the demanding nature of the work, safety concerns, and low pay.

To attract and retain employees, waste companies should offer fair wages, health insurance, paid leave, training, and retirement plans, along with good working conditions including breaks, rest areas, and welfare facilities like showers, especially in the hot climates of the Mekong River Corridor.



Efficient and Convenient Payment Mechanisms

Alongside waste collection services, it is essential to efficiently collect household and business fees. In many cities within the Mekong River Corridor, manual fee collection is still common, which poses significant administrative challenges. This method often requires multiple visits to the same household per month, as many residents are unable to pay the fees immediately, forcing staff to return multiple times. To streamline this process and improve efficiency, the following key aspects should be considered:

Responsibility for Fee Collection

- *Local authorities vs. private companies.* Decide whether the local authorities or private companies should manage fee collection. Local authorities typically have a higher success rate due to their established presence, regulatory powers, and direct connection to the community. Local authority-managed collections also allow a portion of the fees to be allocated to cover broader SWM services and administrative costs.

Volume Based Pricing

- *Flat fee vs. volume-based fee.* Many cities along the Mekong River Corridor use a flat fee for waste collection, where all households and businesses pay the same rate regardless of their waste generation. This fee structure can create inequities, as lower waste producers effectively subsidise heavier users. In contrast, volume-based pricing encourages fairness by charging users according to the amount of waste they produce, promoting waste reduction. A pay-as-you-throw system can facilitate this transition through different-sized wheeled bins or by requiring residents to purchase official waste bags.

Technology Integration

- *Smartphone apps.* Many local authorities are adopting smartphone apps to improve fee collection. These apps facilitate electronic payments, provide real-time transaction tracking, and reduce administrative burdens by eliminating manual processes and notifying the driver of the collection vehicle which houses have paid for the service.

- *Automated billing systems.* Implementing automated billing systems and online payment portals can further streamline fee collection. In some cities, waste collection fees are combined with other utilities, such as electricity or water, reducing administrative overhead and making it easier for households to manage payments.

Operational Efficiency

- *Multiple payment options.* Offering a variety of payment methods through digital platforms increases user convenience, making it more likely that fees will be paid on time.

- *Real-time payment tracking.* Use technology to monitor payments and manage accounts efficiently, reducing the risk of errors and improving collection rates. This approach also allows for immediate follow-up on late payments and ensures better cash flow management.

By focusing on these strategies, local authorities can enhance fee collection efficiency, reduce administrative costs, and improve overall financial management within waste collection systems, ultimately ensuring the sustainability of SWM services.

Costs and Revenue for Waste Collection Services

The costs and revenues of waste collection services in the Mekong River Corridor vary widely based on service type (public or private), operational scale, regional economic conditions, and local regulations. Operational costs typically include labour expenses for waste collection personnel, maintenance of vehicles and equipment, infrastructure upkeep (including transfer stations and sorting facilities), and administrative overhead. These costs can range from $20 to $100 per ton of waste collected, depending on the specific circumstances of each locality. Disposal and processing costs also contribute to overall expenditures, encompassing landfill tipping fees and recycling processing costs. Additionally, compliance with environmental regulations and investment in technology for smart waste collection can further impact operational budgets.

Regarding revenue, waste collection services often rely on user fees, including household and business charges for waste disposal. These fees are set too low in many parts of the region, making cost recovery challenging. Government funding, such as subsidies and grants, can also support operational costs, but these are often limited in the Mekong River Corridor.

Summary of Requirements for Waste Collection

Waste collection requires well-maintained trucks and infrastructure to ensure broad coverage and efficiency. Decentralised collection schemes with smaller vehicles should be introduced in areas that large trucks cannot access. Cost-saving measures such as route optimisation, standardised containers, and appropriate and well-maintained vehicles can boost efficiency.

Public awareness and convenient containers are key to encourage source segregation and separate collections for different materials. Ensuring high service quality, with reliable and well-communicated schedules, will build public trust and foster participation in the system.

Figure 44:
Summary Checklist for the Waste Collection Phase

1 COVERAGE

- Assess waste collection areas and approaches
- Consider use of decentralised waste collection schemes
- Promote waste collection services

2 COLLECTIONS

- Assess demand and benefits of separate collections
- Encourage segregation of waste at source
- Identify end markets for waste of value

3 EFFICIENCY AND QUALITY

- Improve customer service and communications
- Efficient and effective vehicles, equipment and staff
- Efficient and convenient payment mechanisms

Vietnam.
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Stage 3: Sorting Recyclables

Introduction to Issues and Opportunities

What is a Materials Recovery Facility?
An MRF is a specialised facility where recyclable materials are sorted, cleaned, and prepared for further processing. Its primary purpose is to efficiently recover valuable recyclables from the waste stream, reducing the amount of waste that ends up in landfills while supporting resource recovery efforts.

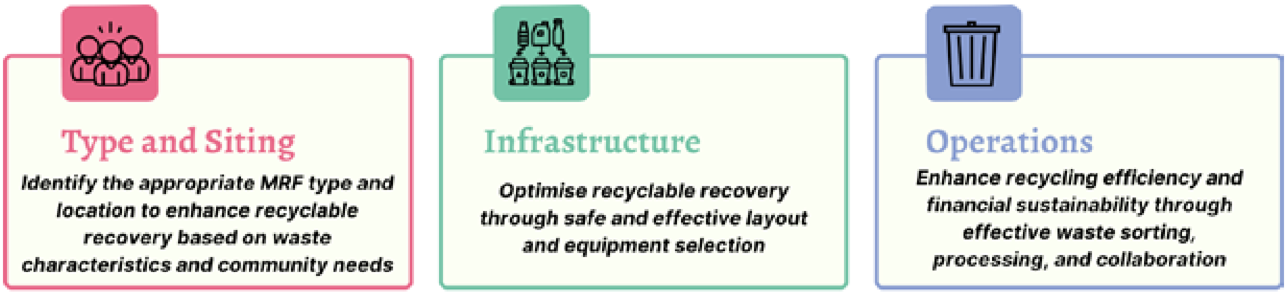
By separating materials, MRFs can recover valuable resources for reuse, reducing the need for raw materials and supporting a circular economy. Different materials such as plastics, metals, paper, and glass each have unique recycling processes, and sorting directs them to the appropriate streams, improving the quality of recycled materials and the prices at which they can be sold. Overall, sorting maximises resource recovery, improves recycling efficiency, and promotes circular economy principles.

Figure 45:
Materials Recovery Facility in Stung Treng, Cambodia

Use of MRFs
Many cities lack MRFs because recyclable collection has been primarily managed by the informal sector, with private buyers, such as junk shops, performing limited sorting after purchasing materials from waste pickers. Establishing a dedicated MRF offers several benefits, including improved recycling rates and efficient sorting, which reduce contamination and increase the value of recovered materials. Additionally, MRFs create economic opportunities and jobs, provide improved working conditions for informal workers, promote environmental sustainability by reducing landfill waste, and enhance community engagement and education on recycling practices. Some cities are beginning to implement MRFs through development projects, often in conjunction with landfill operations, to optimise waste management systems and effectively process recyclables.

At the recyclable sorting stage, cities should focus on three key areas to enhance efficiency, improve material recovery, and reduce contamination (See Figure 46).

Figure 46:
Sorting Recyclables Focus Areas



Case Study: Kaysone Phomvihane City – Savannakhet, Lao PDR

Kaysone Phomvihane City boasts a modern waste management system capable of handling 80–90 tons of garbage daily across a ten-hectare site managed through private sector concessions. The waste segregation efforts produce 20 per cent recyclable waste, with plastic and biological waste forming significant components. A portion of the recyclable waste is procured by companies at the site for plastic pallet production and similar initiatives.

The city has gained international recognition for its waste management efforts. It has been selected for a river plastic reduction project and received ASEAN awards for environmental sustainability and clean tourism. These acknowledgments reflect the

city's commitment to advancing waste management strategies, including youth-led initiatives to foster environmental awareness across schools and villages.


Street in Savannakhet, Lao PDR.
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Types of MRF and Siting Requirements

Types of Materials Recovery Facilities

There are two main types of MRFs:

- A ***clean MRF*** receives mixed recyclables (referred to as co-mingled recyclables) that have already been separated from general waste through segregation at source by waste generators. These MRFs avoid the need for extensive sorting, focusing on further separation and preparation of recyclables based on material type and colour.

- A ***dirty MRF*** receives unseparated solid waste, which includes recyclables, organics, and general waste, all mixed. These MRFs operate in areas where their source separation is not widely practised. Dirty MRFs require much more intensive and complex sorting to extract the recyclable materials. These MRFs tend to result in material streams with higher contamination rates, lower quality and often lower value, though mechanisation can improve processes.

The choice of MRF depends on the budget and whether recyclables are collected separately. Dirty MRFs are less effective than clean ones due to contamination from waste like food or broken glass, which reduces the quality of recyclables and leads to more landfills. As a result, many dirty MRFs are being converted to clean MRFs worldwide.

Clean MRFs can be single- or dual-stream. Single-stream systems combine all recyclables in one bin, making it easier for users but increasing contamination. Dual-stream systems require households to sort recyclables, resulting in cleaner, higher-value materials but requiring more effort from the community.

Other types of specialised MRFs process different wastes, such as construction, demolition, and electronics. Some also produce Refuse-Derived Fuel (RDF) by removing dry recyclables and extracting high-calorific materials such as mixed plastics and treated timber. These are shredded or pelletised into combustible material used as a substitute for fossil fuels in cement kilns, power plants, and industrial furnaces, which require special equipment to minimise pollution and emissions.

Automation and Efficiency in MRFs

MRFs vary in size and complexity, from large, automated facilities to basic ones relying on manual sorting. The choice between automation and manual methods depends on start-up costs, material volume, market demand, and labour availability.

Automated MRFs use equipment such as optical scanners for sorting by colour, shape, and composition; shredders to break down materials; air classifiers for separating lightweight from heavy items; magnetic separators for ferrous metals; and eddy current separators for non-ferrous metals. Basic MRFs rely mostly on manual labour, with workers sorting materials along conveyor belts.

All MRFs generate residue from non-recyclable or contaminated materials, which is typically sent to landfills. MRFs are increasingly exploring strategies to minimise residue generation to address this challenge, including refining sorting technologies and enhancing community education on proper waste separation. Some collaborate with waste-to-energy plants to convert residue into energy.

Siting Considerations

When locating an MRF, various environmental and socio-economic factors must be considered. Key aspects include the facility's proximity to recyclable material sources for cost-effective transport, compliance with zoning laws and environmental regulations, and community engagement for local support. The site should offer access to essential utilities, ample space for operations and future expansion, and traffic volumes to ensure safety and security. Integrating the MRF with existing waste management operations, such as landfills, second-hand outlets, composting and recycling centres, can further enhance efficiency and reduce costs. MRFs should be located at a safe distance from sensitive areas such as schools, hospitals, and cultural and ecological sites. Noise, dust, traffic, and environmental impacts must be carefully managed. Effective leachate management is essential, and MRFs should be located in stable, flood-free areas with proper drainage systems.

Figure 47:
Considerations When Siting a Materials Recovery Facility

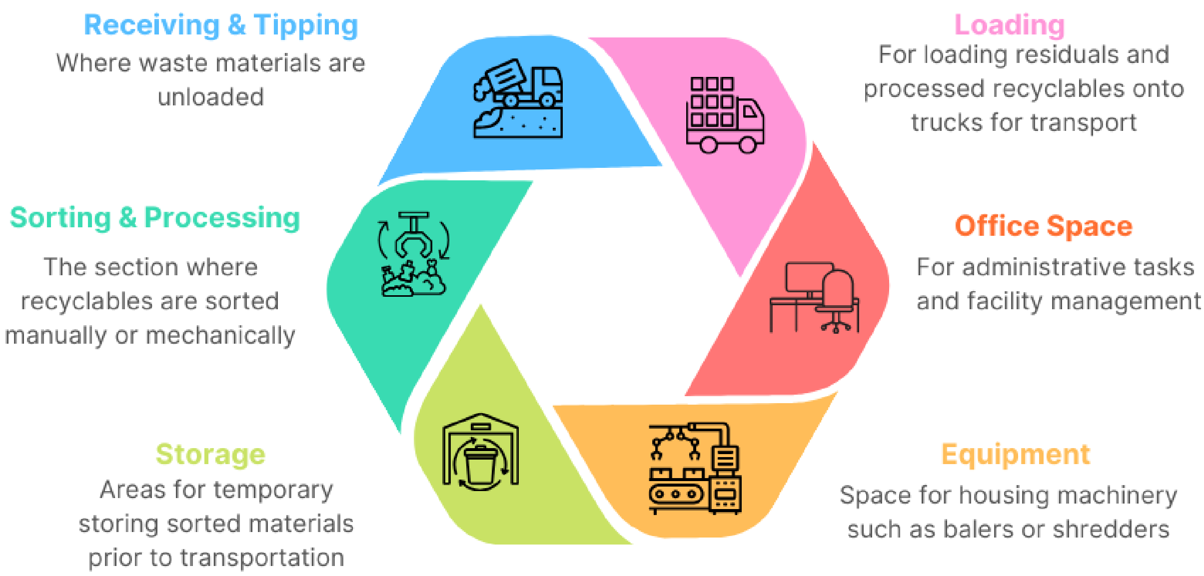
To determine the size of an MRF, consider waste volumes, processing capacity, and storage needs, allowing space for future expansion as waste increases. Manually operated MRFs handling less than 2 tons per day (tpd) require around 50 m^2 of covered space. As mechanisation increases, space needs also grow. According to the Asian Development Bank,[12] semi-automated and fully mechanised MRFs require between 150 and 1,500 m^2, excluding parking and buffer areas. Smaller MRFs processing up to 10 tpd need about 1,400 m^2, while larger ones handling up to 100 tpd require around 1,800 m^2.

12 https://www.adb.org/publications/materials-recovery-facility-tool-kit.

Infrastructure for a Materials Recovery Facility

A typical MRF operates within a warehouse-type building with concrete flooring, enclosed by a perimeter fence for security. The facility generally includes a receiving and tipping area, sorting and processing area, storage areas, equipment area, office space, and a loading area.

Figure 48:
Areas Within a Materials Recovery Facility



The facility requires water, electricity, waste truck access, washing provisions, and a septic tank. The warehouse design minimises columns for efficient movement and allows for high ceilings. The receiving area should handle at least two days' worth of material.

Figure 49:
Sorting Bays in a Materials Recovery Facility in Kratie, Cambodia

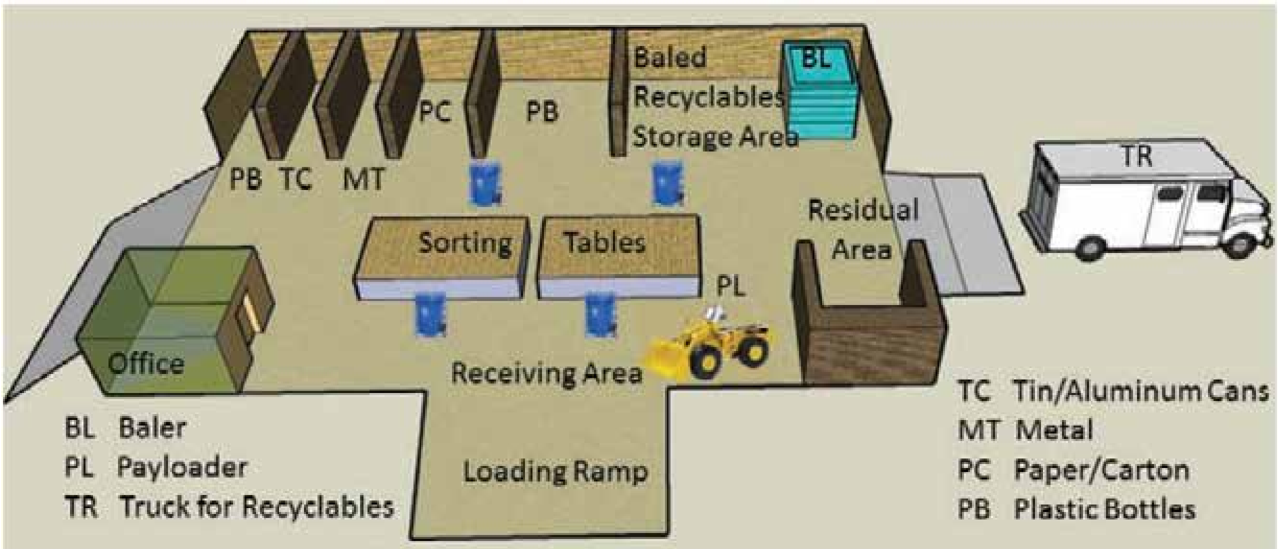
The Layout of the Facility

To ensure operational efficiency and safety, the following criteria should guide the design of the MRF layout:

- **Material flow.** A smooth flow from receiving to sorting, processing, and storage is essential to minimise handling and transport costs.
- **Designated zones.** Separate areas for different functions help prevent cross-contamination and improve workflow. Secure zones should be included for dismantling and inspecting hazardous, electronic waste.
- **Space for equipment.** Adequate room is needed for machinery such as balers, shredders, and conveyors, as well as space for maintenance.
- **Safety features.** Clear pathways for workers and vehicles, proper signage, first aid stations, and emergency exits are essential.

Planning for future expansion is also important to accommodate increased waste processing and storage. Environmental considerations should be incorporated, such as drainage for leachate management and controls for noise, pests, and odours.

Figure 50:
Layout of a Materials Recovery Facility



Source: Asian Development Bank, 2013.[13]

Equipment in a Materials Recovery Facility

MRF equipment varies based on the facility's automation level, affecting investment, operational costs, and capacity. Equipment needs depend on budget, waste volume, and whether recyclables are pre-sorted. Manual and mechanised MRFs require sorting, processing, and handling machinery. Additional equipment is needed for storage and transport preparation. Equipment choices are also influenced by space, workforce availability, and future waste management demands. For a basic MRF, it would be useful to have conveyors or sorting lines for manual waste sorting, tilt carts, floor scales, and a baler for densifying waste.

13 https://www.adb.org/publications/materials-recovery-facility-tool-kit.

Table 3:
Potential Equipment for a Materials Recovery Facility

Item	Function
Feeder Hopper	Regulates the flow of deposited waste onto the conveyor system.
Conveyors	Transport waste through sorting areas.
Sorting Lines	Flat conveyors that allow for waste to be manually sorted.
Trommel Screens	Separate materials by size.
Vibrating Screens	Sort waste by size.
Magnets	Remove ferrous metals.
Eddy Current Separators	Remove non-ferrous metals.
Optical Sorters	Identify and sort materials by colour and type.
Air Classifiers	Separate light materials from heavier items.
Glass Crushers	Break glass into smaller pieces for recycling or reuse.
Tilt Carts	Manual carts on wheels for placing sorted recyclables.
Balers	Compress recyclables for easy storage and transport.
Shredders	Break down large items like plastic and metal.
Forklifts/Loaders	Move materials within the facility and load them onto trucks.
Dust Control Systems	Maintain air quality.
Weighing Scales	Measure incoming and outgoing waste.
Water & Waste Systems	Clean materials and manage waste.

Safety in Materials Recovery Facilities

Safety is paramount in MRFs to protect workers and ensure a secure environment. Key safety measures include:

- **Emergency stop buttons:** For quickly halting machinery in emergencies.
- **Guardrails and barriers:** To prevent falls and protect workers from moving machinery.
- **Ergonomic design:** Reduces strain from repetitive tasks and heavy lifting.
- **Dust control systems:** Ventilation and suppression systems maintain air quality.
- **Fire safety:** Includes extinguishers, alarms, and sprinklers for fire prevention and response.
- **Accessible first aid:** Ensure first aid stations are available with trained responders on-site.
- **Lighting and noise control:** Improves visibility and protects workers from hearing damage.
- **Clear safety signage:** Warns of hazards and marks emergency exits.
- **Hygiene facilities:** Provide clean washrooms, showers, changing rooms, and eating areas for all staff.

Workers should be equipped with appropriate **personal protective equipment (PPE)** such as gloves, goggles, helmets, steel-toe boots, and respiratory gear. They must be trained in PPE use, maintenance, and replacement. Emergency procedures, first aid, and handling of hazardous waste should also be regularly taught, ensuring at least one trained staff member is on-site at all times.

Environmental Controls

Environmental controls minimise the impact of MRFs on air, land, and water pollution. Key measures include:

- **Dust control:** Ventilation and suppression systems for maintaining air quality.
- **Water management:** Effective drainage and wastewater treatment prevent local water contamination.
- **Noise control:** Barriers and soundproofing mitigate noise pollution.
- **Odour and pest control:** Ventilation systems reduce smells, and pest control prevents infestations.
- **Wastewater treatment:** Proper protocols ensure the safe handling of wash water.
- **Energy efficiency:** Use energy-efficient equipment and renewable sources.
- **Hazardous material handling:** Strict protocols for safely managing hazardous substances protect workers and the environment.

Maintenance and Repairs

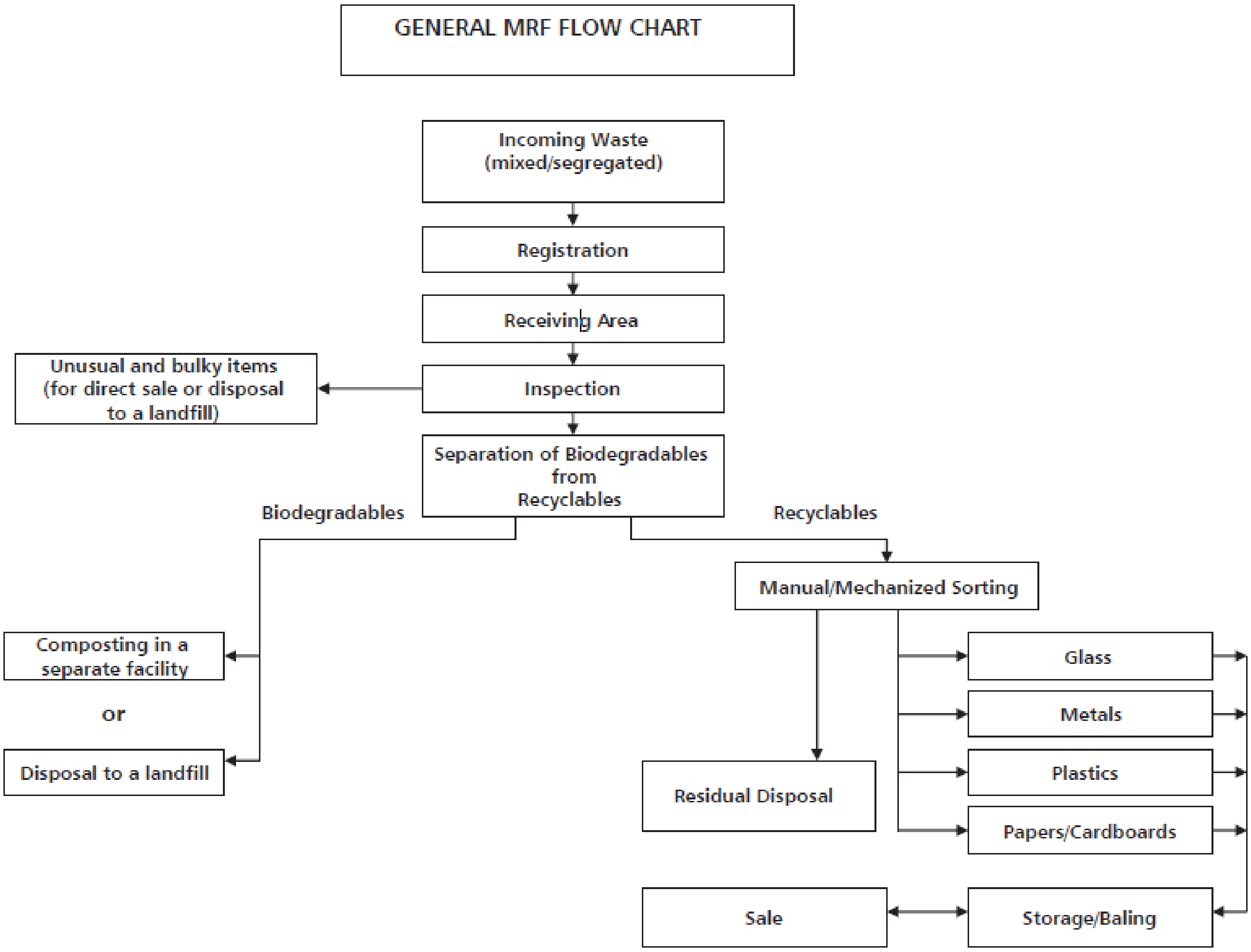
A comprehensive preventive maintenance plan and regular inspections are vital to minimise downtime in MRFs. Skilled technicians should be available to handle quick repairs, adhering to safety protocols, while easy access to spare parts ensures timely repairs. Effective budget planning is essential to cover routine and emergency repairs, preventing operational disruptions. Waste management systems should also be in place to handle materials during equipment downtime, avoiding backlogs. Regular facility evaluations are crucial to ensure safety, efficiency, and compliance, prolonging equipment life and optimising processing capacity. This approach promotes smooth operations, enhances worker safety, and supports environmental protection in MRFs.

Operations in a Materials Recovery Facility

Operational Processes

MRF operations begin with registering, inspecting, and accepting mixed or segregated waste in a designated receiving area. Before tipping, all incoming waste undergoes a visual check to ensure compliance with waste acceptance policies and to identify any contamination or hazardous waste. Once accepted, the waste is deposited on the tipping floor, where bulky or unconventional items are removed for disposal or sent to specialised recycling facilities. The remaining waste is transferred onto conveyor systems, sometimes using a feeder hopper to regulate the flow of materials onto the sorting line. In simpler MRFs, sorting may be done on tables instead of conveyors.

Figure 51:
Materials Recovery Flow Chart



Source: Asian Development Bank, 2013.

For source-segregated waste, valuable recyclables such as paper, cardboard, tin cans, metals, plastics (like PET and PP), and glass are manually or mechanically sorted. Sorting is generally done in two ways:

- **Positive sorting:** Workers focus on removing specific recyclable materials, which leads to higher-quality, less contaminated recyclables.
- **Negative sorting:** Workers remove non-recyclable items from the mixed stream, often resulting in higher contamination rates.

Recovered materials are moved to storage bays using carts or similar equipment and then processed according to buyer specifications, which may include removing caps, washing, or compacting with balers. Plastics are sometimes shredded for easier processing. All materials are weighed before transport to buyers, while residuals are temporarily stored before disposal or repurposed as fuel. Records of incoming and outgoing waste quantities must be maintained throughout the process to monitor the facility's mass balance.

Inclusion of Informal Workers

Informal workers can significantly enhance recycling efficiency and support sustainable livelihoods. Formalising them involves recognising their contributions, providing training and PPE, promoting a supportive work environment, and providing fair compensation. It is also an opportunity to empower women, who are a vital part of informal waste picking, and involve them in decision making.

Informal waste pickers, often working in hazardous landfill conditions, can significantly enhance MRF operations while improving their livelihoods. Transitioning them to MRFs increases safety compared to exposed dumpsite and landfill environments. Including these workers in formal collection activities managed by MRF operators is also beneficial.

Many waste pickers prefer flexible work arrangements due to other seasonal jobs like agriculture. Addressing concerns about machinery use is essential, ensuring proper training and suitable roles. Collaborating with development partners experienced in training informal waste pickers can facilitate this transition.

Formalising informal workers involves recognising their contributions through uniforms, job titles, and formal agreements, reducing stigma and emphasising their environmental importance.

Training on sorting, safety, and health standards is vital, along with providing PPE and enforcing its proper use. Welfare facilities promote a supportive work environment, including gender-specific toilets and showers, safe childcare, and healthcare access. Fair compensation, through wages or revenue-sharing from recyclables, boosts morale and motivation, leading to a more efficient workforce. This integration enhances recycling efficiency and supports sustainable livelihoods.

Women, who play a vital role in informal waste picking, face unique challenges such as gender discrimination and limited resources. Targeted training and support programmes can empower them, while equal opportunities and safe working conditions in MRFs enhance their participation and promote gender equity. Involving women in decision-making and leadership roles can lead to more effective waste management strategies that address the needs of all workers.

Floating market with colourful produce on the Mekong River.

Collaboration with Collection Service Providers

MRFs should work closely with waste collection companies to ensure smooth operations. Aligning collection schedules optimises waste flow, reduces delays, and enhances efficiency. Collaboration on sorting guidelines and contamination prevention helps maintain the quality of recyclables. Sharing data on waste volumes and contamination rates improves operational efficiency, while clear communication and feedback systems allow for continuous improvement. Training collection staff in proper waste handling reduces contamination, and joint route planning improves logistical efficiency. Clear contracts that define roles and expectations ensure seamless collaboration.

Market Requirements for Recyclable Materials

Establishing reliable markets for recyclable materials is crucial for MRF success. Building strong relationships with buyers ensures that sorted recyclables are efficiently processed into new products. Understanding market demand and price volatility helps maintain profitability. Efficient transportation, especially for heavy materials, is essential for competitiveness. Quality control is key. MRFs must clarify preprocessing requirements with buyers, such as removing bottle labels or baling materials. Investing in advanced technology and training can improve sorting accuracy, as contaminated recyclables may be rejected or sold at lower prices. Keeping updated with certifications and standards is also important.

Diversifying end markets helps mitigate risks from price fluctuations. Processing a wider range of materials and forming partnerships with various industries ensures stable revenue streams. Regular communication with buyers and research on global recycling trends is essential. Balancing local and international markets is important; local markets offer lower transportation costs, while international markets may offer higher prices. However, trade agreements and regulations like the Basel and Stockholm Conventions impose strict export requirements, complicating cross-border trade.

In the circular economy, it is crucial to maintain materials at their highest value. Creating markets for high-value applications and minimising downcycling support sustainable practices and boost revenue. This strategic market development ensures MRFs remain economically viable and contribute to effective waste management.

Operational Costs and Revenue at MRFs

Operational costs at MRFs include:

- **Salaries:** For operations, maintenance, administration, and security personnel.
- **Utility bills:** Covering electricity and water usage.
- **Fuel and oil:** For machinery and vehicles.
- **Equipment and facility maintenance:** To ensure longevity and optimal performance.
- **Supplies:** For daily operations, such as cleaning and safety materials.
- **Residual/biodegradable waste disposal:** For managing non-recyclable waste.
- **Facility depreciation:** Reflecting wear and tear over time.

In manually operated MRFs, a supervisor manages utility workers whose numbers depend on the volume of waste. Workers sort recyclables, weigh materials, and load residual waste into collection vehicles. Sorters typically receive a fixed wage plus bonuses based on recovered recyclables to boost productivity.

In semi-automated and fully mechanised facilities, labour costs are lower, but skilled personnel are required to operate and maintain equipment, limiting informal sector workers' use. These facilities employ dedicated staff for operating, sorting, weighing, and recording equipment and security and facility management roles.

Annual operating and maintenance (O&M) costs are generally estimated at 5 per cent to 10 per cent of the initial investment. Effective cost management and optimising revenue streams, such as selling processed recyclables, charging waste processing fees, and forming partnerships with local governments and businesses, can enhance an MRF's financial sustainability.

Summary of Requirements for Sorting Recyclables

MRFs are essential for sorting, cleaning, and preparing recyclable materials, enhancing resource recovery and promoting a circular economy.

MRFs reduce landfill waste and increase the quality and market value of recycled materials by efficiently separating materials such as plastics, metals, paper, and glass.

However, many cities still rely on the informal sector for recycling, highlighting the need for dedicated MRFs to improve recycling rates and create economic opportunities.

Various MRFs exist, including clean and dirty facilities, each with specific siting requirements and operational considerations. Implementing effective sorting, automation, and safety measures can significantly enhance MRF efficiency and environmental performance.

Figure 52:
Summary Checklist for the Sorting Recyclables Phase

1 TYPE AND SITING

- Identify type: dirty or clean MRF
- Determine the level of automation
- Undertake siting assessment

2 INFRASTRUCTURE

- Design the facility and layout based on type and volume
- Procure equipment based on level of automation
- Incorporate safety mechanisms & environmental controls

3 OPERATIONS

- Incorporate informal workers into workforce
- Collaborate with waste collection service providers
- Develop and diversify end markets

Stage 4: Reprocessing

Introduction to Issues and Opportunities

Types of Reprocessing

In a **circular economy**, reprocessing reduces waste and reintroduces materials into production, conserving resources, reducing pollution, and creating jobs. Reprocessing extends the life of waste materials and reduces environmental impact. It includes **reuse**, **remanufacturing**, **repair**, and **recycling**:

- **Reuse:** Using products for new applications with minimal changes.
- **Remanufacturing:** Refurbishing products to like-new condition, replacing parts as needed.
- **Repair:** Fixing damaged items to extend their lifespan and reduce waste.
- **Recycling:** Converting waste into raw materials for new products.
- **Upcycling:** Creates higher-value products from waste.

In the **biological cycle**, organic materials are processed for new uses. **Composting** turns food and garden waste into soil amendments or biogas. **Anaerobic digestion** breaks down organic matter to produce energy and fertiliser. This process captures energy and enhances agricultural productivity.

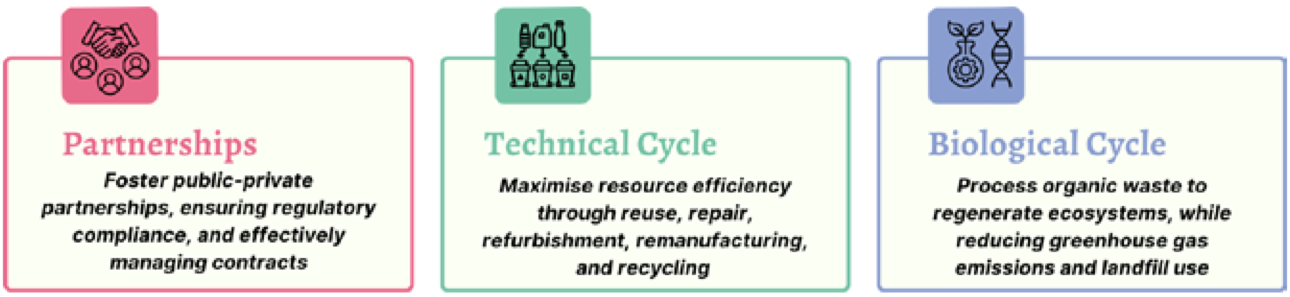
Approaches for Reprocessing

Private investment is key to reprocessing. However, it faces challenges in the Mekong River Corridor, such as unclear regulations, inconsistent policies, and inadequate infrastructure. To encourage investment, it is essential to enhance SWM through better waste segregation, increased community participation, improved collection methods, and the development of MRFs. Supportive policies, including subsidies and tax breaks, can also foster private sector growth.

Municipalities can create a more attractive investment environment by demonstrating effective waste management practices and providing high-quality segregated materials. This approach facilitates the transition to a circular economy where resources are efficiently reused and recycled. Cities should focus on partnering with the private sector, maximising resource efficiency, and processing organic waste to reduce environmental impact.

At the reprocessing stage, cities should focus on three key areas to promote a circular economy by partnering with the private sector, maximising resource efficiency, and processing organic waste to reduce environmental impact (See Figure 53).

Figure 53:
Reprocessing Focus Areas



Partnerships Between Sectors

Governments play a key role in developing waste processing infrastructure by establishing public-private partnerships (PPPs), setting local strategies, creating investment plans, ensuring regulatory compliance, managing contracts, and promoting behaviour change through education. They also provide incentives and technical support to encourage private sector investment, ensuring that waste facilities meet environmental and sustainability standards through effective monitoring and contract management.

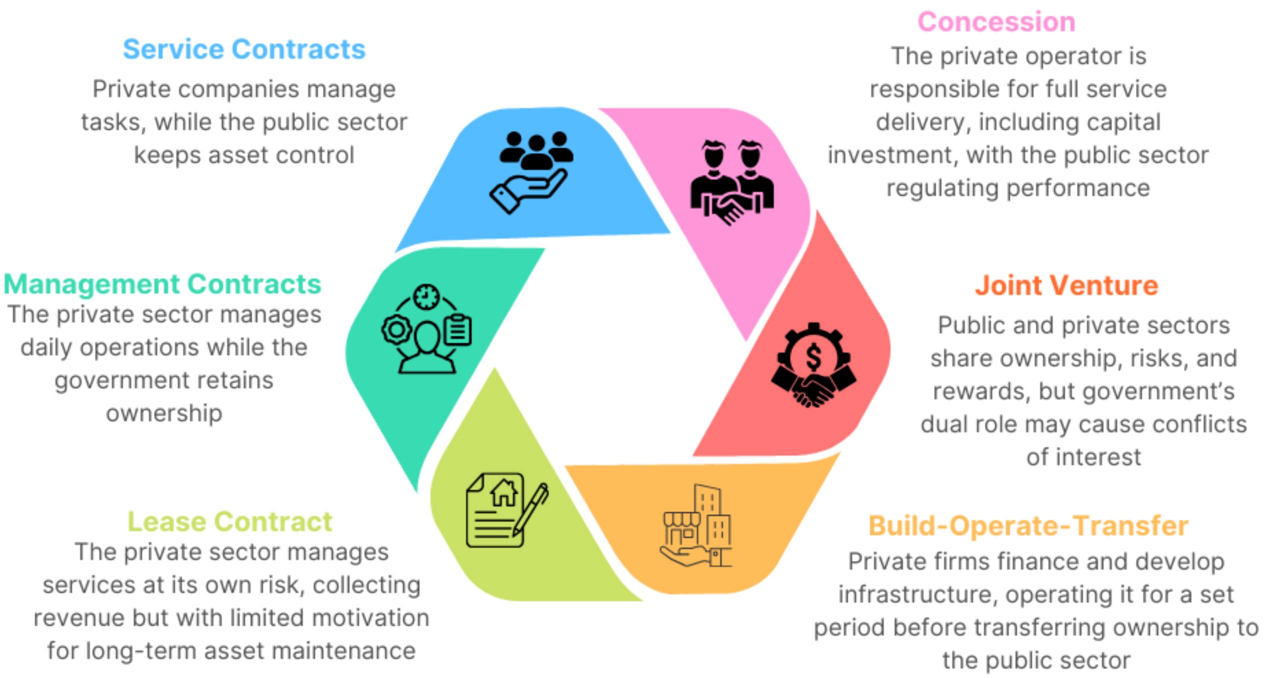
Public-Private Partnerships

Public-private partnerships are collaborations between public and private entities, often used in sectors like water and sanitation, to share responsibilities, risks, and benefits. PPPs aim to improve efficiency, accountability, and private-sector investment. While private involvement can enhance cost-effectiveness, balancing public and private objectives is important. Successful PPPs require clear roles, strong government oversight, and considerations of factors such as cost recovery, efficiency, and public accountability. Common models include service contracts, concessions, and joint ventures.

Governments typically consider PPPs for several key reasons:

- **Improving efficiency and service delivery.** PPPs enhance services like waste management by allowing private operators to focus on cost-efficiency, while the government handles regulation and supervision.
- **Attracting private investment.** PPPs bring in private capital to fund infrastructure development, alleviating the financial burden on governments.
- **Reforming sectors.** PPPs help restructure roles, improve incentives, and enhance accountability, driving broader sector reforms.

Figure 54:
Common Public-Private Partnerships



Contracts Management

Effective contract management between local governments and private sector partners is vital for successful SWM processing plants. Clear agreements should define responsibilities, reporting, performance expectations, and key performance indicators (KPIs) to measure efficiency, compliance, and environmental impact. To ensure accountability, governments must set KPIs for waste processing volumes, recycling rates, and safety standards. Regular reporting and performance reviews foster collaboration, helping address challenges and optimise operations. Strong contractual relationships enable better service delivery, regulatory compliance, and sustainable waste management.

Regulation

Local governments play a crucial role in waste processing by establishing and enforcing regulations and environmental management systems related to the development and operation of waste processing facilities. In the Mekong River Corridor, many unregulated waste facilities pose significant risks, leading to potential land, air, and water pollution while operating with inadequate safety measures – raising health concerns for both staff and local communities. As numerous countries work to develop regulations for these facilities, local governments need to collaborate with the private sector to ensure environmental impacts are minimised and public health is prioritised. This partnership can lead to establishing best practices, compliance monitoring, and implementing advanced technologies to enhance waste processing.

Technical Cycle

The technical cycle in a circular economy focuses on keeping products, components, and materials in use as long as possible through reuse, repair, refurbishment, remanufacturing, and recycling. In SWM, this promotes resource efficiency and reduces the need for raw materials. Rather than discarding products, materials are recovered and reintroduced into production. This approach reduces environmental impact and creates economic value through job creation and resource preservation.

Reuse

Reuse is key to sustainable manufacturing as it reduces demand for raw materials and minimises waste. Reuse extends product life, conserves resources, and lowers environmental impact in industries like packaging, construction, and electronics. Governments can support reuse by implementing extended producer responsibility, offering business incentives, and establishing reuse standards. Public awareness campaigns, reuse in public procurement, and developing repair/refurbishment infrastructure further promote the circular economy.

Repair, Refurbishment, and Remanufacturing

Governments can encourage these practices through tax incentives, subsidies, and Right-to-Repair laws, ensuring access to parts and tools. Promoting public procurement of refurbished goods and EPR programmes can extend product lifecycles. Public awareness campaigns and vocational training are also essential to support these industries and shift consumer behaviour towards repair and refurbishment over replacement.

Mechanical Recycling

Mechanical recycling involves recovering materials like plastics, metals, and glass without altering their chemical structure. Waste is collected, sorted, cleaned, and transformed into raw materials. Types of recycling plants include:

- **Plastic Recycling:** Shredding and pelletising plastic waste into new raw materials.
- **Metal Recycling:** Shredding and smelting ferrous and non-ferrous metals for reuse.
- **Glass Recycling:** Crushing and sorting glass before melting it to make new products.
- **Paper Recycling:** De-inking and pulping paper waste to create new paper products.

Chemical Recycling

Chemical recycling breaks down plastic waste into chemical components, making it reusable for new products. Unlike mechanical recycling, it uses chemical reactions to depolymerise plastics, which is useful for hard-to-recycle plastics. Though energy-intensive and still developing, chemical recycling holds the potential for producing higher-quality materials.

Pyrolysis

Pyrolysis is a thermochemical process that decomposes organic materials like plastics and biomass at high temperatures without oxygen. It produces solid char, liquid bio-oil, and gaseous syngas, all of which have valuable uses. While pyrolysis reduces waste and recovers resources, it requires high energy input and careful management to maximise benefits and minimise environmental impact.

Biological Cycles

The biological cycle in a circular economy focuses on returning organic materials to nature through composting and decomposition, regenerating ecosystems. In the Mekong River Corridor, organic waste, mainly food and garden waste, makes up 40 to 70 per cent of total waste. When landfilled, it takes up space and generates methane, a potent greenhouse gas. Managing this waste through composting and biogas generation reduces disposal costs and creates revenue. Due to the volume and weight of organic waste, processing usually needs to be close to its source.

Composting

Composting is an aerobic process that converts organic materials like food scraps and garden waste into nutrient-rich compost. Microorganisms, along with larger decomposers, break down the organic matter. The right balance of oxygen, moisture, and temperature speeds up decomposition. While some compost at home, municipal-scale organic waste requires commercial composting approaches. There are various commercial approaches to composting, as shown in Box 6.

Biodigesters

Anaerobic digestion breaks down organic waste in an oxygen-free environment, producing biogas and bio-slurry. Biogas can be used for cooking, heating, or electricity, while bio-slurry serves as organic fertiliser. Anaerobic digesters range from large industrial units to small household systems, offering a sustainable way to manage food waste, manure, and other biodegradable materials.

Box 6:
Approaches to Composting

Windrow composting is a large-scale method of recycling organic waste by arranging it in long rows (windrows) and turning the piles to maintain oxygen flow and temperature. It is cost-effective and scalable, making it ideal for municipal or agricultural waste. The process encourages microbial activity, decomposing waste in three to six months, with temperatures of 55–70°C to kill pathogens and weed seeds. While it is simple to operate and produces high-quality compost, windrow composting requires significant space, equipment for turning, and regular management to control odours, pests, and ensure efficient decomposition.

Windrow composting. Source: [Biotech Solution](#).

Static pile composting. Source: [Waste Advantage](#).

Static pile composting involves loosely stacking organic waste and allowing it to decompose without turning. Bulking agents like wood chips are added to ensure airflow and oxygenation for microbial activity. While it is lower maintenance than windrow composting, decomposition takes longer. Some systems use pipes to blow air through the pile, speeding up the process. This method is suitable for large volumes of organic waste in areas with limited space, but moisture and airflow must be carefully monitored to prevent odours.

In-vessel composting involves placing organic waste in a sealed container, such as a drum or silo, where temperature, moisture, and airflow are controlled to accelerate decomposition. This method is faster than other composting techniques, with processing times from a few days to several weeks. It handles various waste types, including food waste and even nappies, but often requires further stabilisation after initial processing. In-vessel composting is highly efficient and ideal for areas with limited space.

In-vessel composting. Source: [Global Composting Solutions](#).

Summary of Requirements for Sorting Recyclables

Reprocessing converts waste into new products, reducing environmental impact and supporting a circular economy. It includes practices such as reuse, remanufacturing, repair, and recycling. Reuse involves repurposing items with minimal alteration, while remanufacturing restores products to like-new condition. Recycling transforms materials like plastics, metals, and paper into new raw materials.

Biological processes like composting and anaerobic digestion break down organic waste, producing compost and biogas. Public-private partnerships, regulation, and effective contract management are key to fostering private-sector investment in reprocessing, particularly in regions with infrastructure and regulatory challenges.

Figure 55:
Summary Checklist for the Reprocessing Phase

1 PARTNERSHIPS
- Establish public-private partnerships
- Manage contracts effectively
- Enforce regulations

2 TECHNICAL CYCLE
- Implement Extended Producer Responsibility
- Support infrastructure development
- Invest in advanced technologies

3 BIOLOGICAL CYCLE
- Implement policies to separate organic waste
- Support infrastructure development
- Invest in advanced technologies

Stage 5: Waste Disposal

Introduction to Issues and Opportunities

Introduction to Disposal

Disposal is the least preferred option in the waste management hierarchy and should only be used when all other strategies (e.g., reduction, reuse, recycling, and recovery), are fully utilised. While effective disposal minimises environmental and health risks, it is costly and resource-intensive, making it crucial to prioritise more sustainable methods earlier in the waste cycle.

Dumpsites

In the Mekong River Corridor, much waste has historically been dumped in unmanaged open sites, causing environmental damage, fire hazards, and methane emissions. These sites lack pollution control, such as waste compaction or use of cover, leading to soil and groundwater contamination. Dumpsites are now considered unsustainable, with many regions transitioning to engineered landfills or waste-to-energy facilities, though these require significant international funding.

Landfills

Sanitary and controlled landfills differ mainly in protection and management. Sanitary landfills are engineered sites with advanced systems – including liners, leachate collection, gas management, and daily waste covering – to minimise environmental impact and protect groundwater. They also feature odour control and regular monitoring. In contrast, controlled landfills use basic practices like occasional covering and simpler liners that offer less environmental protection. Informal waste pickers typically access controlled landfills, while sanitary landfills restrict access for safety reasons.

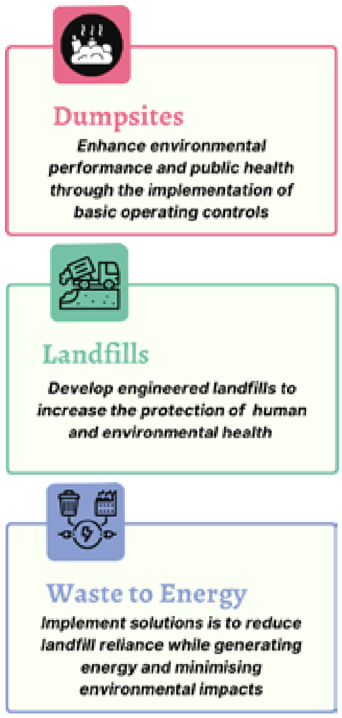
Sanitary landfills have higher operational costs due to their comprehensive safeguards. In the Mekong River Corridor, the challenge lies in the high expenses of engineered landfills. Although dumpsites incur minimal costs, engineered landfills require significant spending on fuel, staff wages, and utilities. Local authorities often struggle with these ongoing costs, as their budgets are unprepared for such expenses. Establishing sustainable revenue streams across the SWM system is essential, yet covering these operational costs remains a significant challenge in the region.

Waste-to-Energy

Waste-to-energy converts non-recyclable waste into electricity, heat, or fuel through incineration, gasification, or anaerobic digestion. It reduces landfill use and provides renewable energy but still produces greenhouse gases like carbon dioxide. While waste-to-energy helps manage waste and displace fossil fuel use, it requires balancing its benefits with concerns about emissions and public perception to be integrated effectively into waste management.

At the disposal stage, cities should focus on three key areas to enhance environmental performance and protect human health (Figure 56).

Figure 56:
Disposal Focus Areas



Developing Landfills

Siting of Landfills

The location of a new landfill is crucial for minimising environmental and human health risks. Poorly sited landfills can cause significant harm to both the environment and nearby communities. In many Mekong River Corridor cities, landfills have been placed on unsuitable, cheap land due to a lack of comprehensive assessments.

Figure 57:
Potential Negative Impacts from Landfills

A proper siting assessment should include environmental and socioeconomic surveys and consultation with local communities.

A preliminary **economic assessment** must compare development and operational costs, including land acquisition, design, construction, and management while factoring in revenue sources like tipping fees. Post-closure aftercare costs must be included to ensure financial sustainability.

A **geological survey** ensures the site's suitability for containing leachate and landfill gas. Natural impermeable soils, such as clay, are ideal, though not all clay soils are suitable due to potential shrinkage and cracking. Permeable soils like sand or gravel should be avoided unless synthetic liners are used. The survey should also assess the availability of on-site materials for lining and other infrastructure needs, as sourcing off-site materials increases costs.

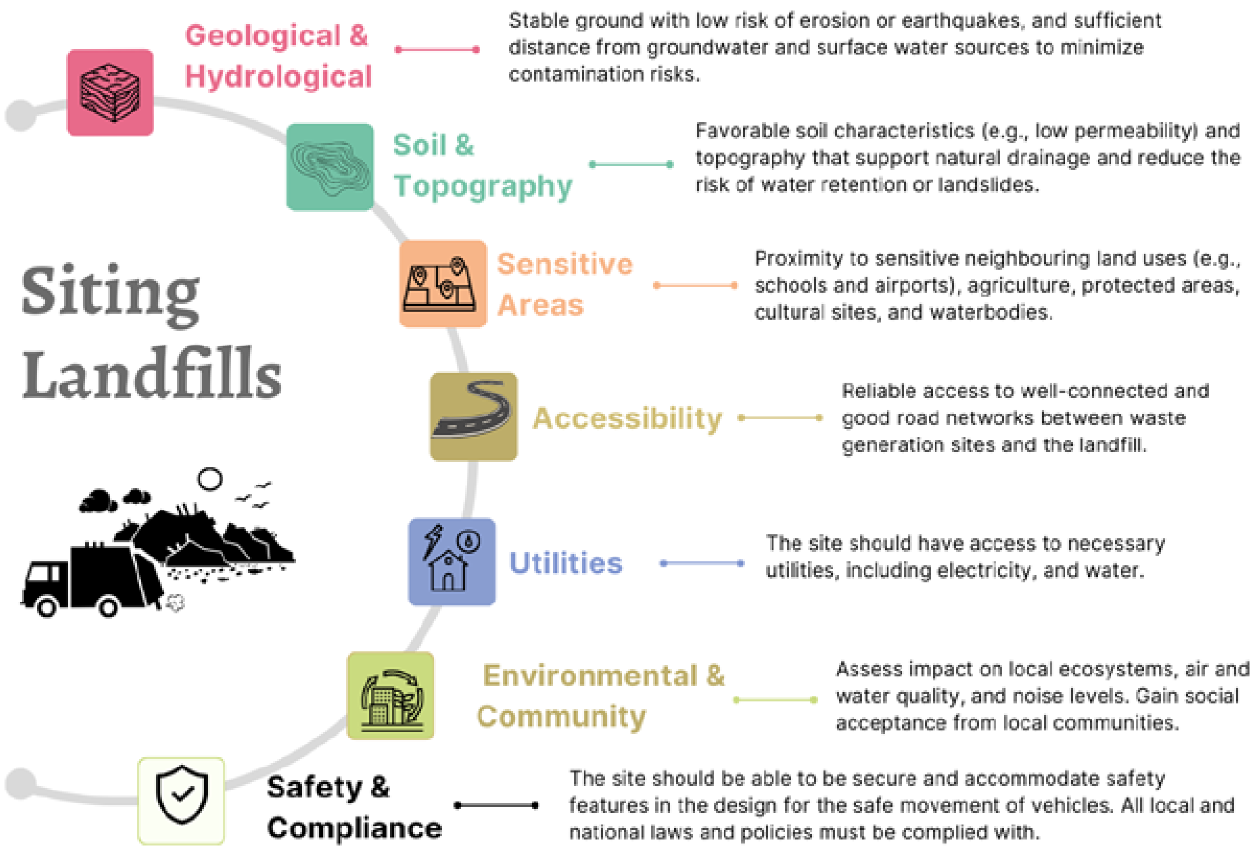
A **hydrogeological survey** assesses risks to groundwater. Landfills must not contaminate groundwater, particularly if used for drinking. Key factors include groundwater depth, flow, proximity to users, and baseline quality. The landfill base should be at least 1.5m above the water table for semi-permeable soils, or 1m for impermeable soils without liners.

A **surface hydrology survey** evaluates risks to nearby water bodies like rivers, streams, and lakes. Proximity to floodplains and water supply catchments should be avoided, and baseline water quality must be established.

Topographical and landscape features, like slopes and tree cover, can reduce landfill impacts on communities by screening odours, noise, and litter, while slopes aid water movement within landfill cells. Risks such as landslides and subsidence must also be considered.

Balancing geological, hydrological, and topographical factors with social, cultural, and ecological concerns is essential when selecting a landfill site. The site should be close enough for cost-effective transport but far enough to minimise nuisance and health risks. A common recommendation is to site landfills at least 500m from homes, with greater distances for schools and hospitals. Proximity to cultural sites and airports should also be considered, along with road infrastructure and potential unexploded ordnance (UXO).

Figure 58:
Considerations for the Siting of Landfills



Box 7:
Landfill in Vang Vieng, Lao PDR

A new landfill was completed in 2024 under the ADB's Second Greater Mekong Subregion Tourism Infrastructure for Inclusive Growth Project to address SWM challenges in Vang Vieng, which aims to meet the ASEAN Clean Tourist City Standard. The landfill includes engineered cells, leachate and gas management systems, a weighbridge, an office, a materials recovery facility, a hazardous waste facility, and a drying bed for faecal sludge. The Urban Development and Administration Authority (UDAA) will manage the landfill, with some facilities, like the MRF, contracted to a private operator who must employ informal waste pickers.

The main challenge in Laos and the region is not landfill construction, but operations, due to human and financial capacity limitations. Controlled landfills are significantly more expensive to run than open dumpsites. With current waste tonnage at 25 to 30 tonnes per day, the landfill will cost about $80,000 in the first year, with rising costs thereafter. Revenue from collection and gate fees will not cover these costs, making waste reduction and diversion critical.

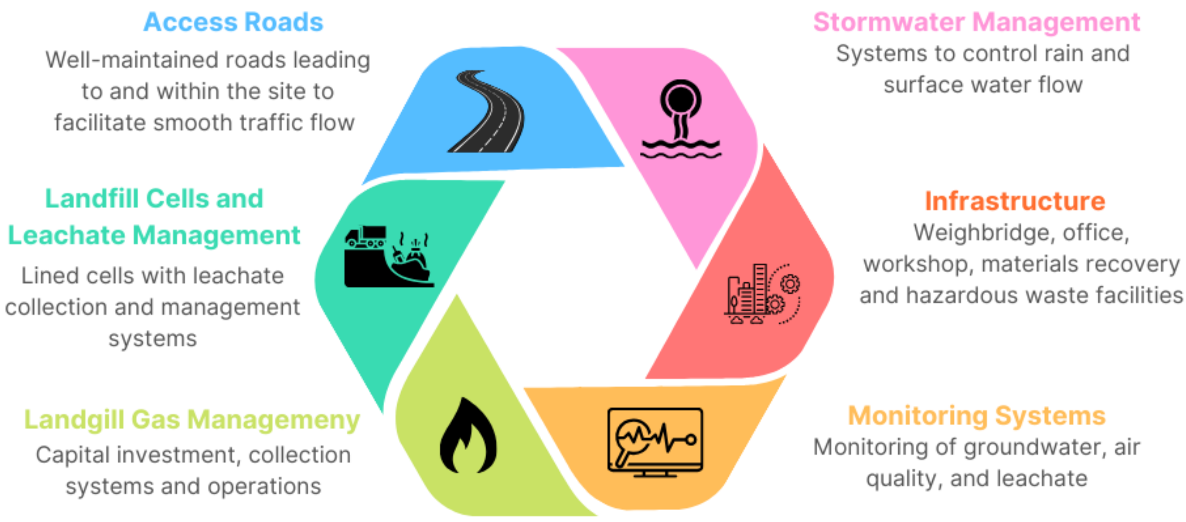
The ADB Project Team and UDAA recognise that focusing solely on landfill development, without integrating broader SWM systems, risks failure. Similar projects in the region have reverted to dumpsites due to capacity constraints. A systems approach that involves waste collection, segregation at source, and processing recyclables is essential. The project also is considering developing a biodigester/compost facility, which could produce electricity for EVs, including waste collection vehicles and tourism transport, potentially generating revenue. However, broader efforts beyond the ADB project are needed to improve waste segregation, recycling collection, and participation in waste disposal schemes.

Design of Landfills

Landfill design should follow international best practices, which must be adapted to the Mekong River Corridor's unique climate and resource limitations. Key considerations include managing leachate during prolonged wet seasons and ensuring the design fits local operational capacities (financial and human). Properly adapting landfill designs helps protect human health and the environment and improves efficiency.

Design specifications depend on factors like waste volume, location, and budget, focusing on simplifying operations and reducing costs in regions with limited government budgets.

Figure 59:
Design Considerations for Landfills



Access Roads and Site Security

The landfill site should be securely fenced to prevent unauthorised access, while paved internal roads ensure year-round access, particularly during wet seasons exacerbated by climate change. The road network should be designed to facilitate efficient and safe traffic flow and reduce accident risks, with elevation above flood levels to ensure accessibility during adverse weather conditions. Appropriate signage and lighting can enhance safety and guide vehicles effectively within the site.

Landfill Cells

Landfill cells are designated areas for waste deposition, typically featuring a liner and leachate collection system. The liners typically consist of compacted clay and high-density polyethylene (HDPE) membranes to minimise leachate infiltration into groundwater. A leachate collection system, made of gravel and perforated pipes, transports leachate via gravity flow to treatment facilities, reducing the need for costly pumping. Dual collection systems can discharge rainwater as clean stormwater in unused landfill areas.

Figure 60:
Construction of Serei Saophoan Landfill, Cambodia

Leachate Treatment

Landfill leachate is a contaminated liquid that forms when rainwater or other fluids percolate through waste, carrying pollutants. Management systems vary from full-scale wastewater treatment plants, which effectively treat leachate but are expensive, to biological pond systems that provide partial treatment, especially when only one pond is used. These ponds should include anaerobic and aerobic conditions to reduce organic matter and nutrients, though they are less effective against heavy metals. Constructed wetlands enhance leachate treatment through natural filtration processes such as sedimentation, microbial degradation, plant uptake, and absorption. Leachate recirculation systems can also reintroduce leachate under low pressure into the active waste layer, helping control volumes and promote waste degradation.

Landfill Gas Management

Landfill gas, primarily composed of methane and carbon dioxide, poses environmental and safety risks due to methane's potency as a greenhouse gas and its flammability. Management strategies include passive systems that vent gas into the atmosphere using vertical plastic pipes. Active systems such as flaring burn off methane, while waste-to-energy processes capture and convert it into renewable energy. The benefit of active systems is that they reduce a landfill's greenhouse gas emissions.

Stormwater Management

Systems designed to manage rainwater runoff and prevent flooding in landfill areas, which is especially critical during the heavy wet seasons common in the Mekong River Corridor. Effective stormwater drainage may include gutters, natural drainage channels, and retention ponds. Gutters are essential for intercepting surface water runoff, preventing it from entering landfill cells and increasing leachate volumes.

Buildings

A landfill may include various buildings based on operational needs. A weighbridge is essential for accurate waste recording, site management, and applying gate fees. Offices for management and administrative staff are typically required, along with welfare facilities such as toilets, showers, and a dining area. A workshop is useful for maintaining electrical and mechanical systems, while a supply building may house distribution boards and groundwater pumps. A solar power system can help reduce operational costs if space and budget allow. A vehicle washing ramp is also beneficial to clean collection vehicles before they leave the site, preventing waste and mud from being transferred onto public roads.

Figure 61:
Buildings at Kratie Landfill, Cambodia

Materials Recovery Facility

As outlined in Section 3, MRFs are facilities where recyclables are sorted and separated into individual material streams for further processing. In some cases, a landfill site may incorporate an MRF, depending on the location of the landfill and the broader waste collection strategies. However, landfills are often situated far from primary waste generation areas, which can present logistical challenges. This must be weighed against the availability of land. Having an MRF on the same site as the landfill provides the benefit of easy disposal of residual waste from the sorting process, reducing transport costs and streamlining operations. Co-locating an MRF can optimise space and resources by integrating waste sorting, recovery, and disposal processes within one facility.

Hazardous Waste Facilities

Hazardous waste management is limited across the Mekong River Corridor. Municipal landfills are not designed for industrial hazardous waste. Household or business hazardous materials, such as medical waste, batteries, e-waste, chemical containers, paints, and oils, should also not be mixed with regular landfill waste. A dedicated hazardous waste facility at landfill sites should be considered. This could include a designated storage area for inspecting and temporarily holding hazardous waste and a dedicated landfill cell for disposal. Such cells typically have a thicker liner and additional safeguards to prevent environmental contamination.

Environmental Monitoring Systems

Continuous groundwater, air quality, and leachate monitoring are crucial during landfill operation and after closure. These systems typically include groundwater monitoring boreholes to detect contamination, gas monitoring equipment for methane and carbon dioxide, and leachate collection systems to track pollutant levels. Regular monitoring ensures regulatory compliance, identifies early signs of environmental impact, and helps protect nearby ecosystems and communities. Integrating these systems is essential for sustainable landfill management and long-term post-closure care.

Operations at Landfills

Landfill operations are crucial for effective waste management and environmental protection. These include site access and security, waste acceptance and weighing, landfill cell management (waste spreading, compaction, and cover application), final capping, leachate and gas management, stormwater control, and ongoing monitoring and reporting. Each function is interconnected, contributing to landfill sustainability and regulatory compliance. Proper execution maximises capacity, minimises environmental impact, and enhances public health. This section provides a general overview of landfill tasks, with additional guidance available, such as the ADB's Practical Guide for Local Governments.[14]

Access and Security

Unauthorised access to landfills can result in illegal dumping, fires, and damage to pollution control systems, affecting the environment and public safety. Effective management includes secure fencing, restricted entry procedures, designated entry points, regular inspections, traffic management plans, and emergency preparedness protocols. Ideally, 24-hour security is recommended, especially for isolated sites with expensive equipment.

Waste Acceptance and Tipping

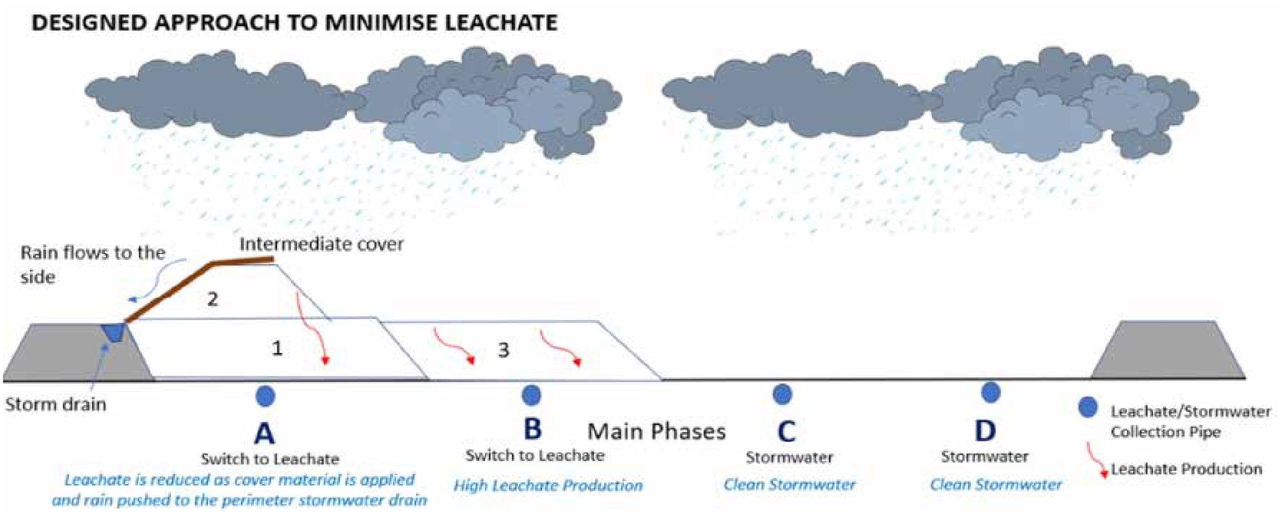
Waste Acceptance Criteria (WAC) ensure that incoming waste is compatible with the landfill's design and operations, minimising health and environmental risks. Waste is categorised as Permitted, Difficult, or Special. Waste collection trucks are weighed upon entry using a calibrated weighbridge, and details are logged into a computer system for payment and invoicing. Information includes waste category, source, tonnage, and any notes on special loads. Trucks are then directed to the active tipping face, often using flagmen or signs.

14 ADB. 2017. Integrated Solid Waste Management for Local Governments: A Practical Guide. https://www.adb.org/sites/default/files/institutional-document/324101/tool-kit-solid-waste-management.pdf.

Waste Placement

Waste deposition should be managed within designated cells, following a clear development plan updated as waste volumes are assessed. A common mistake is depositing waste horizontally across the entire cell, which increases leachate production. A phased approach is recommended, allowing rainwater in empty cell areas to be discharged as clean stormwater. This approach requires a dual pipe system in each phase of the landfill cell for leachate and stormwater. Once waste in one phase reaches a certain height, it is spread into the next phase. Intermediate cover is applied to minimise rainfall infiltration and leachate generation.

Figure 62:
Approach to Minimising Leachate



Waste Compaction

Compaction is essential for maximising landfill space and reducing airspace. It creates a stable surface for vehicles, promotes stormwater runoff, prevents waste escape, minimises odours, and reduces the risk of fires and pests. Compaction involves spreading waste in thin layers and passing machinery over it multiple times. Factors such as slope, moisture, waste composition, and equipment type affect compaction rates, with specialised compactors achieving better results than bulldozers.

Figure 63:
Compacting Waste at Kratie Landfill, Cambodia

Landfill Cover

Two types of cover are used: Daily and Intermediate. Daily cover, usually 15 cm of uncompacted soil, controls odours, reduces pests, and suppresses fires. Intermediate cover – up to 60 cm thick and made of low-permeability materials like clay – reduces rainfall infiltration and fire risks. Applying intermediate cover before the wet season helps minimise leachate production. Excavated material from the site is preferred but may not always be feasible.

Figure 64:
Cover Material on Exterior Slopes at Battambang Landfill, Cambodia

Final Capping of Landfill Cells

Final capping is applied when a landfill cell is full, using several compacted layers to minimise water infiltration, control gas, and reduce leachate. A four-layered approach is recommended:

- **Topsoil:** A 150 mm layer for vegetation establishment and erosion control.
- **Intermediate:** A 150–300 mm drainage layer of permeable material.
- **Barrier:** A layer of approximately 600 mm comprised of compacted clay or low-permeability material, preventing water infiltration and controlling landfill gas.
- **Gas collection:** A layer of 150–300 mm comprised of low permeability material to facilitate gas transmission to passive wells for removal.

Leachate Management

Maintenance requirements should be minimal if a pond system is utilised. Key management tasks include maintaining health and safety equipment, clearing sediment from pipes, and ensuring pumps are functional. Sediment accumulation may require periodic hydraulic dredging to prevent odours and maintain pond capacity. Solar paddle wheel aerators can be used for oxygenation in aerobic ponds. Plants require care if constructed wetlands are used, especially during the dry seasons.

Landfill Gas Management

Landfills generate gas for up to 20 years post-closure. Methane is flammable and poses an explosion risk, but compacting waste and installing gas wells mitigate this. Initially, vents are not usually needed at the base of the landfill cell, as little gas is produced. As the landfill height reaches approximately 25 per cent of the final height of waste, then gas vents should be incorporated. These can comprise perforated plastic pipes in a rock-filled wick, installed at 30 to 50m intervals. The pipes should be built up as the waste pile increases.

Building Maintenance

Ongoing monitoring and maintenance of buildings are essential. Tasks include daily cleaning, monthly safety inspections, and annual lighting, electrical, and plumbing system checks. Critical issues identified during inspections must be repaired promptly, with temporary fixes made if immediate repairs are not feasible. Clear communication about defects is essential, with hazard areas marked and discussed at staff meetings to ensure safety and awareness throughout the building.

Equipment Maintenance

Equipment maintenance focuses on keeping vehicles, machinery, and equipment in good condition through proactive preventative maintenance, reducing the need for crisis repairs. Staff must be trained in efficient operation and basic daily checks, with maintenance logs tracking service history. Regular service extends equipment lifespan, lowers fuel use, and improves safety. While routine maintenance can be done in-house, more complex tasks may require specialised personnel. Safety precautions, like equipment shutdowns and following manufacturer guidelines, are essential. As equipment ages, maintenance costs rise, requiring careful planning for future replacements.

Nuisance Control

Nuisance control at landfills reduces environmental impacts and fosters good community relations. These controls include managing litter, pests, fires, and dust. Proper cover minimises odours, deters pests, and prevents fires. Firefighting equipment and clear procedures are vital. Litter control prevents pollution and protects waterways through windbreaks, screens, and clean-up patrols. Non-lethal methods deter scavenging animals, especially endangered species. Dust control helps maintain air quality and reduce respiratory issues.

Hazardous Wastes

Municipal landfills are not designed for hazardous waste, which, if mishandled, poses significant risks to human health and the environment. Consulting national guidelines is crucial for proper management.

Monitoring and Reporting

Monitoring landfill conditions is essential for assessing environmental impact, compliance, and the effectiveness of mitigation measures. Focus areas include leachate, groundwater, surface water, and landfill gas, with data compared to regulatory standards. Monitoring continues for 20-30 years post-closure. Reports include daily operational updates and semi-annual environmental monitoring for stakeholders such as the Ministry of Environment. A Continuous Improvement Request system addresses non-compliance, and a Grievance Redress Mechanism handles community concerns.

Landfill Closure

Landfill closure and aftercare focus on pollution control and restoration. Key activities include managing leachate, gas systems, and re-vegetation. With stakeholder input, after-use planning determines post-closure land uses like parks or agriculture. A detailed Closure and Aftercare Plan is developed and regularly reviewed. Ongoing monitoring and maintenance are critical to mitigating risks, requiring inspections and remediation efforts until safety is ensured.

Landfill Equipment

Efficient landfill operations require a range of equipment tailored to local conditions. Local mechanics should be capable of servicing the machinery, and spare parts must be readily available to reduce downtime. Local staff should also be trained to operate the equipment effectively.

Landfill equipment falls into three main categories:

1. **Waste placement and compaction**
   This process requires machines that spread and compact waste to increase density and extend landfill lifespan. The two main options are:

   - *Specialised landfill compactors* with knobbed steel wheels, achieving compaction rates of up to 950 kg/m^3.

   - *Bulldozers* are more versatile, easier to maintain locally, and require less specialised operators but only achieve compaction rates of 700 to 750 kg/m^3. While more affordable, bulldozers need undercarriage and operator protection to avoid damage from waste materials.

2. **Cover material handling**
   Equipment needs vary depending on whether cover material is excavated onsite or imported. Onsite excavation requires a tracked excavator and a tipper truck for difficult terrain, with a bulldozer and/or excavator to spread the material.

3. **Support functions**
   These include preparing temporary roads, constructing bunds, clearing drainage ditches, and maintaining leachate ponds. Machinery for these tasks may include excavators, backhoe tractors, mini-diggers, and water bowsers/trucks.

Staff Requirements at a Landfill

Adequate and adaptable staffing is essential for responsible and safe landfill management, varying with waste volumes, types, and site size. Fewer staff may be needed, with some roles combined when operations are small. As waste volumes increase, dedicated staff are required for tasks such as waste reception, security, compaction, leachate treatment, and maintenance. Key roles include a landfill site manager, weighbridge operators, security, administration, and heavy machine operators.

Each staff member must have a clear contract outlining their responsibilities, and comprehensive training is crucial. Training should cover environmental protection, operational practices, and health and safety procedures. Ongoing training is necessary, with orientation for new hires and quarterly refreshers for all staff. Safety protocols must be enforced, including barring access to anyone under the influence of drugs or alcohol, ensuring safe unloading processes, and controlling activities near active tipping areas to reduce hazards.

Budget Requirements at a Landfill

For long-term sustainability, landfill budgets must account for short-term operations and long-term aftercare, which can last 20 to 30 years.

Effective financial planning must consider factors such as population growth, changes in waste generation and types of waste due to evolving consumer habits, and updates in legislation and technology.

Revenue typically comes from gate fees, recyclable sales, and government subsidies, while key expenses include labour (for staff and contractors), utilities (electricity and water), fuel and vehicle maintenance. Labour costs should cover additional benefits such as insurance and sick pay. Fuel, especially diesel, and maintenance for machinery represent a significant expense. Reserves must be set aside for capping landfill cells, constructing new ones, and eventual site closure. Additionally, costs related to asset ownership, such as insurance and depreciation, need to be planned for as older equipment becomes less efficient and more expensive to maintain, requiring timely asset replacement planning.

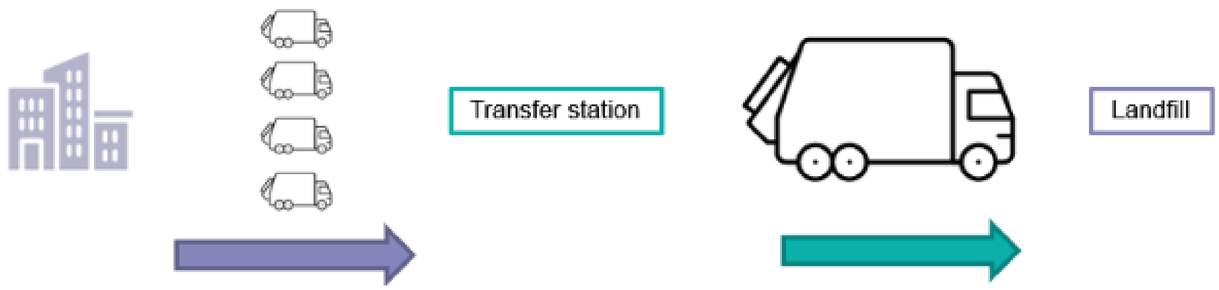
Introduction to Transfer Stations

New landfills or waste-to-energy plants are far from urban centres in many cities due to limited land availability and site suitability. When these sites are distant and road conditions are poor, transfer stations become essential for improving efficiency and reducing waste transport costs.

A waste transfer station is where municipal solid waste is temporarily stored before being sent to a landfill or treatment facility. The primary benefit of using a transfer station is the reduction of transportation costs. Smaller loads from collection vehicles are consolidated into larger, high-volume transfer vehicles, which reduces hauling expenses by allowing collection crews to spend more time collecting waste and less time travelling to distant disposal sites. This also lowers fuel consumption and vehicle maintenance costs and minimises traffic, air emissions, and road wear.

Transfer stations can also be used for the initial screening and separation of organics and recyclables, enhancing waste management efficiency. In some cases, they allow the public to dispose of waste directly and may include shops selling upcycled items, adding further value and sustainability to the waste management system.

Figure 65:
Concept of Transfer Stations



View of slums along the river in Ho Chi Minh City, Vietnam.
© De Visu/AdobeStock.com

Siting a Transfer Station

Several factors need to be considered when planning and siting transfer stations, as shown in Figure 66.

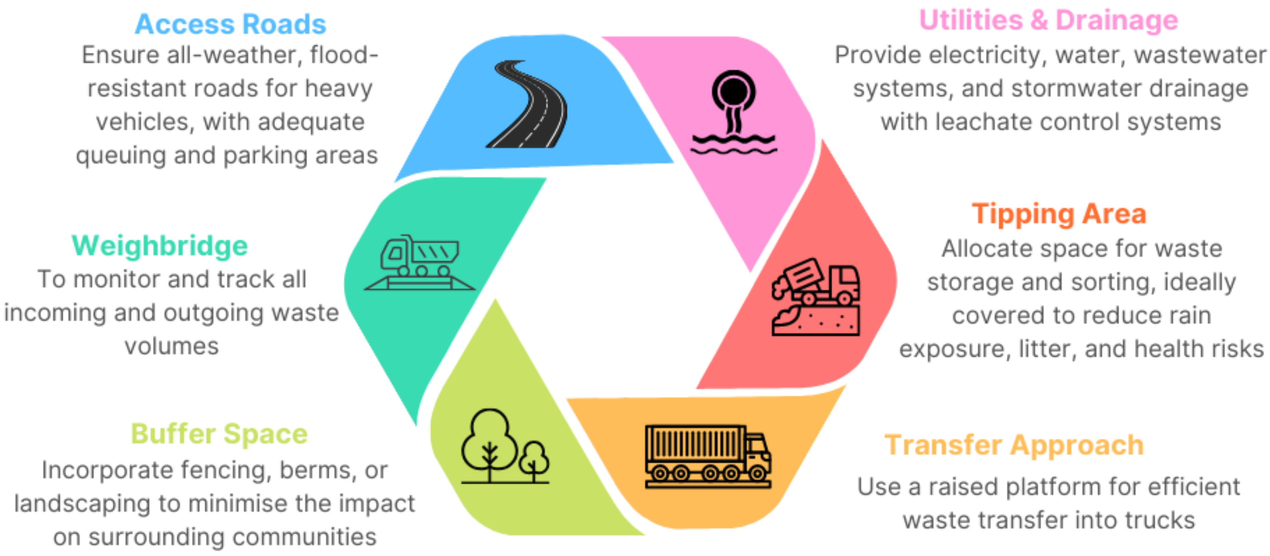
Figure 66:
Siting Considerations for Transfer Stations

Requirements for a Transfer Station

Transfer stations can range from basic, manual setups to advanced facilities with compaction equipment, resulting in varied establishment and operating costs. The primary goal is to optimise waste transfer efficiency, with simpler facilities suited to low-volume waste in smaller towns.

Key infrastructure requirements for a transfer station include all-weather access roads suitable for heavy vehicles, with concrete construction and areas for queuing and parking. A buffer (fence/berm/landscaping) is needed to reduce community impact. Utilities like electricity, water, wastewater systems, and amenities (toilets and washing facilities) must be provided. Effective stormwater drainage and leachate management systems are essential. A weighbridge is required to track waste volumes, while a covered tipping area allows for waste sorting and reduces health risks and rain impact. A raised transfer area should efficiently move waste into haulage trucks.

Figure 67:
Infrastructure Requirements for a Transfer Station



Key equipment includes compactors (stationary or mobile) to improve transportation efficiency, wheel loaders or material handlers for moving waste, mass haulage trucks or waste transport. Materials recovery equipment such as sorting conveyors, scales, tilt carts, and balers may be needed for improved efficiency if waste is to be screened at the site. General equipment includes PPE, firefighting tools, communication devices, and signage. When designing a transfer facility, the US Environmental Protection Agency recommends allowing for an initial 370 m^2 of space as the base area and adding 1.7 m^2 per tonne of waste received.

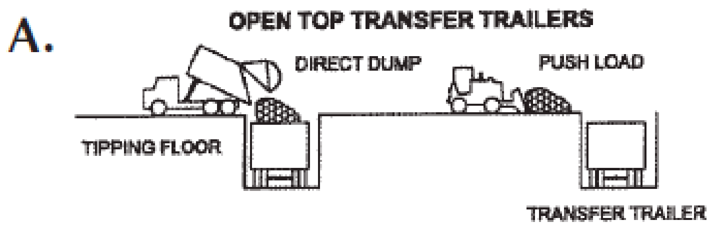
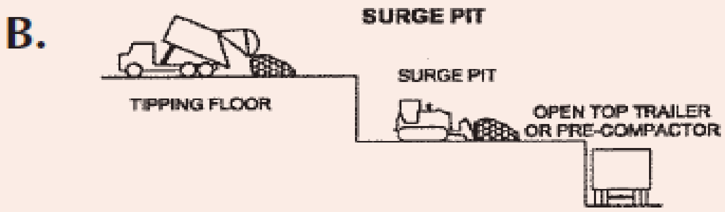
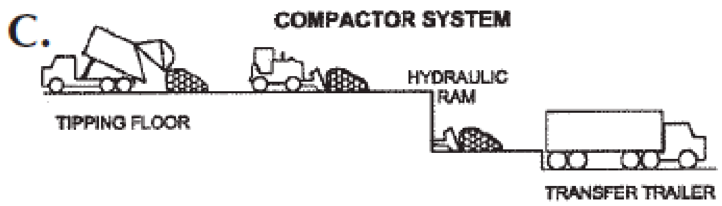
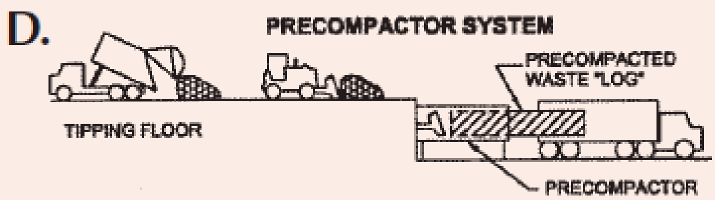
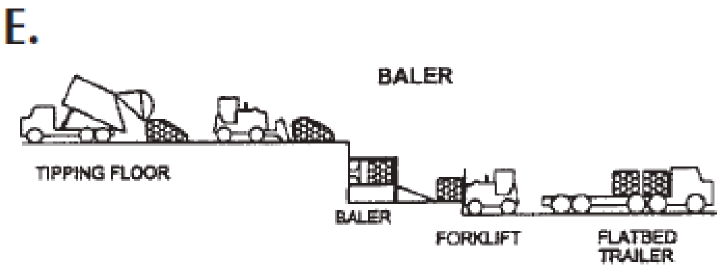
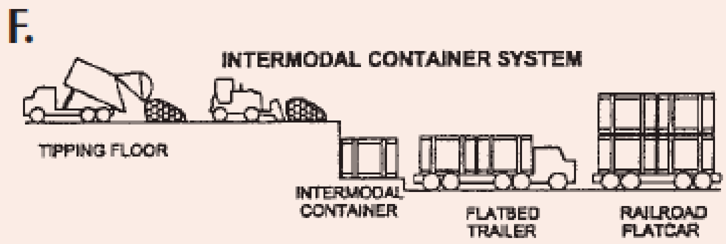
A range of staff is essential for efficient transfer station operations. Key roles include a station manager overseeing daily activities and compliance; machinery operators handling compactors, loaders, and other equipment; weighbridge operators tracking waste volumes; and truck drivers transporting waste to landfills. Health and safety officers enforce safety regulations and manage risks, and administrative staff handle records, reporting, and logistics. All staff must receive proper training, with clear responsibilities to ensure safety, efficiency, and regulatory compliance.

Transfer Technologies

Efficiently transferring waste from small waste collection trucks to mass-haul transfer trucks is critical for sustainable operations. As shown in the table below (adapted from the US EPA[15]), various approaches for transferring the waste have different advantages and disadvantages. Most transfer stations utilise a tipping floor higher than the area where the transfer truck receives waste. The simplest approaches involve a tipping floor and lower pit (A & B). Other approaches involve the use of compactor systems. While these will result in operational gains due to the larger waste a truck can accommodate, these are capital-intensive approaches.

15 https://www.epa.gov/sites/default/files/2016-03/documents/r02002.pdf.

Table 4:
Transfer Technologies

Open Top Transfer Trailers: This involves either directly dumping waste into the transfer truck or pushing the waste from the tipping floor. The waste is not compacted and requires large transfer trucks.	
Surge Pit: This approach allows waste to be stored, before being compacted by a tracked vehicle and pushed into the transfer truck.	
Compactor System: Stationary compactors use a hydraulic ram to push the waste into a specially designed transfer trailer.	
Pre-compactor System: Waste is compacted in a cylinder to create a dense "log" of waste.	
Baler: Waste is compressed into self-contained bales and loaded into trucks using forklifts.	
Container System: Waste is loaded into containers, which are then loaded onto trucks/rail.	

Instead of using a pit, waste can be directly loaded into vehicles at the same level as the tipping floor. However, this is less efficient than the approaches detailed above, as it takes more time and will require greater fuel volumes for machinery to operate. The two approaches are detailed in Figure 68.

Figure 68:
Direct Loading and Pit Loading

Source: Amor, 2020.

Improving the Management of Dumpsites

While some major cities in the Mekong River Corridor are developing engineered landfills, many other secondary cities rely on open dumpsites. Despite this ongoing reliance on the open dumpsite model, various cost-effective measures can be implemented to enhance environmental performance and improve health and safety.

Siting Dumpsites

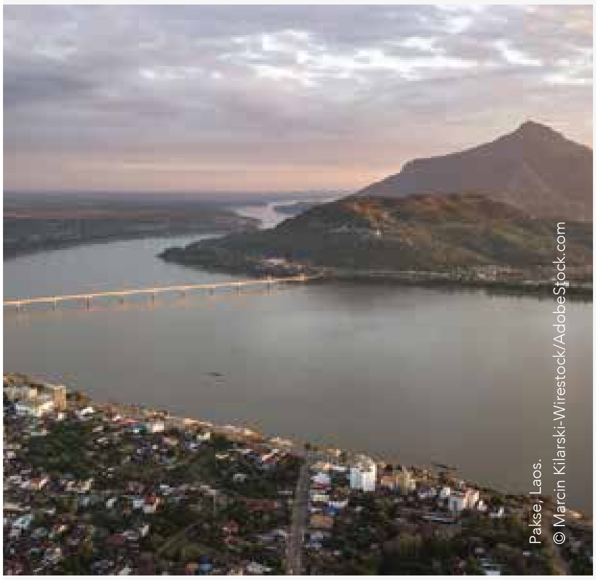
Many dumpsites in the Mekong River Corridor are poorly located, often situated near watercourses, residential areas, roads, sloping terrain, or close to protected environments.

Dumpsites can be improved from the beginning through better initial siting. Although the comprehensive surveys recommended for landfills will not be financially possible in small communities, basic checks can be incorporated when selecting a dumpsite location, including:

- **Distance from sensitive land uses:** Ensure that the dumpsite is situated at least 200m away from agricultural areas, rivers, lakes, or other waterbodies to prevent leachate contamination.
- **Buffer zones:** Establish a buffer zone of at least 500m from residential areas to minimise odour and health impacts on local populations.
- **Topography analysis:** Avoid sloped or uneven terrain to reduce erosion risks and manage stormwater runoff effectively.
- **Environmental impact assessment:** Conduct a simplified environmental impact assessment to identify potential effects on local ecosystems and wildlife.
- **Accessibility:** Choose locations that are easily accessible for waste collection vehicles while minimising traffic disruption in residential areas.
- **Community consultation:** Engage with local communities to gather input and address concerns about the proposed dumpsite location, including any impacts on cultural sites.

Figure 69:
Siting of Dumpsites, Vang Vieng District, Lao PDR

Case Study: Pakse, Lao PDR



Pakse generates approximately 125 tons of solid waste daily, with organic waste constituting 48.07 per cent (60.8 tons/day) and plastic waste 16.13 per cent (20.2 tons/day).

Despite these figures, the city's solid waste collection volume stands at 87 tons/day, including both formal (76.5 tons/day) and informal (10.5 tons/day) collections. However, about 38 tons/day of waste remain uncollected, indicating areas for improvement in waste management services.

To combat these challenges, Pakse's landfill – located 17 km northwest of the city centre in Sanasomboun District – spans 13.7 hectares and features impervious bottom layers for leachate extraction and treatment. Despite its operation as an open dump, ongoing installations aim to reduce landfill waste volumes and promote recycling and waste-to-resource initiatives.

Dumpsite Design

Once a location is identified, a project plan should be developed to guide the construction process. Even small dumpsites need a basic design document that outlines terrain configuration, preparatory work, construction order, access roads, and leachate management. The design should consider the dumpsite's size, waste types, site characteristics, and surrounding land use. Two common methods for construction are the trench method and the area method.

The trench method, suitable for clay soils, involves creating parallel trenches about three to four meters deep. It is cost-effective if implemented in clay soils, eliminating the need for expensive liners. The area method, on the other hand, is used for flat terrain where trench excavation is impractical. In this approach, an earthen levee (or bund) is first from the hazardous conditions of scavenging in landfills to safer, more regulated environments like materials recovery facilities, it is recognised that this process may take time. In the interim, it is crucial to enhance the welfare of informal workers, especially as landfill operations evolve and heavy machinery, such as bulldozers, are introduced to landfill cells, thereby increasing risks for waste pickers.

To address these challenges, it is essential to implement comprehensive safety measures. Waste pickers should be provided with clear protocols outlining safe working practices at the site. This includes establishing designated areas for waste retrieval, restricting access to heavy machinery zones, and ensuring that waste pickers are equipped with appropriate PPE such as gloves, masks, and reflective clothing.

Moreover, regular training sessions should be conducted to familiarise waste pickers with safety rules and emergency procedures. These sessions can also foster a culture of safety and cooperation among all site workers. Additionally, implementing a communication system, such as handheld radios, warning bells/sirens or signal flags, will facilitate quick alerts regarding the movement of machinery and potential hazards. Engaging with waste pickers to gather their insights and experiences can further improve safety protocols and enhance their sense of ownership in the process.

By prioritising the welfare and safety of informal workers, we can mitigate risks and create a more secure working environment while working towards the long-term goal of providing safer employment opportunities.

Waste-to-Energy

Approaches for Waste-to-Energy

Waste-to-energy technologies convert waste into usable energy, such as electricity, heat, or fuel. As the Mekong Corridor expands and waste generation rises, WtE offers solutions for both waste management and energy production. However, it is important to note that WtE ranks low on the waste hierarchy and in circular economy approaches. There are a number of different approaches to WtE.

Incineration involves burning waste at high temperatures, reducing waste volume by up to 90 per cent, and generating energy such as steam or electricity. Modern plants have advanced pollution controls to minimise emissions, but incineration faces challenges due to high capital costs, operational expenses, and public opposition over environmental concerns.

Cement kilns use waste as alternative fuel and raw materials during cement production. Operating at around 1,450°C, they effectively combust waste like municipal solid waste, industrial by-products, and agricultural residues, reducing landfill usage and fossil fuel consumption. This approach supports sustainable cement production by utilising waste minerals as raw materials. However, strict monitoring is required to manage pollutants and hazardous waste.

Refuse-derived fuel (RDF) is produced from municipal solid waste by removing non-combustibles and enhancing calorific value through processes like shredding and pelletising. RDF can be used in cement kilns, boilers, and power plants, reducing fossil fuel use and landfill waste. However, managing RDF requires careful regulation to prevent hazardous material combustion and ensure compliance with environmental standards.

Challenges and Opportunities with Waste-to-Energy

Key challenges include resource loss and the potential for greenhouse gas emissions during incineration. Despite these concerns, WtE technologies provide environmental and economic benefits, such as diverting waste from landfills, extending landfill lifespan, supporting energy security, and creating construction, operation, and maintenance jobs.

The development of WtE projects faces public opposition due to emission concerns, and regulatory frameworks must ensure strict environmental compliance while encouraging investment. Economic viability depends on a consistent supply of waste with suitable calorific value and policies that incentivise waste diversion from landfills.

Summary of Requirements for Disposal

Disposal is the final step in the waste management hierarchy, used only after waste reduction, reuse, recycling, and recovery are exhausted. It aims to minimise environmental and health impacts but is often costly and resource intensive.

In the Mekong Corridor, unmanaged dumpsites have led to severe contamination and health risks, prompting a shift toward engineered landfills WtE facilities that require significant investment. Engineered landfills provide better environmental protections than controlled landfills, which allow access to informal waste pickers.

While WtE processes convert non-recyclable waste into energy, they still emit greenhouse gases, necessitating careful management. Cities should prioritise effective waste management strategies to enhance environmental performance and protect human health at the disposal stage.

Figure 71:
Summary Checklist for the Disposal Phase

1 DUMPSITES

- Improve the siting of dumpsites
- Introduce basic controls (e.g., occasional use of cover)
- Support informal workers

2 LANDFILLS

- Undertake siting assessments
- Ensure design aligns with human & financial capabilities
- Consider the use of transfer stations to improve efficiency

3 WASTE TO ENERGY

- Consider the regulatory requirements
- Ensure consistent supply of suitable feedstock
- Consider different technologies available

Open-air dump, Afuá, Brazil
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5

CALL TO ACTION

Cities in the Mekong Corridor have a unique opportunity to lead the way in sustainable waste management aligned with circular economy principles. By embracing innovative waste management practices, these cities can enhance public health and environmental quality while empowering their communities. When waste is managed effectively, it transforms into a resource, creating a cleaner, more vibrant environment for all residents.

By prioritising sustainable waste management, cities can create job opportunities and stimulate economic growth while encouraging community participation. Residents will feel empowered to contribute to a healthier environment, leading to improved quality of life and stronger community ties.

Wat Xieng Thong temple in Luang Prabang, Laos.
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