Digital perspective on JICA's waste management program

Feb 2023

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Today's topics

1. JICA DX Vision & Role
2. Mapping potential digital solutions for a waste management value chain
3. Promoting development scenarios utilizing digital solutions & KPI acquisition/management
4. Digital architecture for utilizing digital solutions
5. Examples of digital solutions

Key Message

- By utilizing digital solutions, it is possible to establish the first stage of waste management flow and promote development scenarios in developing countries (applicable digital solutions already exist and can be used)
- By combining digital solutions and accumulating, managing, and utilizing the data obtained, more comprehensive impact can be made
- In order to realize the above, it is important to have an overall vision (digital architecture) that includes the infrastructure for data generation and utilization, and to encourage the development of a data sharing infrastructure in addition to the introduction of individual solutions
- Support using digital solutions cannot be provided solely by JICA, thus cooperation between the public and private sectors is essential

JICA DX Vision

JICA Digital transformation

DX Vision to drive the achievement of JICA's Mission/Vision in a digital age we are facing.

JICA Mission & Vision

Leading the world with trust

Human Security

Fostering societies where people can protect themselves from various threats and lead their lives in security and with dignity

Quality Growth

Promoting sustainable growth with less disparity and without harming environment.

People　Peace　Prosperity　Planet

JICA DX Vision

Human Security
Diverse Well-being for All with Digital

Creating a quality digital society where everyone can realize diverse Well-being

Quality Growth
Quality Industrial & Societal Transformation with Digital

ODA Business Transformation

1 **Data&Tech**
Utilize data and technology to fullest for value creation

2 **Co-Creation**
Generate innovation and collective impact with digital partners

3 **HR Networks**
Strengthen and activate human resource networks

HR Transformation

4 **Mindset**
Change our mindset to be agile in a rapidly changing world

5 **Digital HR**
Reskill/Upskill ourselves on digital literacy and skillsets

6 **Workspace**
Modernize flexible, positive working environment for diversity

Institutional Transformation

7 **BPR**
Reengineer efficient, effective business process/systems

8 **Data-Driven**
Realize data-driven institutional management

9 **Digital Infra**
Develop resilient, modern digital infrastructure

Role of JICA STI-DX Office

DX Team, as an internal advisory, spearheads the digital transformation initiative in cooperation with 20 Global Agenda (Thematic areas) and Regional Projects. STI/ICT team leads ICT Infrastructure development, cybersecurity, Digital Skills.

Goals

DX Vision

Create a quality digital society where everyone can realize diverse Well-being

Enabling Environments

Develop infrastructure to promote the benefits of digitization and reduce disparities and cybersecurity risks.

Mandate

Driving DX across the Sectors

Basic Infrastructure for Free & Secure Digital Economy

- ICT/Digital Infrastructure
- Digital Skills and Business
- Cybersecurity

Focus Activity

JICA DXLab

1. Promote to utilize data & technologies in operation.
2. Facilitate agile/flexible collaboration with private digital partners.

Cybersecurity Cluster

Capacity building on cybersecurity, especially for Asia Region countries, by referring Data Free Flow with Trust (DFFT).

DX Ecosystems

DX Enablers

Knowledge Sharing

Experts Group
Development Partners

Exploration

Quick-win PoC

Platform

Satellite Data PF
JICA-VAN

Data Base

Data catalogue system

Partners

- Private Companies
- University Research Inst.
- Other GoJ Organization
- Experts
- Municipalities
- CSOs

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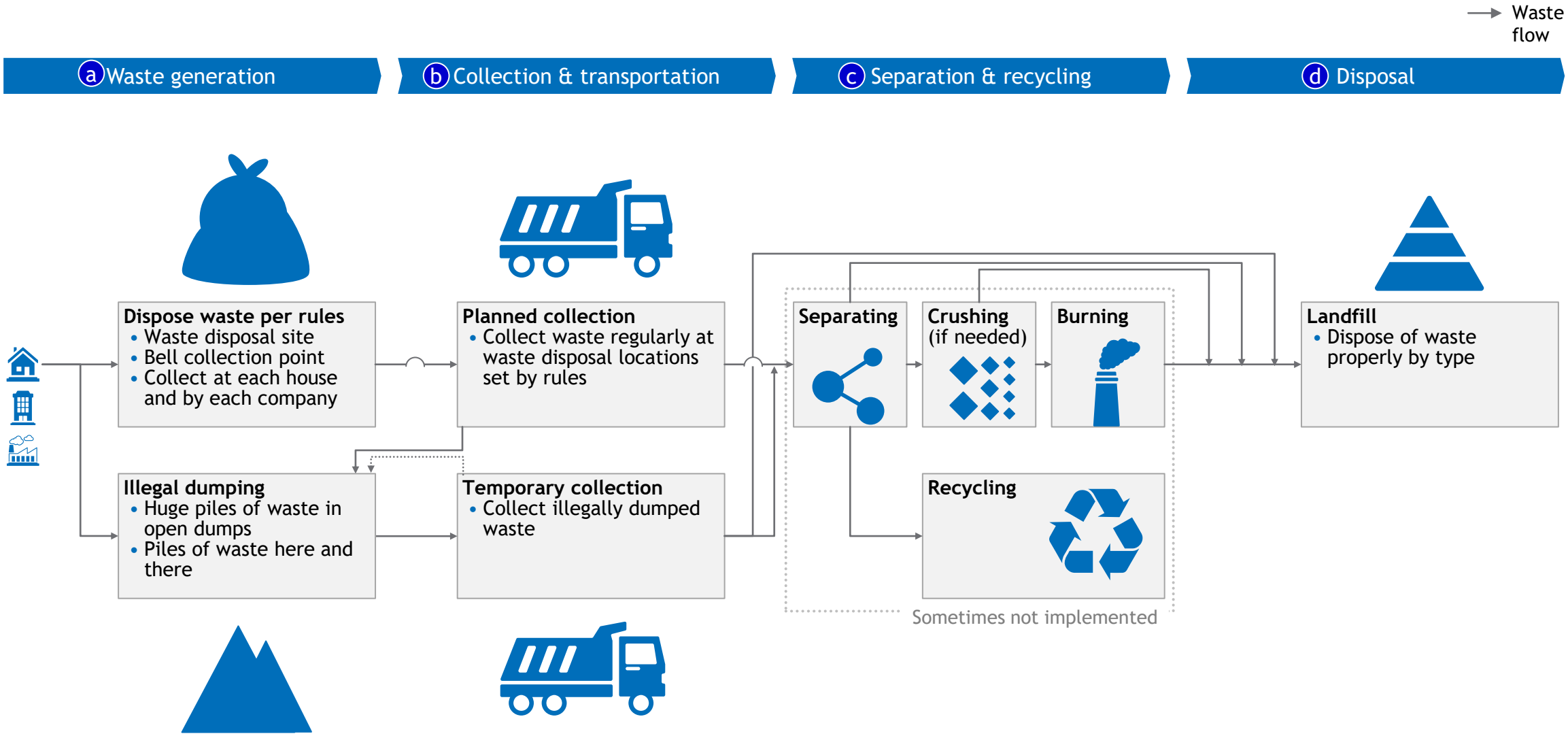
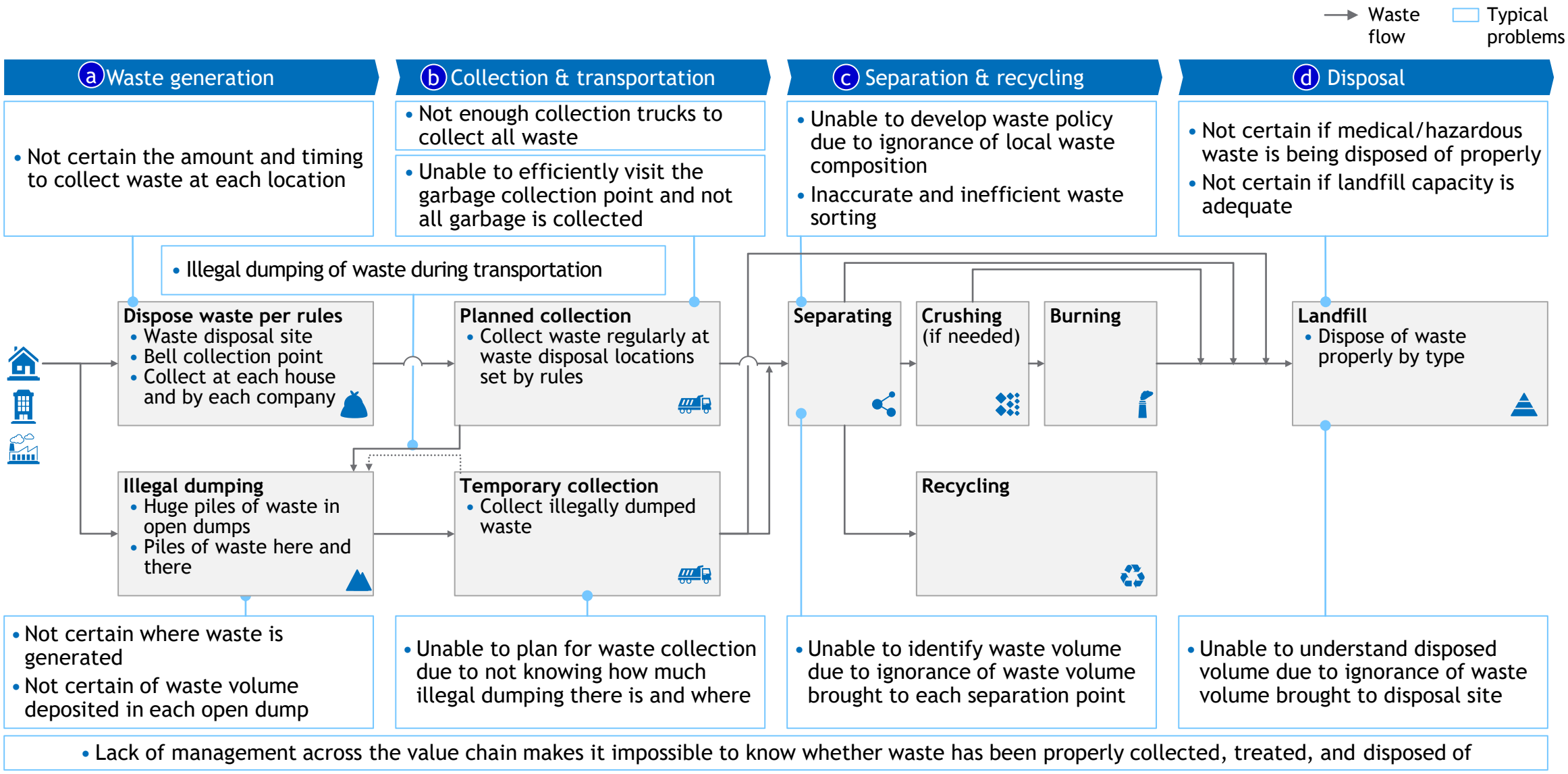
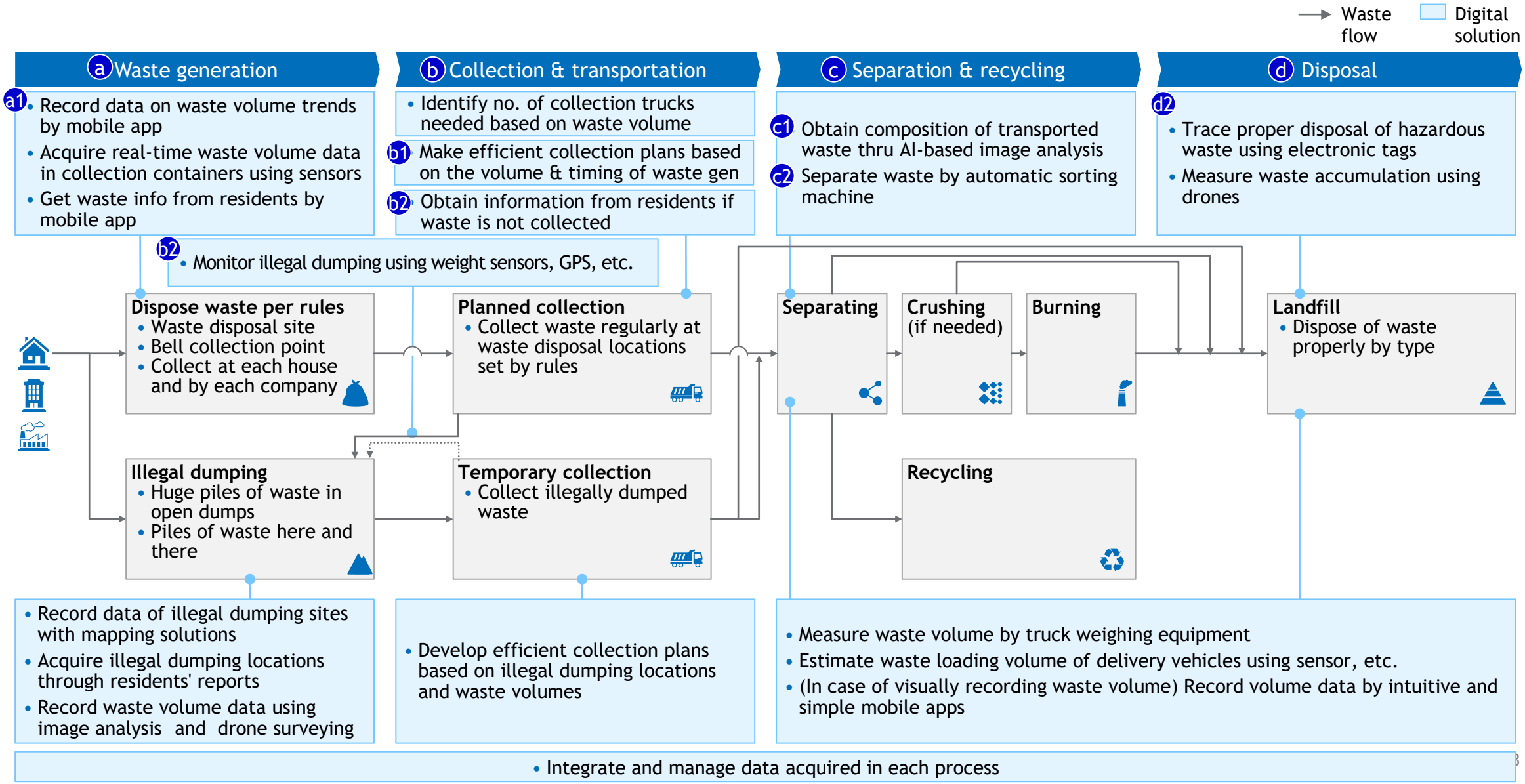
Overview of waste value chain



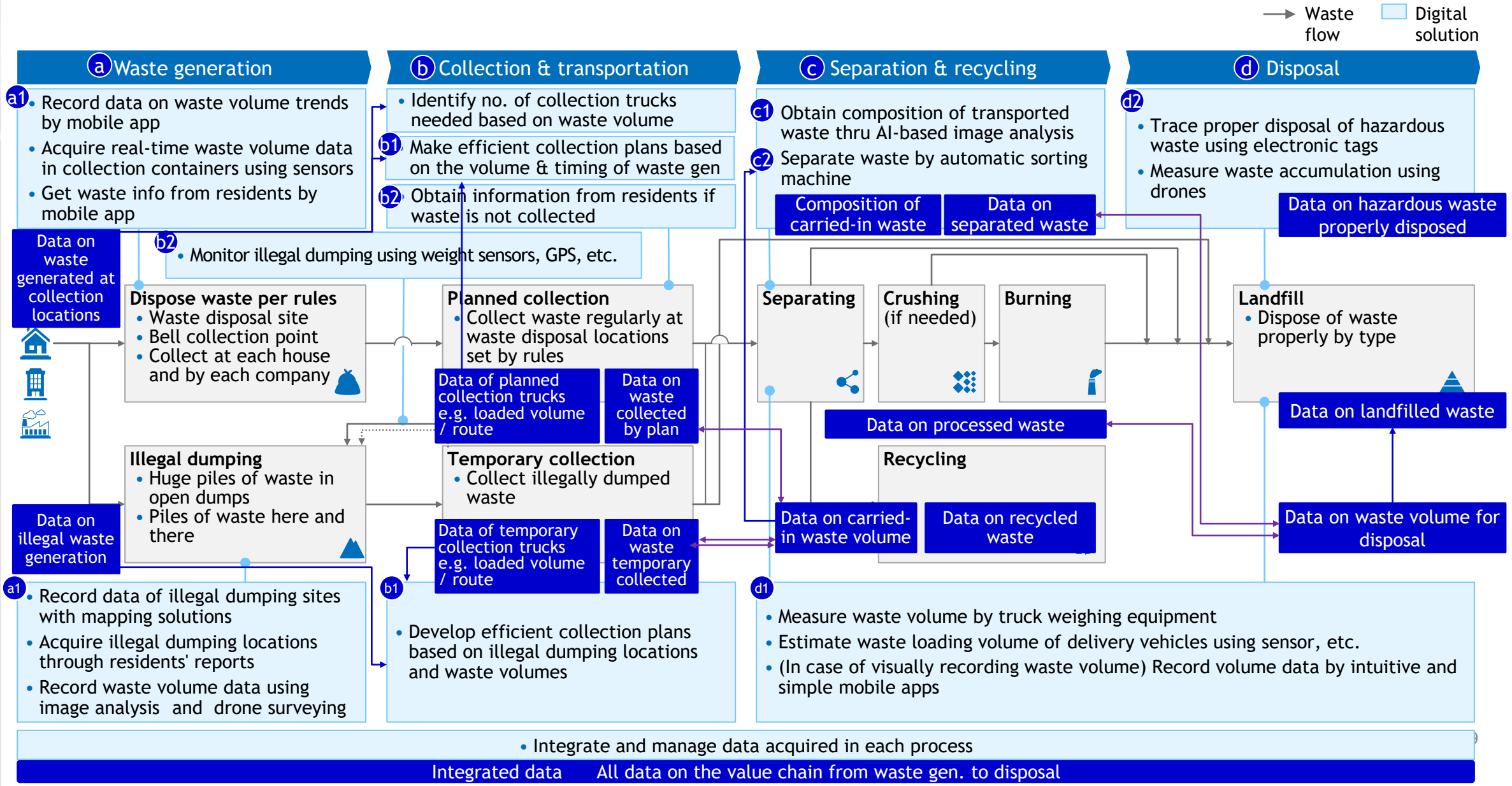
General issues in waste value chain



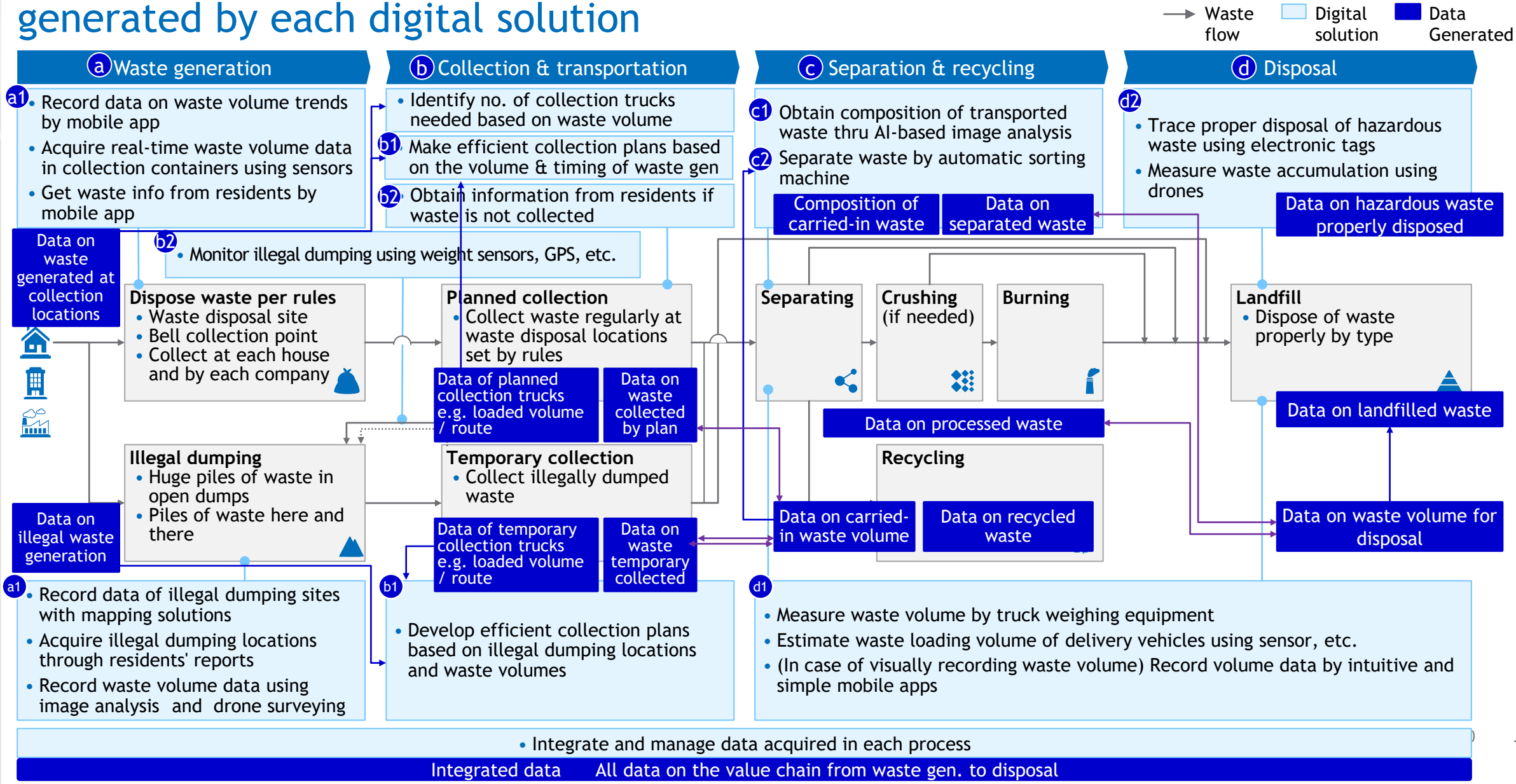
General issues in waste value chain ➡ Possible digital solutions



Possible digital solutions in waste value chain + Generation of data

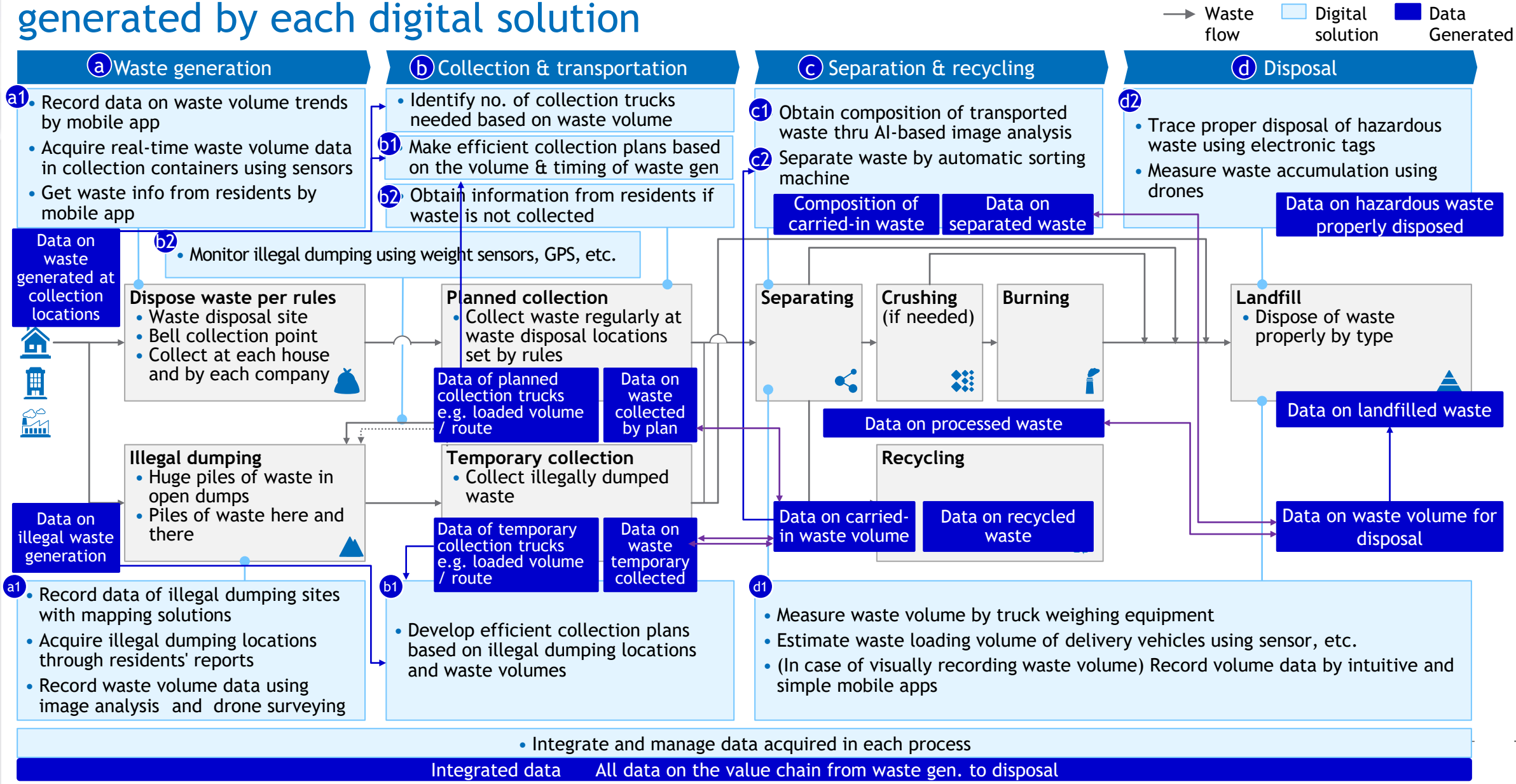


Establishing waste mgnt. flows is accelerated by organically linking data generated by each digital solution



Using digital solutions helps establish waste mgmt flows in any segment of municipality

Establishing waste mgnt. flows is accelerated by organically linking data generated by each digital solution



Using data linked across value chains, rapidly determine measures based on urgency/ priority and evaluate/improve initiatives in the long-term

→ Data linkage Data generated by digital solutions

a Waste generation

Waste disposed by rules

- **Establish efficient collection route using waste generation data**
- **Improve waste collection rate by identifying over capacity**
  - Reorganize waste collection locations
  - Update waste disposal rules
  - Add collection vehicles/ outsource to companies
  - promote resident participation

Planned collection

Data on waste generated at collection locations × Data on waste collected by plan → Data on waste that couldn't be collected by plan

Illegal dumping

- **Establish temporarily collection plan of illegally dumped waste based on waste generation data**
- **Analyze trends and consider measures to reduce illegal dumping**
  - Set regulations, review punishments
  - Design incentives for proper waste disposal

Data on illegally dumped waste → Trends in illegal dumping

b Collection & transportation

c Separation & recycling

- **Understand the volume of waste w/o being separated, consider measures to improve intermediary processing rate**
  - Prepare intermediary treatment facilities
  - Improve processing capabilities of facilities

Data on locally collected waste × Data on waste brought in → Data on waste that can't be separated

- **Understand recycling rates and consider measures to improve them**
  - Improve capabilities for sorting recyclables
  - Develop recycling industry

Composition data on waste brought in × Data on recycled waste → Data on amt of recyclable waste

d Disposal

- **Based on amount of waste in landfill, identify necessary future disposal capacity and consider countermeasures**
  - Estimate remaining life of disposal site
  - Specify scale, no., timing of necessary add'l sites
  - Develop treatment plan maint plan

Data on waste brought in × Data on landfill waste → Capacity needed in future

Unify and visualize data across value chains

e Strategy, rules, etc.

- **Visualize issues and plan/formulate strategy & policy based on data and evaluate results (EBPM)**
  - Assess impact of policy on value chains via simulation/data
- **Prepare legal regulations/rules to promote data/digital tech usage & data linkage infrastructure**

Source: University of Cambridge_waste & recycling dashboard, Slide Geeks_Waste management tracking dashboard sample templates, Slide Team_Industrial Analysis Dashboard For Solid Waste Management sample

Linking & utilizing data enables data-based policy making & impact measurement

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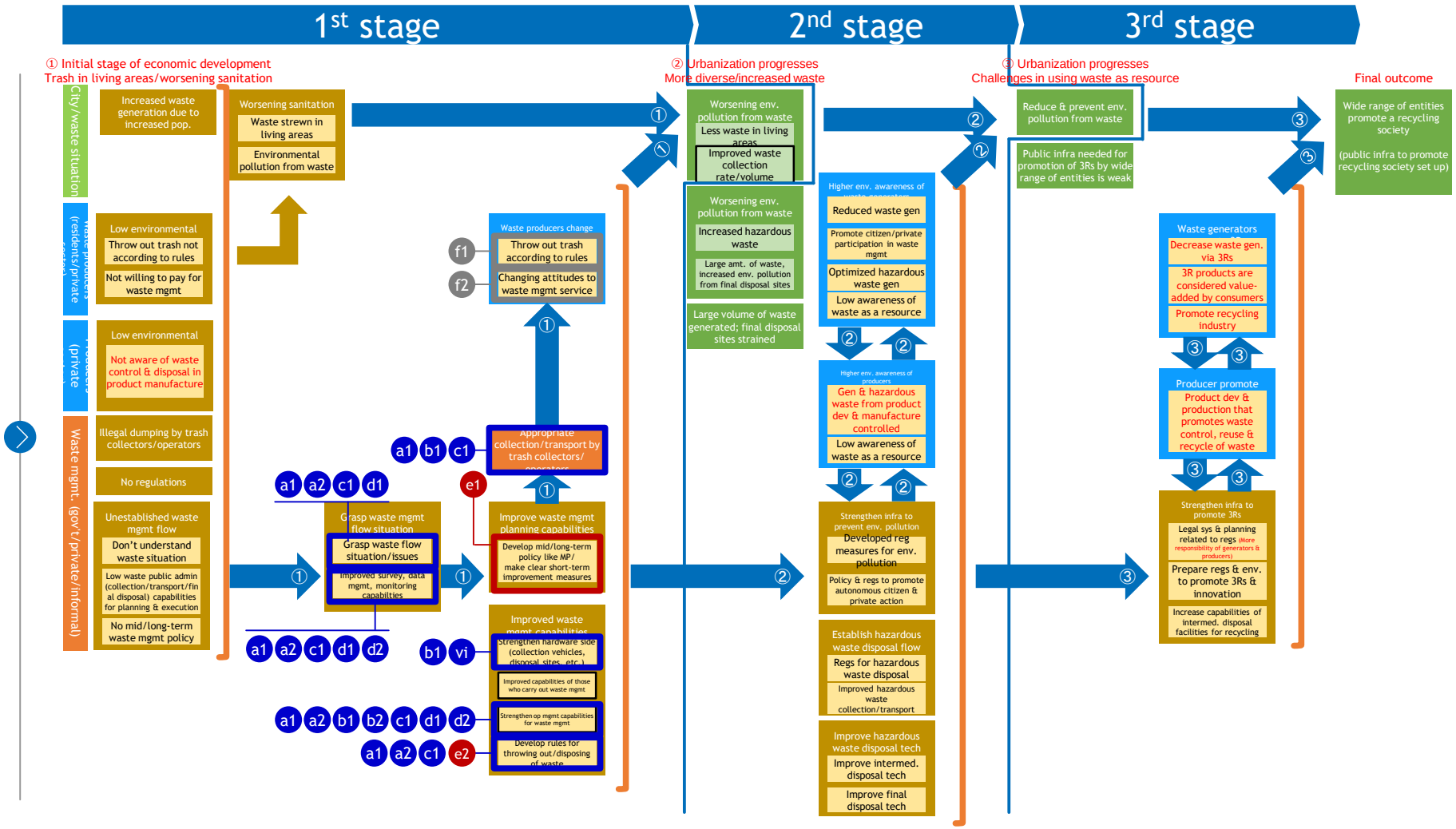
(Ref) Using digital solutions/data boosts helps promote development scenarios

Use of digital solutions/data

- **a Waste generation**
  - a1 Understand local waste generation
  - a2 Understand amt. of plastic waste generated on coast
- **b Collection & transportation**
  - b1 Understand waste collection timing & optimize collection routes
  - b2 Guarantee waste collection & transportation is carried out properly
- **c Separation & recycling**
  - c1 Determine type of waste
  - c2 Optimize waste separation
- **d Disposal**
  - d1 More efficiently understand volume of trash to be unloaded
  - d2 Trace disposal based on type of waste
- **e Strategy/ rules**
  - e1 Consider short-term reform measures, develop mid/long-term policy
  - e2 Reflect in rules
- **f Other**
  - f1 Share info on rules about taking out trash
  - f2 Attitude surveys



Using digital solutions/data helps realize individual development scenario factors

(Ref) Using digital solutions/data also helps improve development scenario KPIs

XX: Hypothetical (not in cluster biz plan)

KPI (from cluster business plan)[1]	Intermed. outcome measurement items	Direct outcome indicators	KPI components	Categories of digital solutions that could improve KPIs
Strengthen org capabilities of waste mgmt-related agencies (central, local gov't) in 40 cities by end of FY 2030	✓	✓	Digital Solution may not match for the KPI	N/A
Increase capabilities of 20k employees at waste mgmt-related agencies by end of FY 2030	✓	✓		
Waste collection service coverage or waste collection rates in 20 cities are over 80% by end of FY 2030 (1st stage :50%, 2nd stage: 50-80%, 3rd stage: 80%)	✓	✓	"Waste collection waste"(%)= A "Amt. of waste collected annually" / B "total amt. of waste generated annually"	A: d1 More efficiently understand volume of trash to be unloaded B: e1 Understand local waste generation; e2 Understand amt. of plastic waste generated on coast
Develop short & mid/long-term policy/plan (1st stage: No, 2nd/3rd stage: Yes)	✓		Digital Solution may not match for the KPI	e1 Consider short-term reform measures, develop mid/long-term policy
Introduce environmentally-friendly landfills (1st stage: 50-80%, 2nd stage: 80%)	✓			e1 Consider short-term reform measures, develop mid/long-term policy
Achieve proper waste disposal rate of 50% by end of FY 2030	✓	✓	"Proper waste disposal rate"(%)=(C "amt of waste properly disposed and reused/recycled annually"+ D "amt of waste properly placed in sanitary landfills for final disposal")/B "total waste generated annually"	C: c1 Determine type of waste D: d1 More efficiently understand volume of trash to be unloaded at disposal site; d2 Trace disposal based on type of waste
Increase recycling rate to 20% by end of FY 2030	✓	✓	"Recycle rate"(%)= E "Waste brought in for recycling annually"/ B "total waste generated annually"	E: c1 Determine type of waste
Improved waste-related regulations (2nd/3rd stage: Yes)	✓		Improvement of waste-related regulations	e2 Reflect in rules
Decrease fill rate of open dump sites among final disposal sites (2nd stage)		✓	"Open dump site fill rate"= F "# of open dump sites"/ G "# of final disposal sites" or H "total amt. disposed at open dump sites"/ I "total volume disposed at final disposal sites"	F H: a1 Understand local waste generation G: N/A I: d1 More efficiently understand volume of trash to be unloaded
Formulate regulations to create & promote recycling society/economy (3rd stage, final outcome: Yes)	✓		Digital Solution may not match for the KPI	e1 Consider short-term reform measures, develop mid/long-term policy e2 Reflect in rules
Citizens participate in 3R cycle activities (2nd, 3rd stage, final outcome: Yes)	✓		Acquire via J "attitude survey?"	J: f1 Promote dissemination of waste rules to waste generators
Expand venous industry (3rd stage, final outcome: Yes)	✓		Digital Solution may not match for the KPI	N/A
Increase citizen awareness of urban waste and the environment (3rd stage)		✓	Acquire via J "attitude survey?"	K: f1 Promote dissemination of waste rules to waste generators
Increase proper disposal rate of hazardous waste (3rd stage: 80%)	✓		"Proper disposal rate of hazardous waste"(%)= K "Amt. of hazardous waste properly disposed of annually"/ L "total amt. of hazardous waste (incl. infectious waste) generated annually"	L: d2 Trace disposal based on type of waste M: N/A
Annual generation of 50kg or less of urban hazardous waste	✓		"Amt of annually waste generate per person annually"(kg/capita/year)= L "total amt of hazardous waste (incl. infectious waste) generated annually"/"total pop."	N/A

1. Intermediate outcomes are select targets from attachment 3 of the cluster business plan draft

Source: Cluster business plan (draft)

Digital solutions/data are also useful for acquiring & managing KPIs

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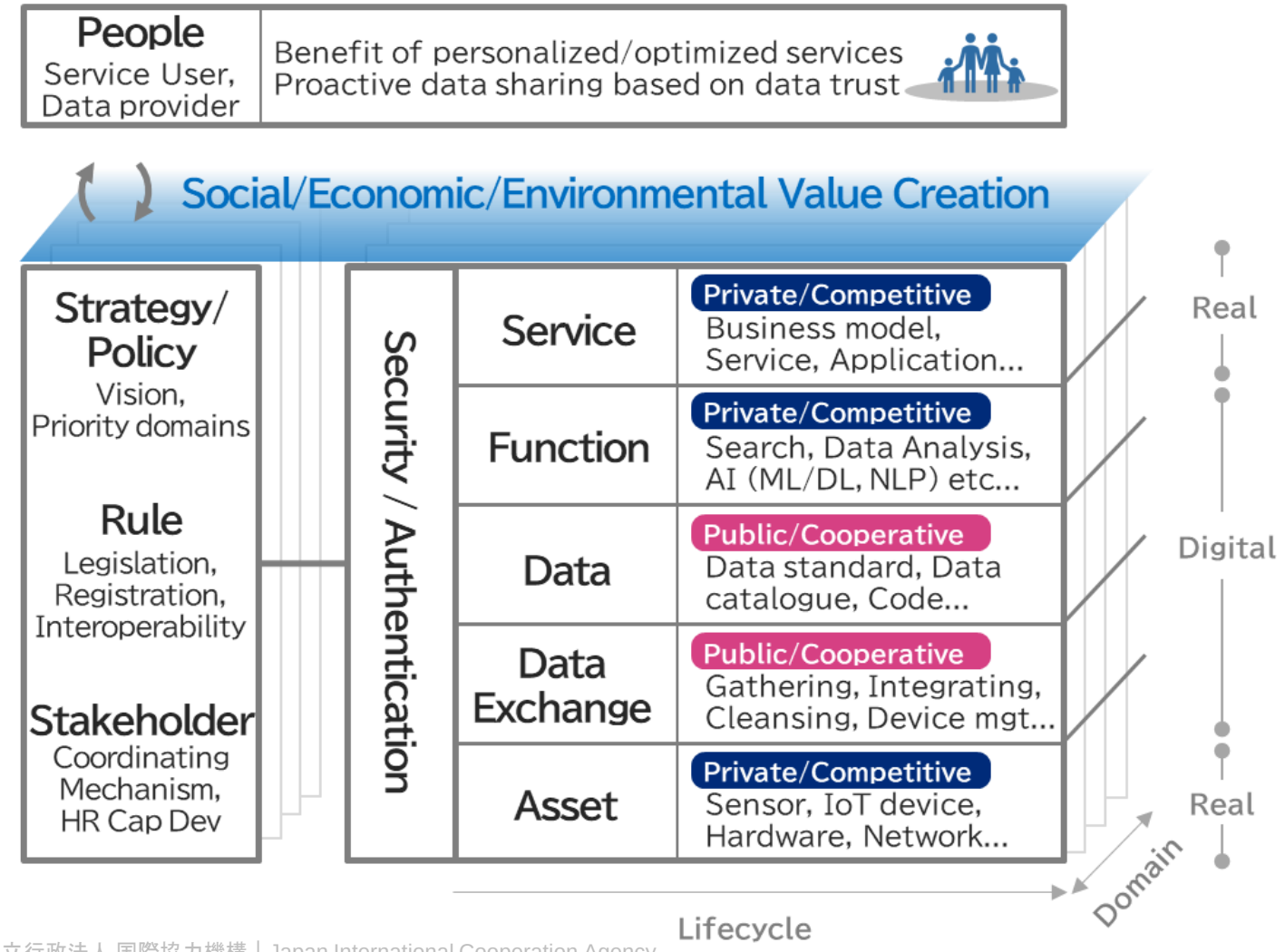
Digital Architecture 1/3 - Overall Structure

When thinking about the DX, the reference digital architecture helps you position what are on the issues and what to do /where to go.



DX Approach 1

Go between Real & Digital

What JICA has been doing is pretty much in Real world. Change our glasses and see and jump into the Digital world.

DX Approach 2

Go Horizontal

Be a platformer on the horizontal layer

Go Vertical

Integrate multi-layers vertically

Go Diagonal

Connect cross-domain data to maximize value

Go the Frame

Create the digital architecture ecosystem

DX Approach 3

Go For the Private

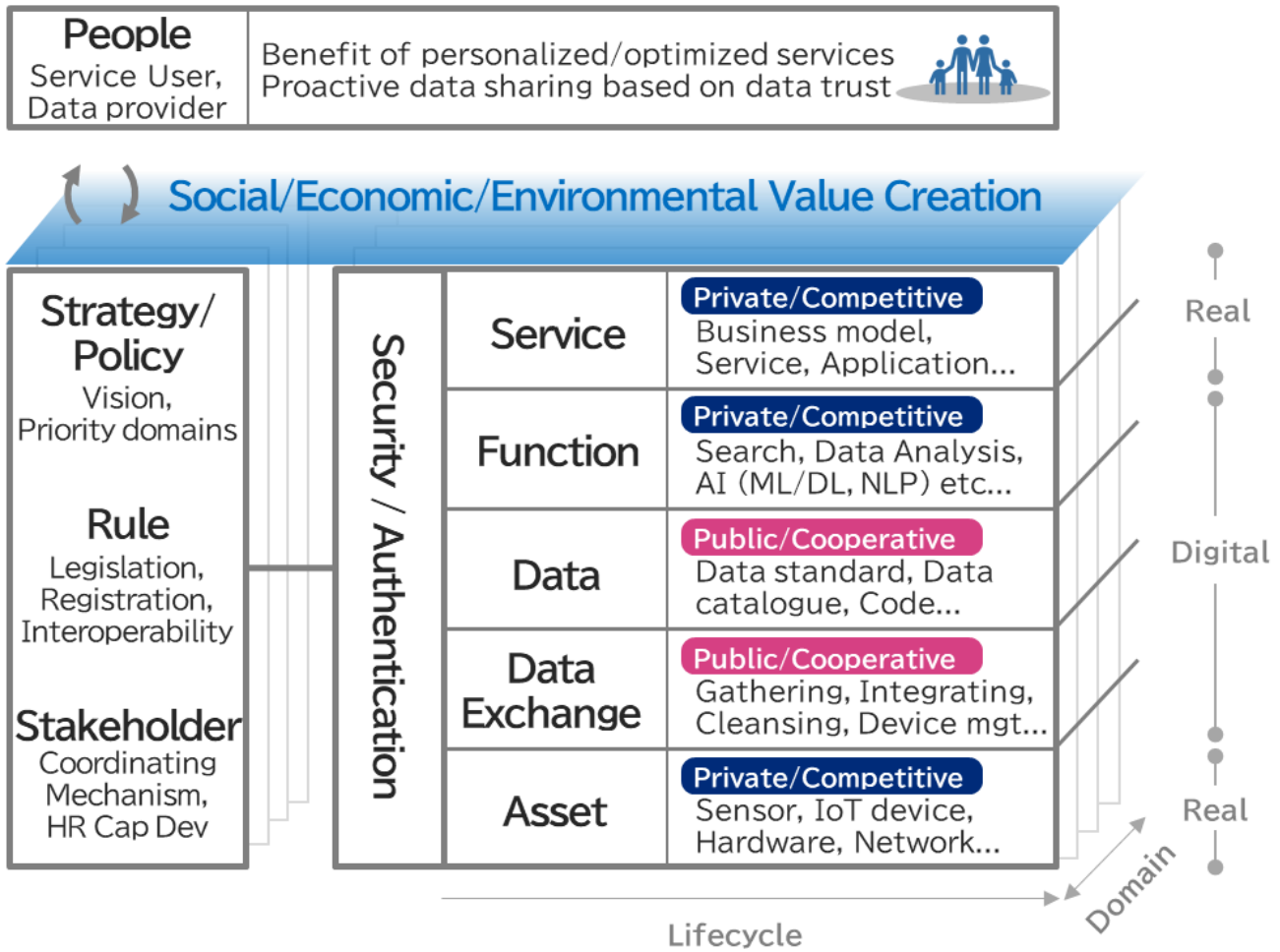
For cooperative area, design the public-led cooperative area to facilitate more private sector participation.

Go With the Private

For competitive area, give space to the private sector to play its fullest role in innovation.

Digital Architecture 2/3 - Cooperative vs Competitive Areas

Digital architecture holds "cooperative/private-led" and "competitive/public-led" areas. This defines a government intervention that avoids excessive competition in the cooperative areas and encourages service improvement through fair competition among the private sector in the comp area.



Role of the Public

Cooperative Area (Public-led)

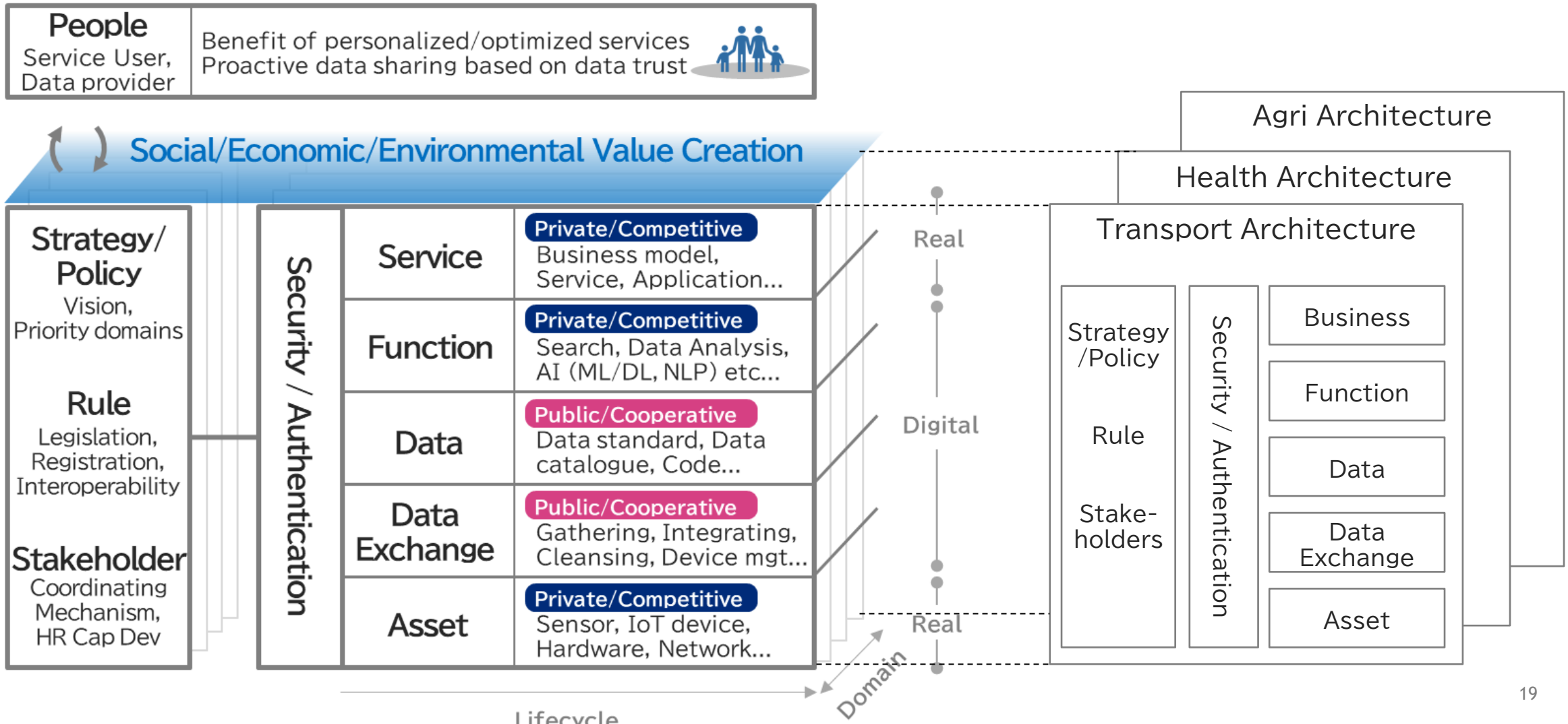
- Difficult to set barriers to entry in the digital space, so dominance by foreign PFs is likely to occur.
- Users lock-in by the PFs that increases the cost of switching and the risk of giving up its profits and value-added data captured, thereby hindering the social return as a whole.
- The government should take the lead in the cooperative area - define common functions, promote data utilization by industry / government / academia, and create an enabling environment for innovation.

Competitive Area (Private-led)

- The private sector develops services, applications, and devices, on the common functions defined in the cooperative area by the public.
- Holding a level playing field to mobilize private-led ideas and finances in the competitive area is a key factor for generating diverse and convenient services for the people.

Digital Architecture 3/3 – Use by Domains

The reference digital architecture is an abstract, conceptual framework. This should be used in response to each sector domain.



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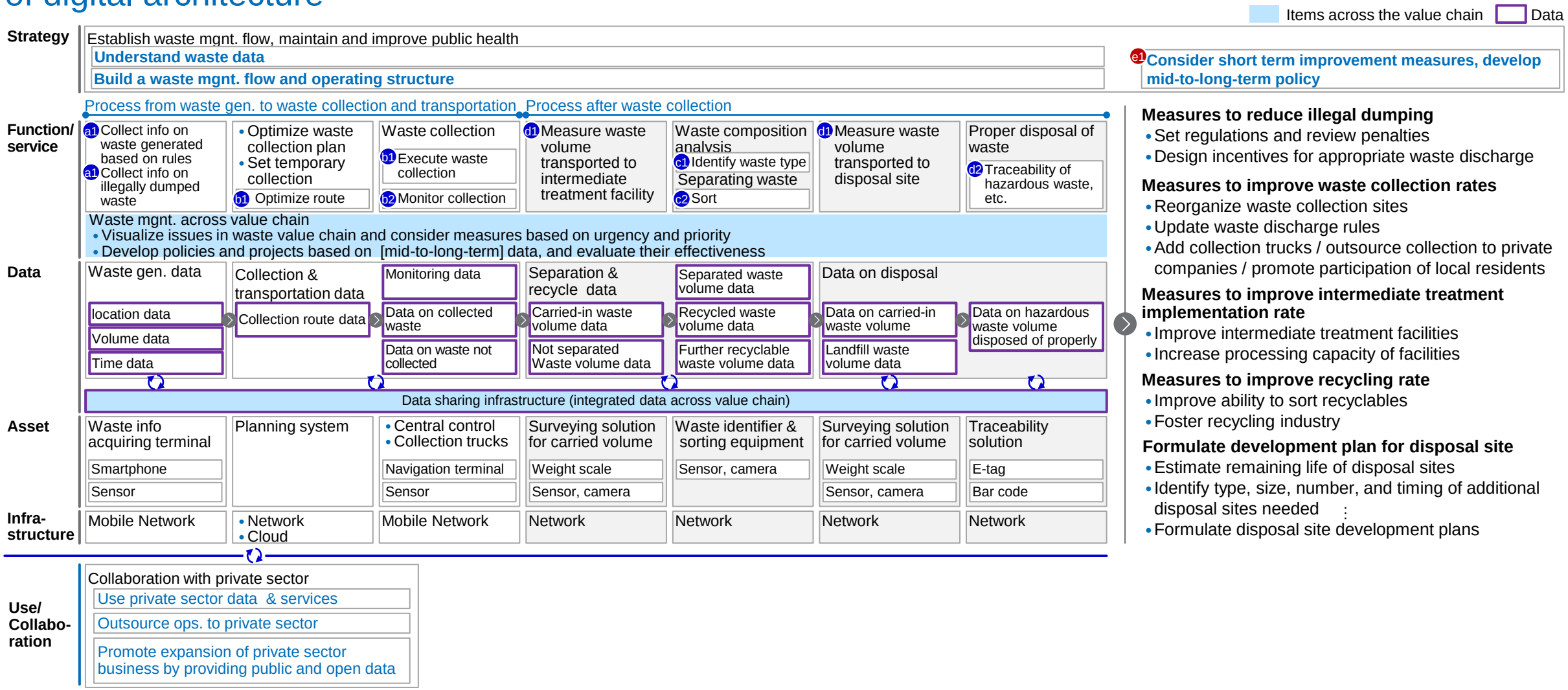
To realize data collaboration across the value chain and create added value, necessary to consider appropriate intervention points and role to be played by public based on a holistic view of digital architecture



Measures to reduce illegal dumping
- Set regulations and review penalties
- Design incentives for appropriate waste discharge

Measures to improve waste collection rates
- Reorganize waste collection sites
- Update waste discharge rules
- Add collection trucks / outsource collection to private companies / promote participation of local residents

Measures to improve intermediate treatment implementation rate
- Improve intermediate treatment facilities
- Increase processing capacity of facilities

Measures to improve recycling rate
- Improve ability to sort recyclables
- Foster recycling industry

Formulate development plan for disposal site
- Estimate remaining life of disposal sites
- Identify type, size, number, and timing of additional disposal sites needed
- Formulate disposal site development plans

To realize data collaboration across the value chain and create added value, necessary to consider appropriate intervention points and role to be played by public based on a holistic view of digital architecture

Items across the value chain | Data

Strategy

Establish waste mgnt. flow, maintain and improve public health

Understand waste data

Build a waste mgnt. flow and operating structure

e1 **Consider short term improvement measures, develop mid-to-long-term policy**

Process from waste gen. to waste collection and transportation | Process after waste collection

Function/ service

a1 Collect info on waste generated based on rules a1 Collect info on illegally dumped waste	• Optimize waste collection plan • Set temporary collection b1 Optimize route	Waste collection b1 Execute waste collection b2 Monitor collection	d1 Measure waste volume transported to intermediate treatment facility	Waste composition analysis c1 Identify waste type Separating waste c2 Sort	d1 Measure waste volume transported to disposal site	Proper disposal of waste d2 Traceability of hazardous waste, etc.

Waste mgnt. across value chain
- Visualize issues in waste value chain and consider measures based on urgency and priority
- Develop policies and projects based on [mid-to-long-term] data, and evaluate their effectiveness

Data

Waste gen. data location data Volume data Time data	Collection & transportation data Collection route data	Monitoring data Data on collected waste Data on waste not collected	Separation & recycle data Carried-in waste volume data Not separated Waste volume data	Separated waste volume data Recycled waste volume data Further recyclable waste volume data	Data on disposal Data on carried-in waste volume Landfill waste volume data	Data on hazardous waste volume disposed of properly

Data sharing infrastructure (integrated data across value chain)

Asset

Waste info acquiring terminal Smartphone Sensor	Planning system	• Central control • Collection trucks Navigation terminal Sensor	Surveying solution for carried volume Weight scale Sensor, camera	Waste identifier & sorting equipment Sensor, camera	Surveying solution for carried volume Weight scale Sensor, camera	Traceability solution E-tag Bar code

Infra-structure

Mobile Network	• Network • Cloud	Mobile Network	Network	Network	Network	Network

Use/ Collabo-ration

Collaboration with private sector
- Use private sector data & services
- Outsource ops. to private sector
- Promote expansion of private sector business by providing public and open data

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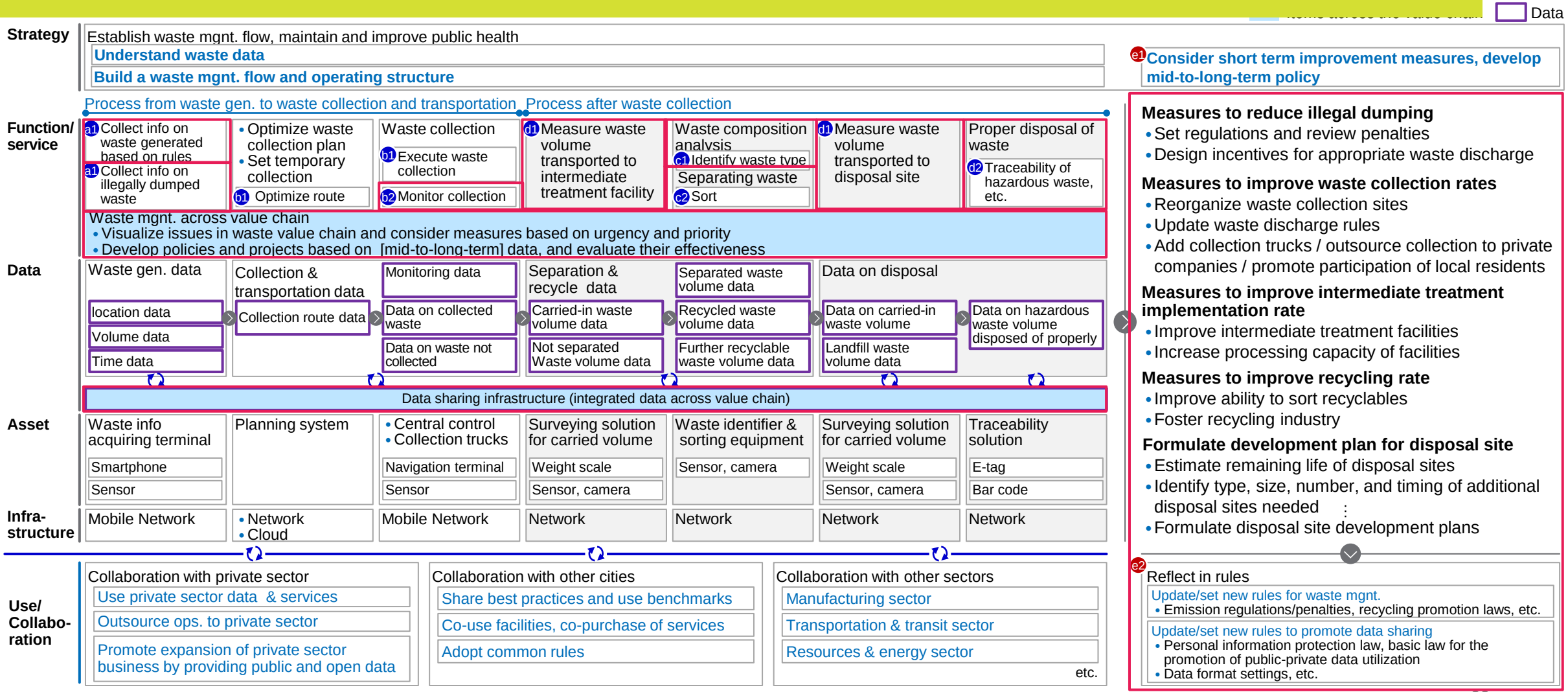
e2 Reflect in rules

Update/set new rules for waste mgnt.
- Emission regulations/penalties, recycling promotion laws, etc.

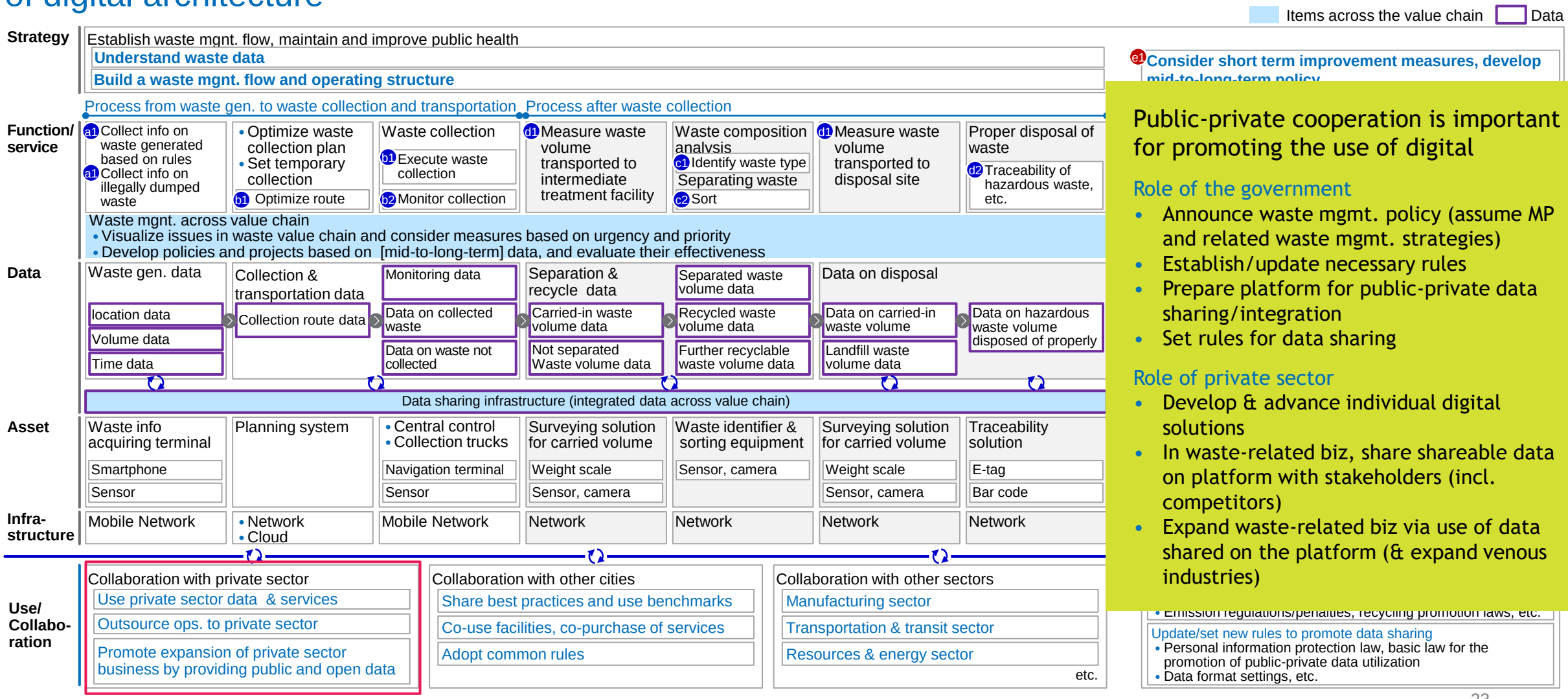
Update/set new rules to promote data sharing
- Personal information protection law, basic law for the promotion of public-private data utilization
- Data format settings, etc.

- Through the appropriate accumulation, mgmt and use of acquired data, using digital solutions enables more comprehensive impact (connect point of individual support to line then plane)
- To do this, it's necessary to imagine the ideal big picture (digital architecture) and promote the preparation of data sharing infra in addition to introducing individual solutions



Since JICA alone cannot provide support using digital solutions, suitable stakeholders (e.g., companies with digital solutions) are needed

of digital architecture



Public-private cooperation is important for promoting the use of digital

Role of the government

- Announce waste mgmt. policy (assume MP and related waste mgmt. strategies)
- Establish/update necessary rules
- Prepare platform for public-private data sharing/integration
- Set rules for data sharing

Role of private sector

- Develop & advance individual digital solutions
- In waste-related biz, share shareable data on platform with stakeholders (incl. competitors)
- Expand waste-related biz via use of data shared on the platform (& expand venous industries)

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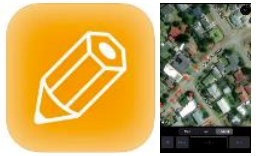
: Data that should certainly have been acquired
: Data that should have been or could have been acquired

1 Smartphone app that lets you pin and make notes on any location (could be used in creating data on waste location)

Japan

Development stage	Value chain				Experimental	Data generated			Internet required	
Stage 1	Waste generation	Collection & transportation	Separation & recycling	Disposal	Practical use	Volume	Composition	Location	Yes	No

Smartphone app that lets you pin locations and make notes
- Can drop a pin and mark current location with a single touch
- Can drop pins offline
- Has note-taking function

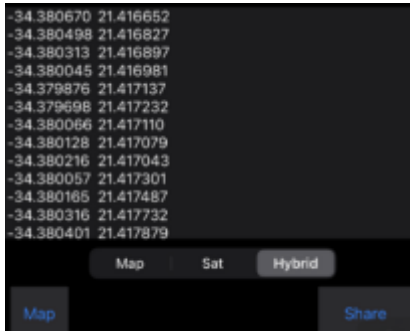


Details of digital solution use

Creator		Shigeto TAKAGI
Use case initiatives		• Smartphone app that lets you record location info and note on a map using app GPS function
Digital tech used/data used		• GPS
Digital architecture	Service/ function layer	• Record of GPS info
	ID/data layer	• Location, map
	Data link/PF layer	• Data linkage
	Device/ infrastructure layer	• Smartphone/(mobile network)

Outcome

Can easily record location info and notes
- Can drop pins offline
- Can output longitude/ latitude of pins



Opinion on use

- Can probably be used in mapping generated waste
- Can add info on volume with notes function
- Can be used in countries/cities with poor mobile networks since pins can be placed offline if map data is downloaded
- Lat./long. data is easily extractable, probably easy to link to other digital solutions

Source: https://apps.apple.com/jp/app/%E5%9C%B0%E5%9B%B3%E3%83%A1%E3%83%A2%E8%A8%98%E9%8C%B2%E4%BD%9C%E6%88%90-%E4%BD%8F%E6%89%80%E6%A4%9C%E7%B4%A2/id572421776

: Data that should certainly have been acquired
: Data that should have been or could have been acquired

2 Estimating volume of waste piles using stereo camera/LiDAR

Japan

Development stage: **Stage 1** | Stage 2 | Stage 3

Value chain: **Waste generation** | Collection & transportation | Separation & recycling | Disposal

Experimental | Practical use

Data generated: **Volume** | Composition | Location

Internet required: Yes | **No**

Using images taken by stereo camera or LiDAR, estimate the 3D form of an object and roughly calculate the volume to estimate the amount of waste

Details of digital solution use		
Provider		Applied Vision Systems Corporation
Summary		• Roughly calculate the volume of piles of trash • Can measure efficiently since stereo cameras/LiDAR are easy to move • Highly possible it can also be used in countries with less developed infrastructure since it does not require a network
Digital tech used/data used		• Stereo vision • Image analysis
Digital architecture	Service/ function layer	• Waste volume estimate
	ID/data layer	• 3D cloud point data
	Data link/PF layer	• –
	Device/ infrastructure layer	• Stereo camera or laser scanner(LiDAR measuring tool)

Outcome

Can roughly calculate volume using images taken by stereo camera or LiDAR and estimating the 3D form of an object

- May not be able to correctly measure if there are overexposed whites or crushed blacks in stereo camera picture
- LiDAR is better in terms of measurement stability and equipment maintainability

Opinion on use

- A solution for estimating volume, so must be linked with image location info to map waste
- Can probably be used with GPS
- It can probably be used in many countries since it does not require digital infrastructure
- If smartphone LiDAR can be used, it would improve portability

Source: https://avsc.jp/service/solution/case/AVSCalc3D.html

: Data that should certainly have been acquired
: Data that should have been or could have been acquired

2' (Ref) iPhone 3D scanning function using LiDAR

Japan

Development stage: **Stage 1** | Stage 2 | Stage 3

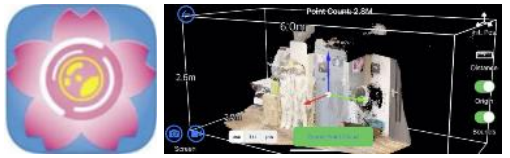
Value chain: **Waste generation** | Collection & transportation | Separation & recycling | Disposal

Experimental | **Practical use**

Data generated: **Volume** | Composition | Location

Internet required: Yes | **No**

Use iPhone LiDAR function to create 3D cloud point data



Details of digital solution use

Provider		Armonicos Co., Ltd.
Summary		• Offer app that creates 3D cloud point data using iPhone LiDAR function
Digital tech used/data used		• LiDAR
Digital architecture	Service/ function layer	• 3D cloud point data creation
	ID/data layer	• 3D cloud point data
	Data link/PF layer	• –
	Device/ infrastructure layer	• iPhone LiDAR sensor

Outcome

Can easily obtain 3D cloud point data

Picture

Generated 3D cloud point data

Opinion on use

- If it can be used in estimating volume of pile of waste using stereo camera/LiDAR, the volume of waste in irregular open dumps could be effectively measured
- Need to keep in mind this digital solution can only estimate volume

Source: https://www.armonicos.co.jp/shop/sakura/

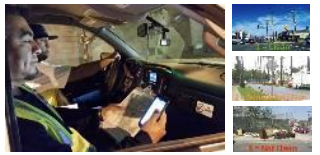
: Data that should certainly have been acquired
: Data that should have been or could have been acquired

3 Mapping trash abandoned on the road via mobile app that uses GIS

United States | 2016～

Development stage	Value chain				Experimental	Data generated			Internet required	
Stage 1	Waste generation	Collection & transportation	Separation & recycling	Disposal	Practical use	Volume	Composition	Location	Yes	No

2 surveyors patrol the survey area by car, then enter a trash accumulation score for each road segment into a GIS-linked mobile app to create a map
- Type of waste (4): regular trash, oversized trash, illegal dumping, weeds
- Trash accumulation score (3 levels): no trash, permissible range, requires collection



Details of digital solution use

Providers		Los Angeles Dept of Public Health
Use case initiatives		• Employees of the city Dept of Public Health patrol city streets to assess trash accumulation, then turn it into data using a mobile system • Map roads with high amt of waste based on data
Digital tech used/data used		• GIS
Digital architecture	Service/ function layer	• Mapping of types, volume of trash on roads
	ID/data layer	• Trash type, volume, location info & map info
	Data link/PF layer	• Data collection, data integration
	Device/ infrastructure layer	• In-vehicle camera/mobile network

Outcome

Map waste info to roads by patrolling over 22,000 miles
- Types (4): regular trash, oversized trash, illegal dumping, weeds
- Trash accumulation score (3 levels): no trash, permissible range, requires collection

Opinion on use

- Can map waste by driving around city in car and recording where waste has been left
- Requires labor but no special skills, probably low hurdle to use
- This solution uses mobile network, but a method to record status using GPS location and read it later may be possible

Source: https://lahub.maps.arcgis.com/apps/MapJournal/index.html?appid=7279dc87ea9e416d9f90bf844505a54a

: Data that should certainly have been acquired
: Data that should have been or could have been acquired

4 Detecting and mapping types of city waste using camera-equipped smartphone and AI

The Netherlands 2020～

Development stage: **Stage 1** | Stage 2 | Stage 3

Value chain: **Waste generation** | Collection & transportation | Separation & recycling | Disposal

Experimental | Practical use

Data generated: **Volume** | **Composition** | **Location**

Internet required: **Yes** | No

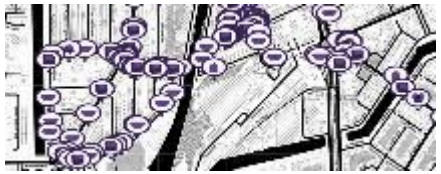
Take pictures of waste within city using mobile camera and app to generate info on and map volume, types, and location of waste using AI image analysis

Details of digital solution use

Providers		City of Amsterdam Innovation Team
Use case initiatives		• Build a reporting scheme for waste info that scales and allows resident participation via installation of a smartphone app • Waste mapping based on collected info
Digital tech used/data used		• Image analysis • GPS
Digital architecture	Service/ function layer	• Waste type, volume mapping
	ID/data layer	• Waste type, volume, location info, map info
	Data link/PF layer	• Data collection, data integration
	Device/ infrastructure layer	• Smartphone with camera/mobile network

Outcome

- Smartphone camera images, GPS location, and time of capture sent to central server in real-time
- Waste is detected in central server and a map created
  - Compatible with cardboard, trash bags, waste disposal containers, lumber (to be expanded)



Opinion on use

- Needs mobile network, smartphone but can be used in creating composition data
- Could also be used to collect waste info via use by citizens
- Code is open source so it could be started at low cost

Source: https://www.odk.ai/#/, https://marketplace.intelligentcitieschallenge.eu/en/solutions/object-detection-kit-scanning-objects-for-a-cleaner-city, https://openresearch.amsterdam/nl/page/54917/object-detection-kit

: Data that should certainly have been acquired
: Data that should have been or could have been acquired

5 Mapping illegally dumped waste using resident participation via smartphone app

Slovakia

Development stage	Value chain				Data generated			Internet required	
Stage 1	Waste generation	Collection & transportation	Separation & recycling	Disposal	Volume	Composition	Location	Yes	No
Stage 2									
Stage 3									
				Experimental					
				Practical use					

Take pictures of illegally dumped city waste using smartphone with camera and map using app
- Resident participation app
- Goal is to alert local government and NGOs of waste info

Details of digital solution use

Providers		TrashOut.NGO
Summary		• Take picture of trash with smartphone camera and map using app
Digital tech used/data used		• GPS (on smartphone)
Digital architecture	Service/ function layer	• Waste mapping
	ID/data layer	• Waste location info, image data, map info
	Data link/PF layer	• Data collection, data integration
	Device/ infrastructure layer	• Smartphone with camera/mobile network

Outcome

- Residents submit info on trash
- A map with images of trash is created
  - Can submit add'l info on whether it was collected or not

Opinion on use

- May be useful in countries/cities where smartphones are commonplace
- Seems good from a cost standpoint since waste is mapped via resident participation
- Useful in fostering resident awareness of waste mgmt?

Source: https://www.trashout.ngo/, https://www.crunchbase.com/organization/trashout

: Data that should certainly have been acquired
: Data that should have been or could have been acquired

5 Mapping & collecting illegally dumped waste using resident participation via smartphone app

Japan

Development stage: **Stage 1** | Stage 2 | Stage 3

Value chain: **Waste generation** | Collection & transportation | Separation & recycling | Disposal

Experimental | **Practical use**

Data generated: **Volume** | Composition | **Location**

Internet required: **Yes** | No

Residents take pictures of illegally dumped trash they have collected using smartphone camera and share info/map it via app

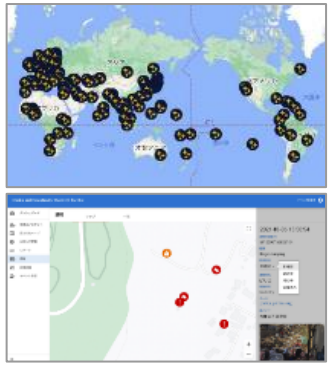
- Citizen participation app
- Forms and develops momentum for litter picking activities by having users mutually share and acknowledge each other
- Also offer a local gov't version of Pirika so they can quantitatively understand status of litter and be alerted to illegal dumping

Details of digital solution use

Provider		Pirika, Inc.
Summary		• Residents take pictures of illegally dumped trash they have collected using smartphone camera and share info/map it via app
Digital tech used/data used		• GPS (on smartphone)
Digital architecture	Service/ function layer	• Waste mapping
	ID/data layer	• Waste location info, image data, map info
	Data link/PF layer	• Data collection, data integration
	Device/ infrastructure layer	• Smartphone with camera/mobile network

Outcome

- Has spread to over 100 countries, with over 200M pieces of trash picked up
- Local gov't version of Pirika has also been introduced to 19 municipalities domestically



Opinion on use

- May be useful in countries/cities where smartphones are commonplace
- Seems good from a cost standpoint since waste is mapped via resident participation
- Useful in fostering resident awareness of waste mgmt?

Source: https://corp.pirika.org/, https://apps.apple.com/jp/story/id1613284617

: Data that should certainly have been acquired
: Data that should have been or could have been acquired

6 Estimate of amount waste in open dump via drone aerial survey

India 2021

Development stage: **Stage 1** | Stage 2 | Stage 3

Value chain: **Waste generation** | Collection & transportation | Separation & recycling | Disposal

Experimental | Practical use

Data generated: **Volume** | Composition | **Location**

Internet required: Yes | **No**

At open dumps in Mumbai, India, volume of waste being removed is estimated using drone photogrammetry, and has shown high accuracy

- Margin of error for estimated volume from aerial photogrammetry and actual volume is under 10%

Details of digital solution use

Providers		Pioneer Foundation Engineers (P) Ltd
Use case initiatives		• In order to use open dumps for other purposes, total amt of waste to remove and periodic progress are estimated using drone photogrammetry & amt of work needed is specified. Utilized in activity planning

Digital tech used/data used		• Drone photogrammetry
		  - Image analysis
		  - GIS
		  - Differential GPS

Digital architecture	Service/ function layer	• Waste volume estimate
	ID/data layer	• Waste volume/location info
	Data link/PF layer	• –
	Device/ infrastructure layer	• Drone, camera

Outcome

Via drone photogrammetry, estimate waste volume with <10% margin of error

- MOE is calculated by comparing drone estimated volume and actual volume removed by truck
  - 1st trial MOE: 8.5%
  - 2nd trial MOE: 9%
  - 3rd trial MOE: 7.8%
- 12 ground reference points set for surveying

Opinion on use

- Drone may not need telecom network
- Can it be used to estimate total amt. of waste in large garbage dumps already located?

Source: https://www.ijert.org/research/waste-volume-estimation-using-drone-based-photogrammetry-IJERTCONV9IS04023.pdf

: Data that should certainly have been acquired
: Data that should have been or could have been acquired

7 Real-time collection of waste levels in containers using sensors

Spain 2021～

Development stage	Value chain				Data generated			Internet required	
Stage 1	Waste generation	Collection & transportation	Separation & recycling	Disposal	Volume	Composition	Location	Yes	No
Stage 2									
Stage 3									
	Experimental								
	Practical use								

Place ultrasonic sensors in city waste containers and collect waste priority level info in real-time

Details of digital solution use

Providers		Liberium
Use case initiatives		• Verify ultrasonic sensors can be placed in city waste containers and collect waste priority level in real-time
Digital tech used/data used		• Ultrasonic sensor tech
Digital architecture	Service/ function layer	• Collect and map volume of waste in waste containers
	ID/data layer	• Waste volume, location info, map info
	Data link/PF layer	• Data collection, data integration
	Device/ infrastructure layer	• Ultrasonic sensor/mobile network

Outcome

Can monitor city waste status in real-time

- Measured 24x/day and info aggregated
- Data to analyze dynamics of waste generation can be acquired and used to plan optimal routes for collection vehicles

Opinion on use

- Needs telecom network, but seems simple to install
- Can be used to get info on dynamic city waste situation
- However, may need periodic battery replacement (once every few years)

Source: https://www.libelium.com/iot-solutions/waste-management/, https://www.libelium.com/libeliumworld/success-stories/libelium-tests-the-new-smart-solution-for-waste-management-in-urban-containers/

: Data that should certainly have been acquired
: Data that should have been or could have been acquired

8 Identifying types and location of waste drifted onto shore via aerial drone images and AI

Japan 2020～

Development stage: **Stage 1** | Stage 2 | Stage 3

Value chain: **Waste generation** | Collection & transportation | Separation & recycling | Disposal

Experimental | Practical use

Data generated: **Volume** | **Composition** | **Location**

Internet required: Yes | **No**

Analyze aerial drone images to identify 9 categories of waste (plastic, Styrofoam, etc.) washed up on shore, then estimate type, distribution, and size

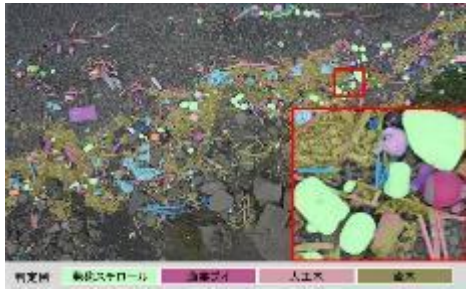
Details of digital solution use

Providers		Ridge-i
Use case initiatives		• Understand types of waste washed up on the beach and where it is located through AI image analysis of aerial drone images
Digital tech used/data used		• Image analysis • GPS
Digital architecture	Service/ function layer	• Estimate of types, distribution, and size of waste washed up on beach
	ID/data layer	• Waste type, amount, location info, map info
	Data link/PF layer	• –
	Device/ infrastructure layer	• Drone and installed camera

Outcome

Estimate of types, distribution, and size of waste washed up on beach

- Identify 9 categories incl. plastic, Styrofoam, fishing buoys, artificial wood and driftwood
- An aerial image can be analyzed in about 4 mins.



Opinion on use

- Drone may not need telecom network
- Can it be used to get distribution of trash on the shore, incl. plastic waste?

Source: https://deep-space.ridge-i.com/solutions/environment#marine-debris, https://prtimes.jp/main/html/rd/p/000000019.000026963.html

: Data that should certainly have been acquired
: Data that should have been or could have been acquired

9 Identifying the location of plastic waste in the city and ocean using satellite remote sensing

Vietnam 2019～

Development stage: **Stage 1** | Stage 2 | Stage 3

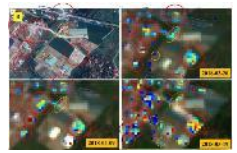
Value chain: **Waste generation** | Collection & transportation | Separation & recycling | Disposal

Experimental | Practical use

Data generated: Volume | **Composition** | **Location**

Internet required: Yes | **No**

Through remote sensing spectral analysis using satellite images, can identify plastic waste hotspots over a wide area



Details of digital solution use

Providers		Japan Manned Space Systems Corporation (JAMSS)
Use case initiatives		• Through remote sensing spectral analysis using satellite images, identify plastic waste hotspots over a wide area
Digital tech used/data used		• Remote sensing (spectral analysis)
Digital architecture	Service/ function layer	• Plastic waste detection
	ID/data layer	• Plastic waste location info, map info
	Data link/PF layer	• –
	Device/ infrastructure layer	• Satellite camera

Outcome

Detect plastic waste hotspots using satellite imagery

- There are limitations due to satellite camera resolution, can't detect plastic waste with area of <10m^2
- Rock faces and ships are sometimes detected as plastic waste, so accuracy can be improved

Opinion on use

- Can analyze without going on-site
- Can it be used to identify location of plastic waste hotspots in areas of support?
- Since false recognition is possible, if accuracy is required, add'l surveys on the ground may be required

Source: https://www.undp.org/vietnam/blog/remote-sensing-smart-city-solution-municipal-waste-management, https://www.jamss.co.jp/corp/sdgs/

: Data that should certainly have been acquired
: Data that should have been or could have been acquired

10 Understanding of waste container fill rates using sensors & waste collection route optimization

Turkey 2022～

Development stage: **Stage 1** | Stage 2 | Stage 3

Value chain: **Waste generation** | **Collection & transportation** | Separation & recycling | Disposal

Experimental | Practical use

Data generated: **Volume** | Composition | **Location**

Internet required: **Yes** | No

Understand fill rate via sensors placed in each waste container & optimize waste collection routes to minimize travel distance of multiple collection vehicles

Details of digital solution use

Providers		evreka
Use case initiatives		• Understand fill rate of via sensors installed in waste containers • Optimize waste collection routes to minimize total travel distance of multiple collection vehicles based on sensor volume and collection vehicle capacity • Done using device with internet connection
Digital tech used/data used		• Ultrasonic sensor tech • GPS
Digital architecture	Service/ function layer	• Mapping of amt of waste in containers, collection route optimization
	ID/data layer	• Waste volume, location info, map info
	Data link/PF layer	• Data collection, data integration
	Device/ infrastructure layer	• Ultrasonic sensors, mobile device/mobile network

Outcome

By understanding the fill rate of city waste containers, an optimal collection plan for multiple vehicles can be developed

Opinion on use

- Waste Mgmt Dept containers, telecom network needed but sensors can be retrofitted so low hurdle besides initial costs?
- Sensor batteries last for several years so seems good from maint. perspective once installed

Source: https://evreka.co/solutions/route-optimization/, https://evreka.co/blog/waste-routing-software-paving-the-way-for-smart-waste-management/, https://evreka.co/wp-content/uploads/2021/01/Evreka-Sense-1.pdf

: Data that should certainly have been acquired
: Data that should have been or could have been acquired

11 Optimization of waste collection routes

Japan 2020～

Development stage			Value chain				Experimental	Data generated			Internet required	
Stage 1	Stage 2	Stage 3	Waste generation	Collection & transportation	Separation & recycling	Disposal	Practical use	Volume	Composition	Location	Yes	No

Can record where trash has accumulated, plan route, and give route guidance (route mgmt)
Can also change the route, reflecting sudden changes in collection system and real-time collection status (route adjustment)
Collection status and location of collection vehicles can also be confirmed on map (collection status mgmt)

Details of digital solution use

Providers		Odakyu
Use case initiatives		• Used and customized RUBICON Global tech for Japanese waste collection, and offer route mgmt, route adjustment, and collection status mgmt functions
Digital tech used/data used		• GPS
Digital architecture	Service/ function layer	• Collection route optimization
	ID/data layer	• Waste volume, location info, map info
	Data link/PF layer	• Data collection, data integration
	Device/ infrastructure layer	• Mobile device/mobile network

Outcome

- Optimize route to collect waste from registered collection points
- Can also change routes based on real-time collection status

Opinion on use

- Can set points for waste collection, may be easy to link to waste generation info from other digital solutions
- Can also be used to manage vehicle driving conditions, amt. collected, could address many functions needed in developing countries

Source: https://www.wooms.jp/case/zama/

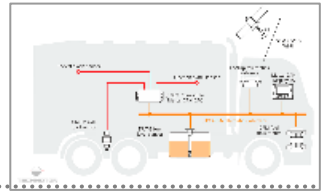
: Data that should certainly have been acquired
: Data that should have been or could have been acquired

12 Monitoring of improper loading & unloading of trash using GPS and weight sensors

Belarus

Development stage			Value chain				Experimental	Data generated			Internet required	
Stage 1	Stage 2	Stage 3	Waste generation	Collection & transportation	Separation & recycling	Disposal	Practical use	Volume	Composition	Location	Yes	No

Track where waste is loaded/unloaded via data on weight applied to axle and GPS, monitor unauthorized loading/unloading
Can also detect inefficient or improper operations such as idling, speeding, sudden braking and fuel theft



Details of digital solution use

Providers		TECHNOTON
Use case initiatives		• Record key parameters of truck operations using waste collection vehicle monitoring system • Track where waste is loaded/unloaded via weight applied to axle and GPS, monitor if there are irregularities such as unauthorized loading/unloading
Digital tech used/data used		• GPS • Axle sensor tech • Fuel level sensor tech, etc.
Digital architecture	Service/ function layer	• Analyze behaviors and weight of trash in vehicle and detect any irregularities
	ID/data layer	• Waste volume, vehicle location, record of operations
	Data link/PF layer	• Data collection
	Device/ infrastructure layer	• Various sensors/mobile network

Outcome

Can now understand whether collection is going well or if it is being properly loaded/unloaded via changes in load

Opinion on use

- Telecom network needed but may be effective in the case of human wrongdoing
- Could also be used in understanding amt. of waste carried in from dump site
- Need to keep necessity of hardware and maint in mind

Source: https://jv-technoton.com/solutions/garbage-truck-monitoring/, https://technoton-usa.com/industries/waste-collection-vehicles/

: Data that should certainly have been acquired
: Data that should have been or could have been acquired

13 Understanding of waste collection records for each household using a smartphone app

India 2022～

Development stage: **Stage 1** | Stage 2 | Stage 3

Value chain: **Waste generation** | **Collection & transportation** | Separation & recycling | Disposal

Experimental | Practical use

Data generated: **Volume** | Composition | **Location**

Internet required: **Yes** | No

The state of Kerala in India provides an app to manage and track amt of inorganic waste collected from each household
- Each household assigned QR code, can understand volume of waste from each household
- Each household can request waste collection through the app if it has not been collected properly
  - If the collection request is not dealt with in time, it will automatically be forwarded to a higher agency, guaranteeing it will be dealt with

Details of digital solution use			Outcome	Opinion on use
Providers		Indian state of Kerala, (Tech provider: Keltron)	Can now acquire info on amt of waste and disposal timing for each household • Local gov't can understand amt of waste and when it is disposed of for each household, and can receive requests for collection when it not being collected properly • Households can benefit from a proper waste collection service	• Telecom network needed • Could be effective for door-to-door collection • Could be possible to set QR to dump site to obtain waste collection status of dump sites from citizens
Use case initiatives		• Amt and timing of waste disposal for each household is acquired from their assigned QR code • App has a report function that allows households to request collection if it was not done properly		
Digital tech used/data used		• Camera • QR code		
Digital architecture	Service/ function layer	• Understanding of amt of waste collected, accepting collection requests		
	ID/data layer	• Waste disposal ID, volume data, date/time data		
	Data link/PF layer	• Data collection, storage, mgmt		
	Device/ infrastructure layer	• Smartphone/mobile network		

Source: https://timesofindia.indiatimes.com/city/kochi/app-to-streamline-waste-collection-treatment-in-keralas-district/articleshow/93243350.cms, https://english.mathrubhumi.com/news/kerala/qr-code-scanners-to-install-in-houses-for-real-time-data-availability-of-waste-management-1.7965553, https://timesofindia.indiatimes.com/city/thiruvananthapuram/mobile-app-for-waste-collection-monitoring/articleshow/87766691.cms

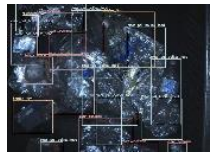
: Data that should certainly have been acquired
: Data that should have been or could have been acquired

14 Identifying types of waste with AI in real-time & creation of composition data

England 2019～

Development stage			Value chain				Experimental	Data generated			Internet required	
Stage 1	Stage 2	Stage 3	Waste generation	Collection & transportation	Separation & recycling	Disposal	Practical use	Volume	Composition	Location	Yes	No

Accurately identify types of waste in real-time via AI image analysis
- Used in creating composition data and assuring purity of recyclables
- Can be linked to other systems via API

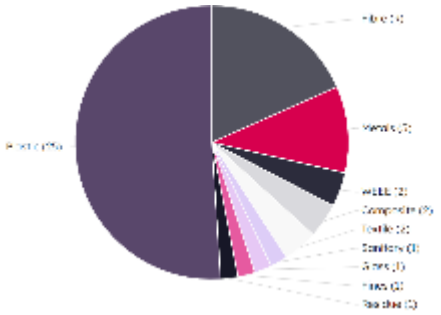


Details of digital solution use

Providers		Greyparrot
Use case initiatives		• Identify types of waste in real-time using AI image recognition and acquire composition data • Can be linked with various systems as open API • Can be installed by retrofitting existing conveyor belts
Digital tech used/data used		• Image analysis • API • Dashboard function
Digital architecture	Service/ function layer	• Identify types, volume of waste, create composition data
	ID/data layer	• Image data, volume data, composition data
	Data link/PF layer	• Data collection, analysis
	Device/ infrastructure layer	• Monitoring unit (incl. camera)/telecom network, waste disposal facility

Outcome

Can discern even crushed and overlapping waste that cannot be discerned by the human eye to create composition data
- Waste sorted into 10 categories, 49 types
- Error rate of <1%



Opinion on use

- High-precision composition segmentation possible so it may be used in verifying quality of recycled goods & acquiring basic data on recycling rate

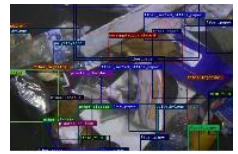
Source: https://www.greyparrot.ai/,

: Data that should certainly have been acquired
: Data that should have been or could have been acquired

15 Identifying types of domestic waste with AI in real-time and separation using sorting robots

United States	2015～	Development stage	Value chain				Data generated			Internet required	
		Stage 1	Waste generation	Collection & transportation	Separation & recycling	Disposal	Volume	Composition	Location	Yes	No
		Stage 2									
		Stage 3									
			Experimental								
			Practical use								

Identify types of household waste via AI image analysis in real-time, pick up and separate using sorting robots



Details of digital solution use		
Providers		AMP Robotics
Use case initiatives		• Identify type of waste in real time via AI image recognition • Pick up and separate specified types of waste using sorting robots
Digital tech used/data used		• Image analysis
Digital architecture	Service/ function layer	• Identify types of waste and classify
	ID/data layer	• Image data, composition data
	Data link/PF layer	• Data collection, analysis
	Device/ infrastructure layer	• Picking system (incl. camera, robot arm) /telecom network

Outcome

- Can separate up to 80 pieces of trash per min.
- Can reduce 8h of sorting to 3h by using this system with an assembly line

Opinion on use

- Could it be used to increase accuracy and efficiency of separation?
- May need to be cautious of necessary initial costs & maint

Source: https://www.amprobotics.com/artificial-intelligence, https://www.amprobotics.com/robotic-system

: Data that should certainly have been acquired
: Data that should have been or could have been acquired

16 Identifying types of construction waste, industrial waste with AI in real-time and separation using sorting robots

Finland

Development stage			Value chain				Experimental	Data generated			Internet required	
Stage 1	Stage 2	Stage 3	Waste generation	Collection & transportation	Separation & recycling	Disposal	Practical use	Volume	Composition	Location	Yes	No

Identify types of construction & industrial waste via AI image analysis in real-time, pick up and separate high-quality, recyclable trash using sorting robots

Details of digital solution use

Providers		ZENROBOTICS
Use case initiatives		• Identify type of waste in real time via AI image recognition • Pick up and separate specified types of waste using large-scale sorting robots
Digital tech used/data used		• Image analysis
Digital architecture	Service/ function layer	• Identify types of waste and classify
	ID/data layer	• Image data, composition data
	Data link/PF layer	• Data collection, analysis
	Device/ infrastructure layer	• Picking system (incl. camera, robot arm) / telecom network

Outcome

Can also efficiently separate large-scale waste, which is difficult to do manually

Opinion on use

- Could this be used to make separating physically large items more efficient?
- May need to be cautious of necessary initial costs & maint.

Source: https://zenrobotics.com/robots, https://zenrobotics.com/construction-demolition-waste

: Data that should certainly have been acquired
: Data that should have been or could have been acquired

17 Optimized aggregation/creation of data on amt. of materials using mobile app

Japan

Development stage: **Stage 1** | Stage 2 | Stage 3

Value chain: **Waste generation** | Collection & transportation | **Separation & recycling** | **Disposal**

Experimental | **Practical use**

Data generated: **Volume** | Composition | **Location**

Internet required: **Yes** | No

No-code mobile app creation tool that lets you easily create a mobile app tailored to company operations
- Possible to make apps that reduce man-hours for inspection, status reports from over 100 templates
- Can collect info via network from each device and easily create summarized info

Details of digital solution use

Providers		Asteria
Use case initiatives		• Service that lets you easily create mobile app with no coding • Can easily create app that lets you enter, aggregate items necessary for operations
Digital tech used/data used		• Mobile app
Digital architecture	Service/ function layer	• Simple data entry, automatic aggregation, management
	ID/data layer	• Data of set items
	Data link/PF layer	• Integration, data linkage
	Device/ infrastructure layer	• smartphone/telecom network

Outcome

Effectively create and aggregate info for operations via smartphone app you created
- Can create an app with only functions needed for your company's operations

Opinion on use

(If processes of determining, recording waste carried in from collection site are being done by hand) could greatly improve efficiency & timeliness of data creation, accuracy of aggregation

Source: https://plat.io/ja/

: Data that should certainly have been acquired
: Data that should have been or could have been acquired

18 Measure volume of waste in container using laser scanner

Portugal	Development stage	Value chain				Experimental	Data generated			Internet required	
	Stage 1	Stage 2	Stage 3	Waste generation	Collection & transportation	Separation & recycling	Disposal	Practical use	Volume	Composition	Location	Yes	No

Analyze containers filled with waste being brought into port using laser scanner to measure types and volume of contents

Details of digital solution use

Providers		CLEVER VOLUME
Use case initiatives		• Cloud-based volume measurement solution • Use laser scanner to estimate types and volume of waste brought into port in containers
Digital tech used/data used		• Laser scanning tech
Digital architecture	Service/ function layer	• Waste types, volume estimate
	ID/data layer	• Scanned image
	Data link/PF layer	• Data linkage
	Device/ infrastructure layer	• Laser scanner

Outcome

Improve efficiency of port inspections by estimating waste volume, types using laser scanner

Opinion on use

- Could be applied if configuration of collection vehicles is the same as vehicles bring waste into port
- Could make creation of data on volume carried in from disposal site more efficient

Source: https://apps.apple.com/jp/app/%E5%9C%B0%E5%9B%B3%E3%83%A1%E3%83%A2%E8%A8%98%E9%8C%B2%E4%BD%9C%E6%88%90-%E4%BD%8F%E6%89%80%E6%A4%9C%E7%B4%A2/id572421776

: Data that should certainly have been acquired
: Data that should have been or could have been acquired

19 Tracing of waste disposal using QR codes

Japan

Development stage			Value chain				Experimental	Data generated			Internet required	
Stage 1	Stage 2	Stage 3	Waste generation	Collection & transportation	Separation & recycling	Disposal	Practical use	Volume	Composition	Location	Yes	No

Trace waste by creating a QR code when it is disposed of, affixing a QR code to the waste, and scanning it whenever the waste is transferred

- Scanned data is sent to a smartphone, then sent via internet to the Japan Industrial Waste Information Center where statistics are automatically calculated for by generating dept

Details of digital solution use

Providers		E-SIS Inc.
Use case initiatives		• Add traceability to waste using QR codes
Digital tech used/data used		• QR code
Digital architecture	Service/ function layer	• QR code reading
	ID/data layer	• Type, weight, location, time
	Data link/PF layer	• Data linkage, data integration
	Device/ infrastructure layer	• QR code reader, QR code printer/telecom network

Outcome

Realize traceability using QR codes

Opinion on use

- Could be used in managing hazardous waste
- Applicability could be increased if it could be read by smartphone camera

Source: http://www.e-sis.co.jp/qr.html

Use case of digital solution #8 in a landfill in Pacific Islands (J-PRISM II)

3D-image of the M-Dock landfill site in Palau produced from a drone photo

Impact observed

- Increase efficiency in terms of cost, time and labor
- Secure staff working in landfills (hygienic point of view)
- Improved measurements in terms of accuracy and time
- Facilitate planning and consensus building among stakeholders

In J-PRISM II project, drones have also been used to take surveys of disposal sites for analysis. Previously, a site could only be observed from the ground, and it was difficult to grasp the complete picture of the site. But with aerial photography, it has become possible to visualize the current state of a site and to more accurately analyze how many more years a site can be used for.

Hundreds of photos were taken by a drone to create 3D model. Since then, the project team has been conducting 3D-mapping every half a year together with land surveys, to monitor the increment by comparing with the previous result. It made easy to plan the landfill site for the future and discuss with stakeholders by using visualized data.

Related article (link) → [Protecting the Pacific Islands from Waste | August 2020 | Highlighting Japan (gov-online.go.jp)]