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# Municipal solid waste collection evaluation tool as basis for LCA of MSW Management

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# Municipal Solid Waste Collection Evaluation Tool as Basis for LCA of MSW Management

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## Project

Development and Application of an Appropriate Municipal Solid Waste Management in Bangalore, India and Electronic City, India

I. Robust Waste Characterization
II. Accepted and Applicable Waste Collection
III. Modular and Flexible Waste Treatment
IV. Value Added Chain out of MSW

Thread

# Object of Investigation

City of Bangalore, India, with 11 million inhabitants


- only **50%** of MSW is collected by **waste collection**
- **20%** is collected by **street sweeping**
- **30%** is disposed on **litter spots**



Problem Statement

# Street View – Street Sweeping

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Problem Statement

# Waste Treatment – MBT

Input

Compost

RDF



Primary Data Collection

# Waste Characterisation

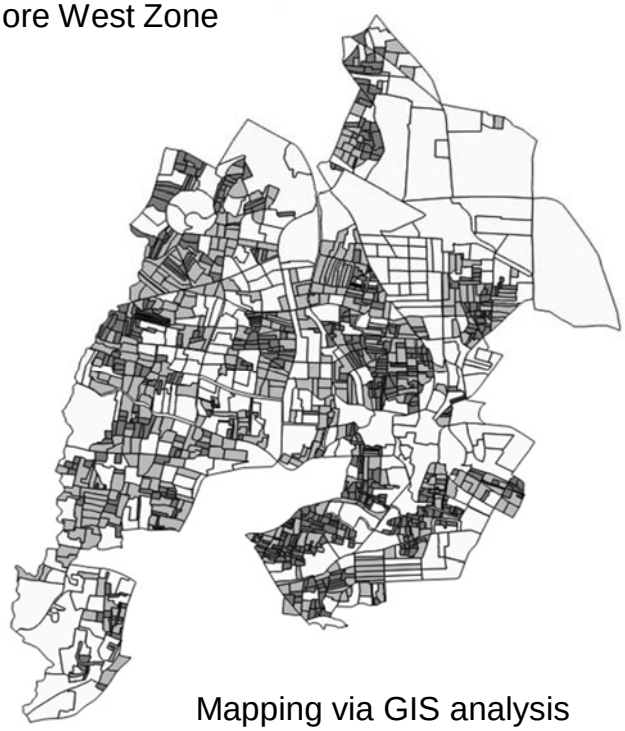
| | |
|---|---|
| Procedure Standard: | EU SWA-Tool (2004) |
| Sampling Area: | 44 Wards, Bangalore West Zone |
| Area Size: | 46.7 km² |
| Population: | 1.66 million |
| Sampling Volume: | **80 m³ MSW** |

Relevant Waste Streams:

- Door to Door Collection
- Litter Spots
- Street Sweeping

Stratification in Population Density [Inh/km²]

| | |
|---|---|
| Low Density | (< 30,000) |
| Medium Density | (30,000 -70,000) |
| High Density | (> 70,000) |



Mapping via GIS analysis

# Waste Characterisation

Primary Data Collection

Leibniz Universität Hannover

**Litter Spots on empty plots**

**Waste Collection Vehicle (1.2 m³)**

**Cleaning of Litter Spots**

**Overloaded street sweeping pushcart**



# Waste Characterization Study

Primary Data Collection

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Fresh collected waste

Fraction > 77 mm

Sorting Process

Fraction 14 - 55

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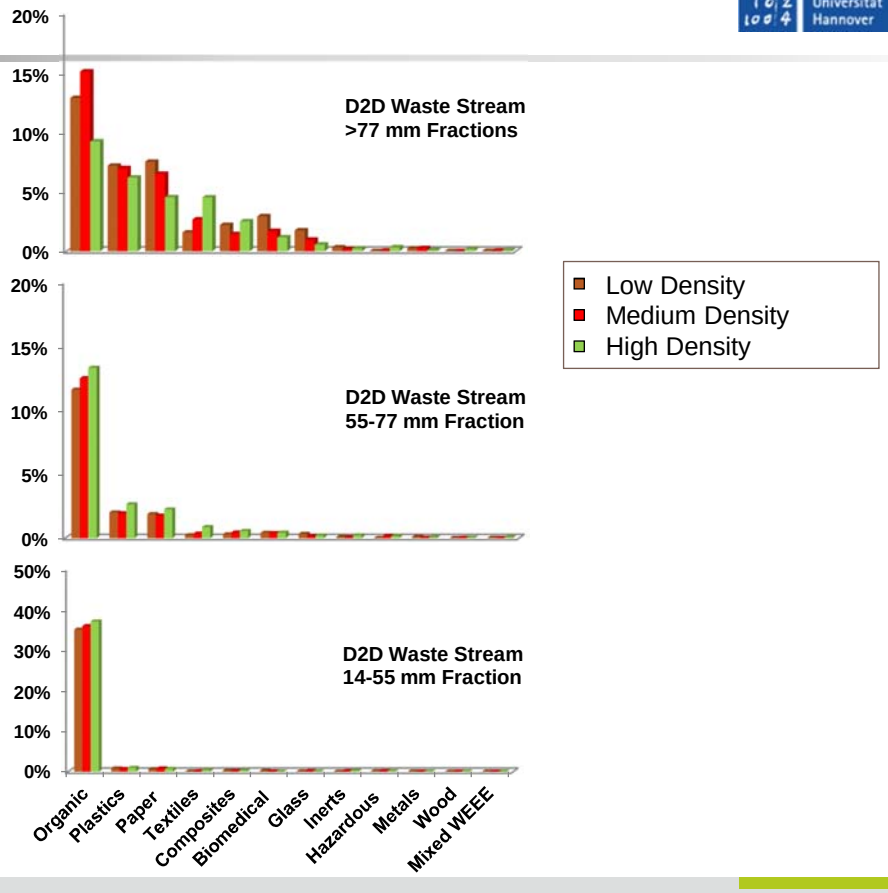
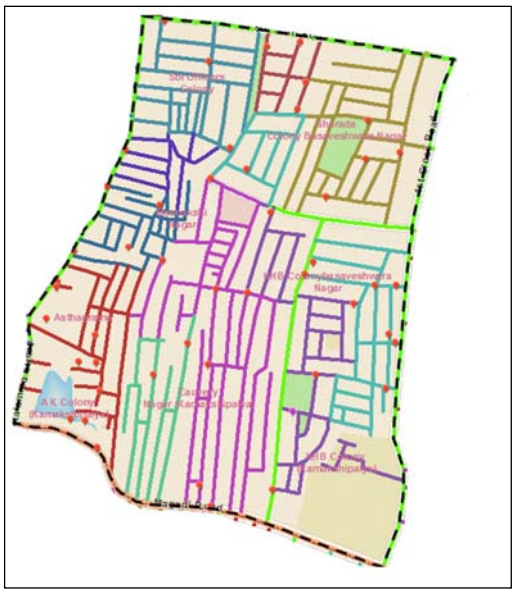







# Local Boundary Conditions

- Routes for MSW collection barely exist
- Low fuel efficiency of collection vehicles
- Low loading capacities of collection vehicles
- Regular breakdowns of equipment / vehicles
- Old and insufficient collection equipment

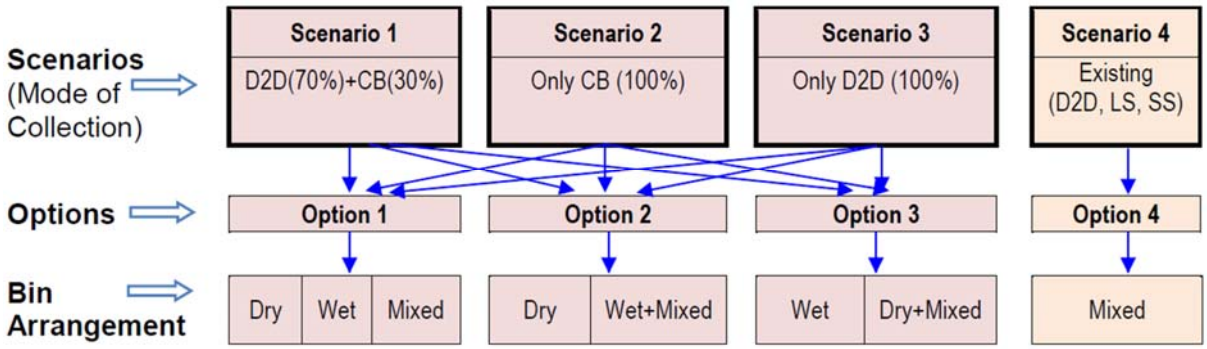


- Mapping of auto routes in Kamakshipalya

# Scenarios, Options and Evaluation

Methodology

Evaluation of three different **collection scenarios** with each three different **waste segregation options**




D2D = Door to Door Collection
CB = Community Bin



# Multi Criteria Analysis Tool & Input Data

Methodology

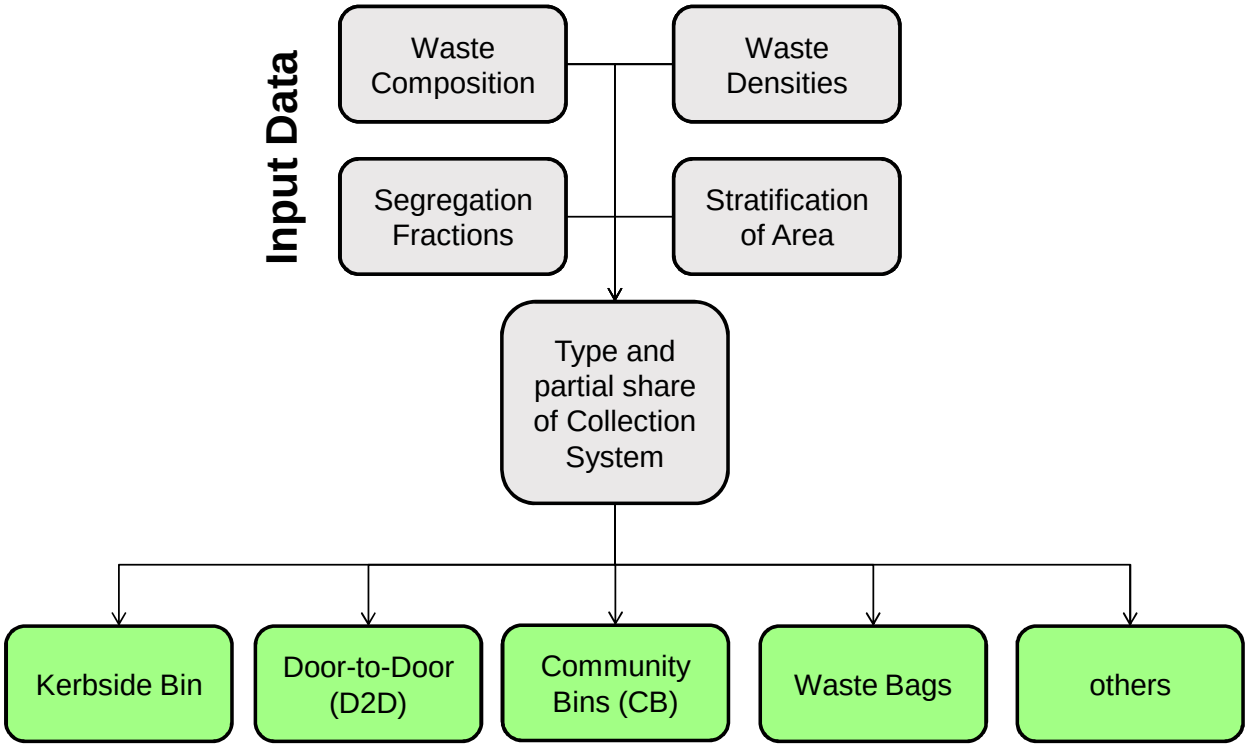
Ranking of collection methods with Multi Criteria Analysis Tool (ELECTRE) with respect to relevant parameters for Life Cycle Assessment (LCA)

**Input Parameter for Calculation**

| | | | | | |
|---|---|---|---|---|---|
| **Project Lifetime** | | 20 years | Total number of PCV routes | : | 1168-999 |
| **Waste density** | | | Fuel consumption per PCV | : | 20 km/l |
| ✓ Dry | : | 120-150 kg/m³ | Fuel consumption per SCV | : | 5 km/l |
| ✓ Wet | : | 350-400 kg/m³ | Avg. collection speed of PCV | : | 10.0 km/h |
| ✓ Mixed | : | 230-270 kg/m³ | Avg. collection speed of SCV | : | 19.2 km/h |
| Dry+mixed | : | 175-210 kg/m³ | Standard PCV bin volume | : | 0.66 m³ |
| Wet+mixed | : | 290-335 kg/m³ | Volume D2D Vehicle | : | 2 m³ |
| | | | Volume CB Vehicle | : | 15 m³ |
| **Waste composition** | | | Man power per PCV & CBV | : | 2 P/vehc. |
| ✓ LD (dry:wet) | : | 34:65 | Working time for PCV | : | 4 h/d |
| ✓ MD (dry:wet) | : | 32:68 | Working time for SCV | : | 22 h/d |
| ✓ HD (dry:wet) | : | 36:64 | Avg. weight of PCV bin | : | 38.55 kg |
| CB cost | : | 19,500 INR | Avg. weight of personnel | : | 70 kg/P |
| PCV cost | : | 2,85,000 INR | Radius for CB distance | | |
| SCV cost | : | 6,00,000 INR | ✓ LD | : | 200 m |
| Fuel cost per liter | : | 64.15 INR/l | ✓ MD | : | 180 m |
| Personnel cost | : | 100 INR/h | ✓ HD | : | 150 m |

# Collection Tool

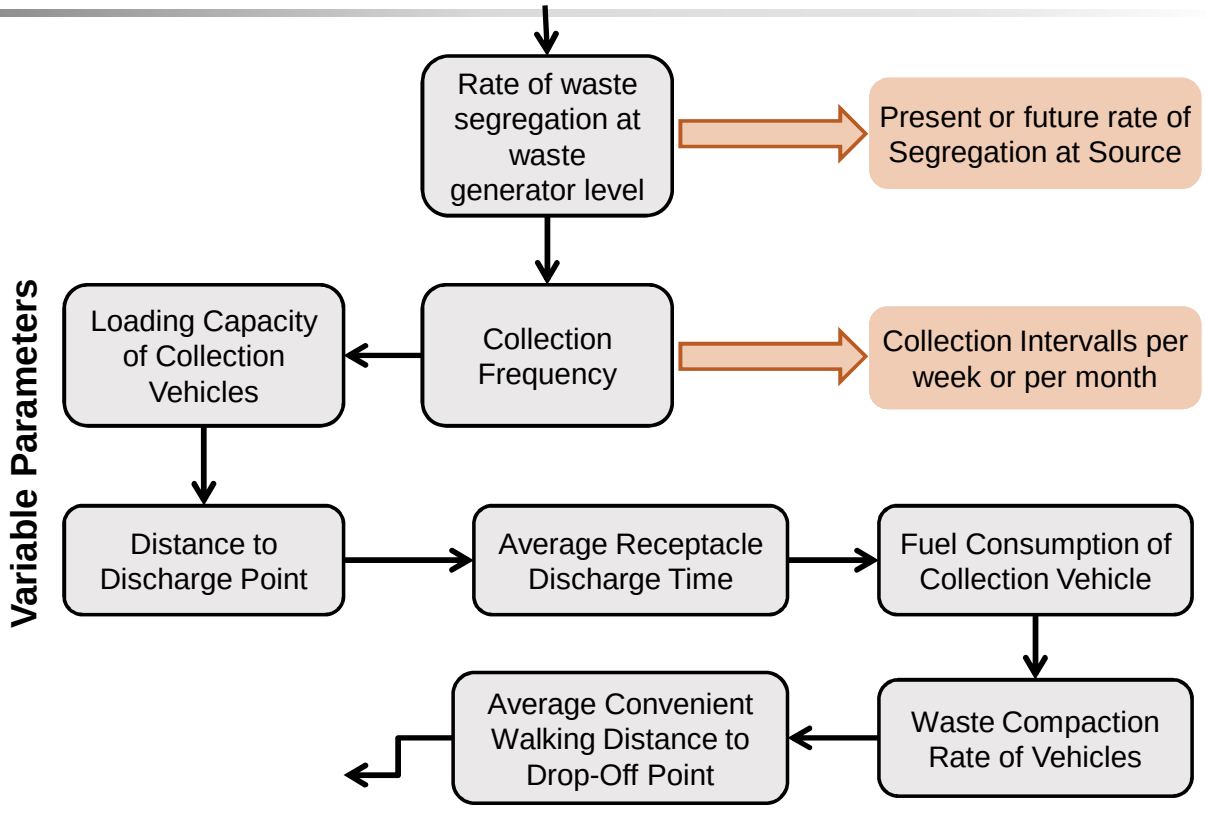
Methodology






Collection Tool

Methodology

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# Collection Tool

Methodology

**Collection Equipment & Work conditions**

- $CO_2$ Emission per Fuel Unit
- Workers per Collection Unit
- Weight of Waste/ Receptacles
- Working hours per Day / Potential Collection Time

**Area + Population Data**

- Waste Generation per Person
- Inhabitants per km²
- Inhabitants per Household
- Street Length per Area
- Average Truck Velocity per Area

**Costs**

- Price for Waste Receptacles
- Price of Collection Vehicles
- Fuel Price per Kilometer
- Salary per Employee
- Maintenance Costs
- Insurance and Taxes
- Lifetime Bins / Vehicles

**Output Data**

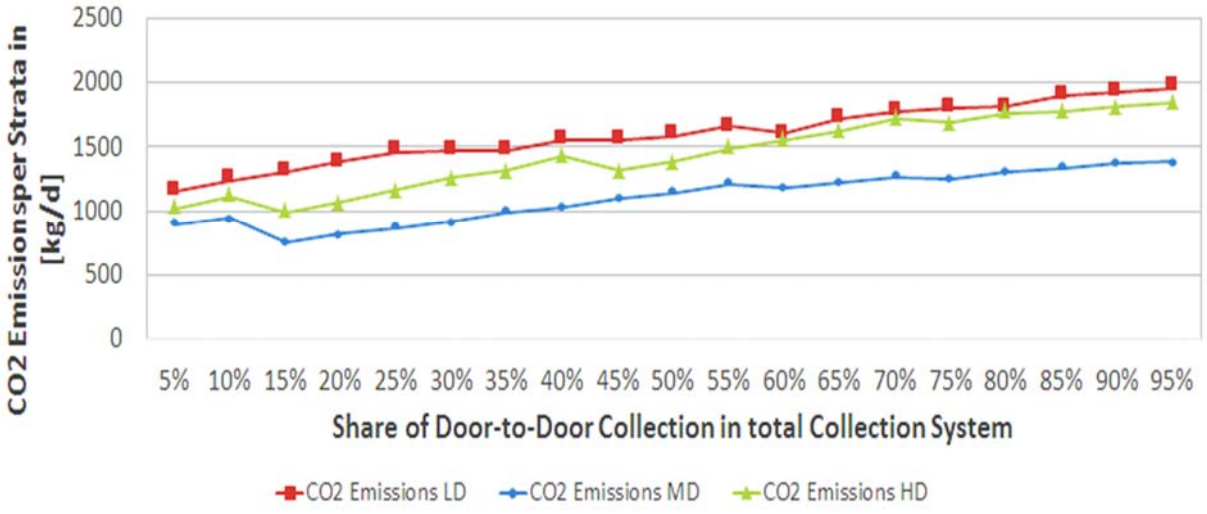
- Greenhouse Gas Emissions per Area and Time
- Capital Expenses per Time Unit
- Operational Expenses per Time Unit
- Required Collection Vehicles
- Required Collection Receptacles
- Required Collection Routes
- Required Receptable Volume

**Options for Waste Treatment**

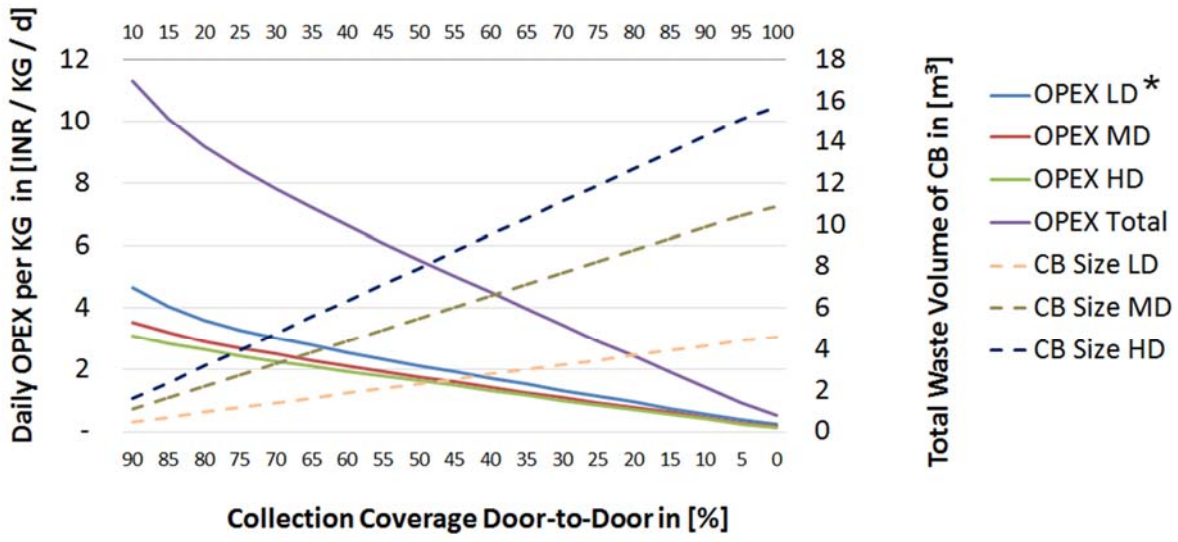


# $CO_2$ Equivalent per Day for West Zone, Banglore, India

Results



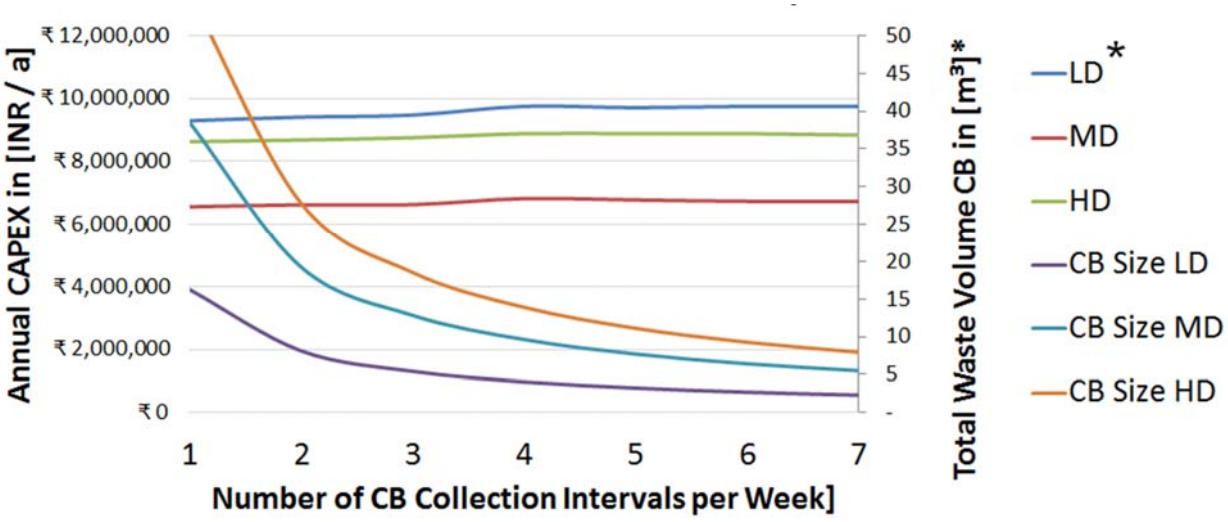
# Collection Coverage, estimated for West Zone, Banglore, India






Results

# CAPEX at different collection frequencies estimated for West Zone, Banglore, India






Results

# ELECTRE Ranking

Results

**Ranking of Collection System Alternatives through MCA for West Zone, Bangalore, according to LCA parameters**

| Rank | Options | | Scenarios |
|---|---|---|---|
| 1 | $S_2Op_3$ | only CB: 2 Separate Bin System-dry+mixed, wet | Scenario 2 |
| 2 | $S_2Op_2$ | only CB: 2 Separate Bin System-wet+mixed, dry | |
| 3 | $S_2Op_1$ | only CB: 3 Separate Bin System-dry, wet, mixed | |
| 4 | $S_1Op_2$ | D2D and CB: 2 Separate Bin System-wet+mixed, dry | Scenario 1 |
| 5 | $S_1Op_1$ | D2D and CB: 3 Separate Bin System-dry, wet, mixed | |
| 6 | $S_3Op_2$ | only D2D: 2 Separate Bin System-wet+mixed, dry | |
| 7 | $S_1Op_3$ | D2D and CB: 2 Separate Bin System-dry+mixed, wet | Scenario 3 |
| 8 | $S_3Op_1$ | only D2D: 3 Separate Bin System-dry, wet, mixed | |
| 9 | $S_3Op_3$ | only D2D: 2 Separate Bin System-dry+mixed, wet | |



# Lessons learned

Conclusions

MSW Collection Evaluation Tool

- simulates scenarios with relevance to LCA
- supports the decision making process with Multi-Criteria Analysis (MCA)
- evaluates variable parameters to identify optimum ranges for MSW collection system designs

Projections of future scenarios and dynamic modelling to evaluate fast-changing conditions in rapidly developing megacities in emerging economies

# Thank you for your attention!

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Bruhat Bengaluru Mahanagara Palike


Dirk Weichgrebe
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Chris Speier
M.Sc.



Moni Mondal
M.Sc..


"We must be the change we wish to see“

"நாம் விரும்பக் காணக்கூடிய
மாற்றமாகவே நாம் இருக்க வேண்டும்"

"हम ही वह परिवर्तन हों, जिसे देखने की चाह हों"

Mahathma Gandhi