

Heuristic vs Metaheuristic algorithms for waste collection route optimization



Adriano S. Silva

Adriano.santossilva@ipb.pt

Supervisor(s): H. T. Gomes¹, A. I. Pereira², A. M. T. Silva³

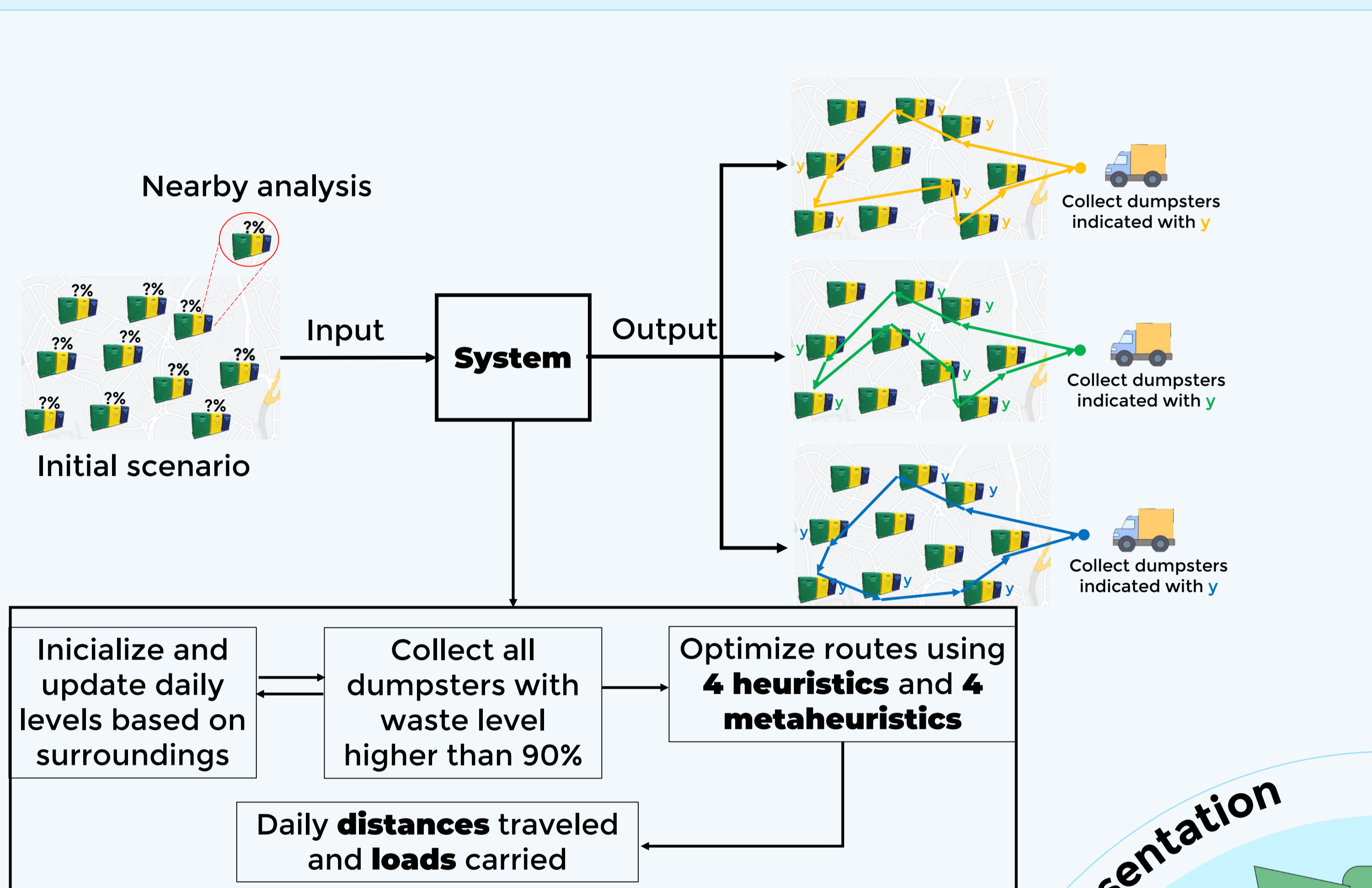
Co-authors: José Lima²

1. Centro de Investigação de Montanha (CIMO), Instituto Politécnico de Bragança, Bragança, Portugal
2. Centro de Investigação em Digitalização e Robótica Inteligente (CeDRI), Instituto Politécnico de Bragança, Bragança, Portugal
3. Laboratório de Processos de Separação e Reação - Laboratório de Catálise e Materiais (LSRE-LCM), Faculdade de Engenharia, Universidade do Porto, Porto, Portugal

MIT Portugal 2023 Annual Conference

Motivation & aims

The future growth of urban populations is expected to lead to a significant increase in both the quantity and complexity of waste generation. As a result, smarter and more sustainable infrastructure in municipal solid waste management systems (MSWMS) will be required. A crucial aspect of waste management is the collection route, which can be greatly enhanced using digital tools like wireless sensors implemented at trash cans to measure their fill levels. One of the objectives of this research work is the optimization of waste collection routes. This research is conducted in collaboration with Resíduos do Nordeste, the company responsible for managing MSWMS in 13 cities in Portugal, including Bragança. Here, a performance comparison between 4 heuristic and 4 metaheuristic algorithms available in the open-source OR-Tools was performed. The heuristic algorithms assessed were Global Cheapest Arc (GCA), Parallel Cheapest Insertion (PCI), Parallel Cheapest Arc (PCA), and Sequential Cheapest Insertion (SCI); and the metaheuristic algorithms were Guided Local Search (GLS), Greedy Descent (GD), Tabu Search (TS), and Simulated Annealing (SA).



- Selective collection of paper, plastic and glass waste
- 300 dumpsters during 30 days were simulated
- Problem will be approached as CWCPTW¹

¹Capacitated Waste Collection Problem with Time Windows



- ☐ Schools (S): 3
- ☐ Temples (T): 1
- ☐ Market (M): 6
- ☐ ATMs (ATM): 2
- ☐ Bakeries (B1): 1
- ☐ Banks (B2): 3
- ☐ Cafe (C): 1
- ☐ Clothing store (CS): 3

$$L_{Tij} = [L_{T(i-1)j} + (S \cdot X_{1T} + T \cdot X_{2T} + M \cdot X_{3T} + ATM \cdot X_{4T} + B1 \cdot X_{5T} + B2 \cdot X_{6T} + C \cdot X_{7T} + CS \cdot X_{8T})] \cdot \frac{TV}{TD}$$

- L_{tij} is the waste level of waste type T (paper, plastic, or glass) in day i for dumpster j
- TV is the total volume carried by the truck
- TD is the number of days in one year (365)
- Parameters were adapted from the literature considering the influence of each establishment in waste generation per type

Objective:

- Minimize total distance traveled

Constraints:

- Trucks have limited capacity
- Number of trucks is limited and fleet is homogeneous
- Dumpsters are visited once and exactly once by one truck
- Each route begins and ends at the central depot
- Dumpsters can be visited in a time window only

$$\text{Minimize } \sum_{k \in V} \sum_{i \in N} \sum_{j \in N} c_{ij} x_{ijk} \quad (1) \text{ Objective}$$

$$\sum_{i \in C} d_i \sum_{j \in N} x_{ijk} \leq Q, \forall k \in V \quad (2) \text{ Capacity constraint}$$

$$\sum_{k \in V} \sum_{j \in N} x_{ijk} = 1, \forall i \in C \quad (3) \text{ Only one visit per customer}$$

$$\sum_{k \in V} \sum_{j \in N} x_{0jk} = 1, \forall k \in V \quad (4) \text{ Route continuity}$$

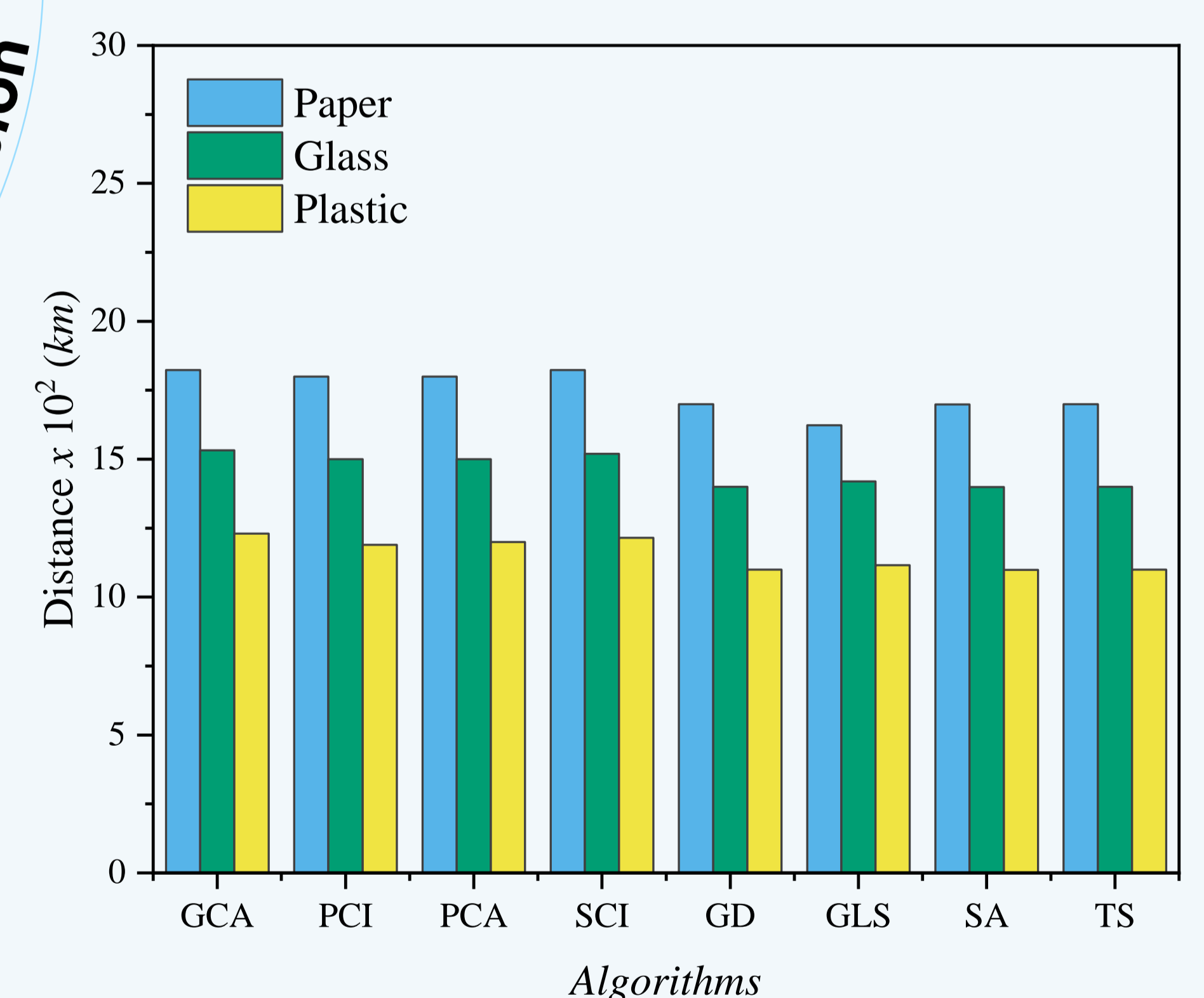
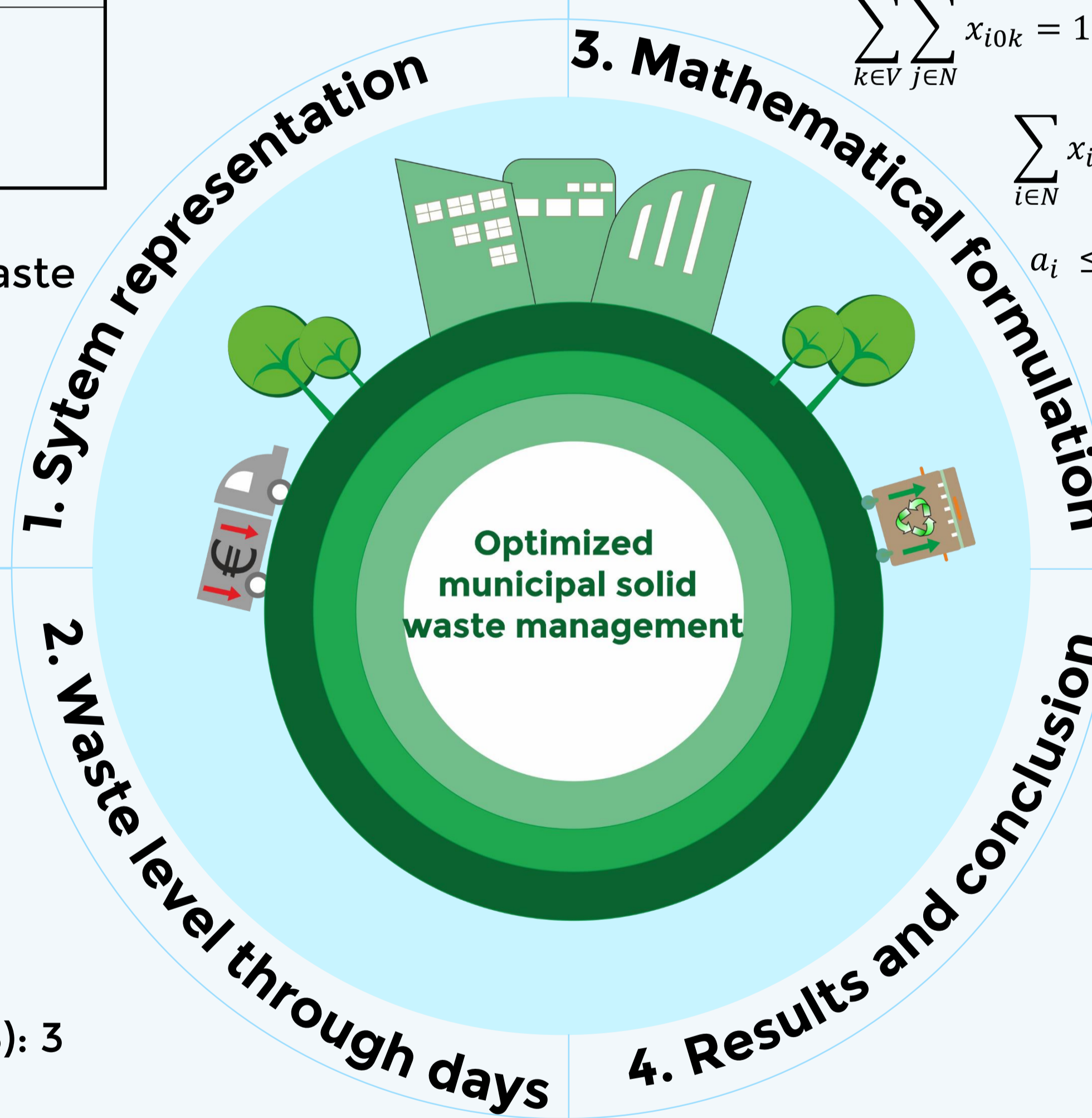
$$\sum_{k \in V} \sum_{j \in N} x_{i0k} = 1, \forall k \in V \quad (5) \text{ Route continuity}$$

$$\sum_{i \in N} x_{ijk} - \sum_{j \in N} x_{hjk} = 0, \forall h \in C, \forall k \in V \quad (6) \text{ Route continuity}$$

$$a_i \leq y_{ik} \leq b_j, \forall i \in N, \forall k \in V \quad (7) \text{ Time windows constraint}$$

$$y_{ik} + t_{ij} - K(1 - x_{ijk}) \leq y_{jk}, \forall i, j \in N, \forall k \in V \quad (8) \text{ Arrival time constraint}$$

$$x_{ijk} \in \{0, 1\}, \forall i, j \in N, \forall k \in V \quad (9) \text{ Integrality constraint}$$



✓ **Metaheuristic algorithms have better performance**

✓ **GLS and GD are the most efficient algorithms**

✓ **CO₂ emission can be reduced up to 200, 142, and 97 tons (average) using metaheuristic algorithms, compared to heuristic ones**

Funded by: