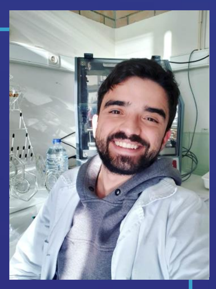
# Bringing the future to municipal solid waste management systems

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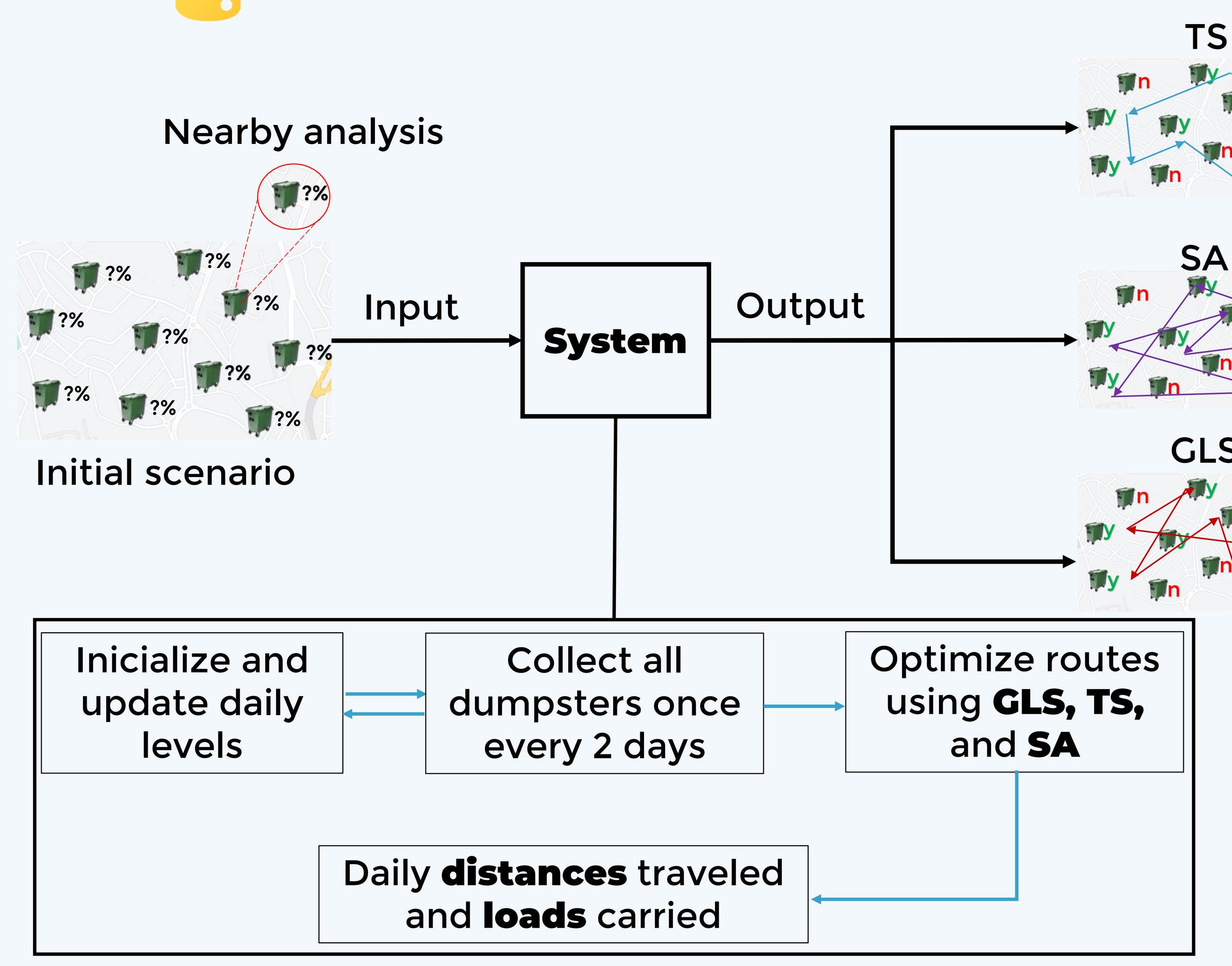
## Motivation & aims

The population growth expected for future cities will probably increase in quantity and complexity the waste generation, requiring smarter and more sustainable infrastructure in municipal solid waste management systems (MSWMS). An important step of a waste management system is the collection route, that can be optimized with digital tools, such as wireless sensors implemented at trash cans for level measurement. Another important aspect in MSWMS is the final disposition, for which Directive 2008/98/EC proposed that, until 2035, 65% of recycling needs to be achieved. Therefore, this Ph.D. thesis work arises from the need to search for strategies to improve operations in MSWMS. For this, the two main objectives are (i) study the optimization of waste collection and (ii) develop technologies for plastic recycling in partnership with Resíduos do Nordeste, the company in charge of MSWMS in 13 cities in Portugal, including Bragança. Here, advances with waste collection optimization algorithm will be shown, along with some of the future steps of this Ph.D. work. The algorithm was developed using an open-source tool, and the results in small scale shows the potential role of route optimization for saving resources in waste collection.

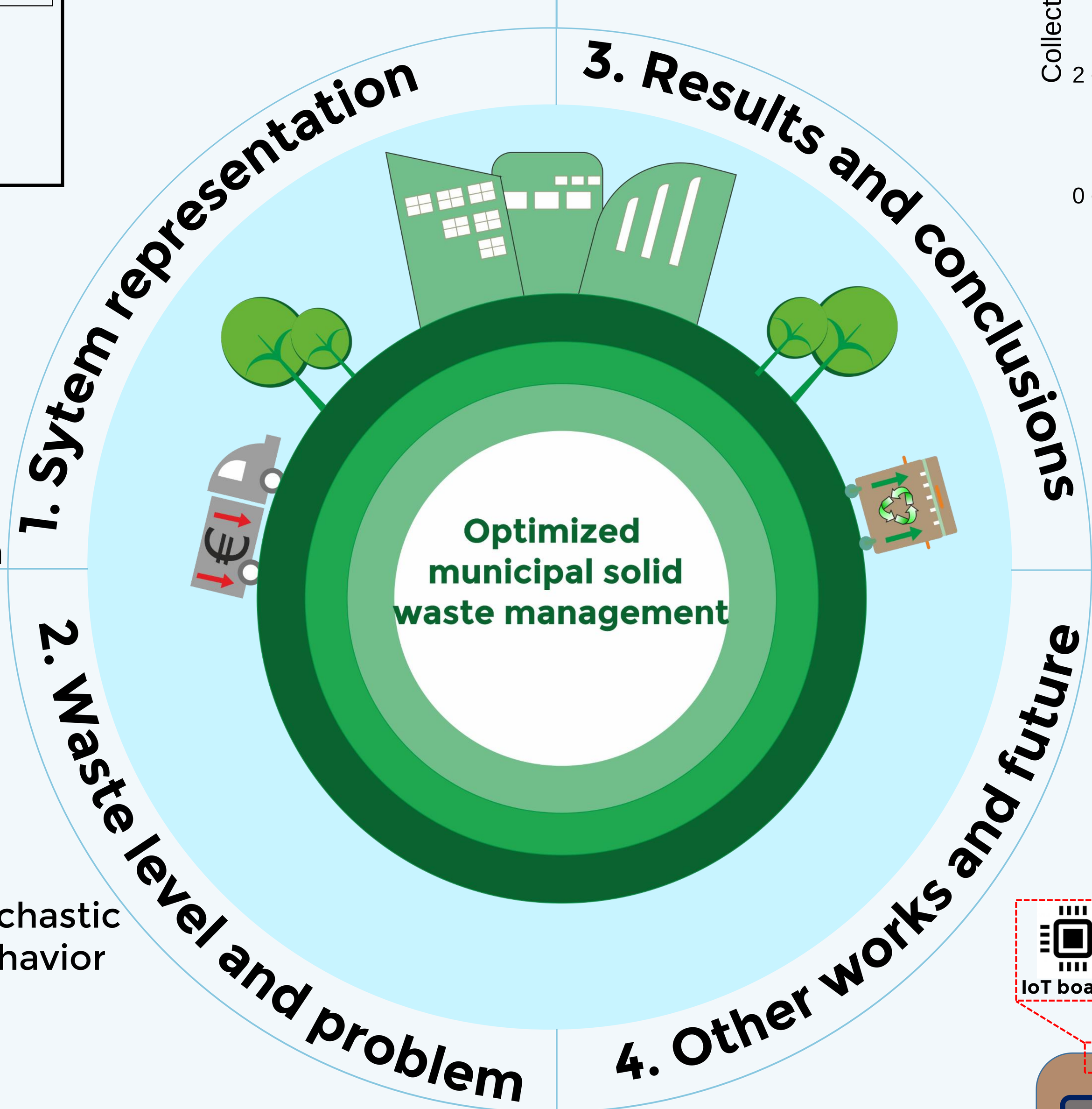
**Tabu Search (TS), Simmulated Annealing (SA), and Guided Local Search (GLS) were assessed**

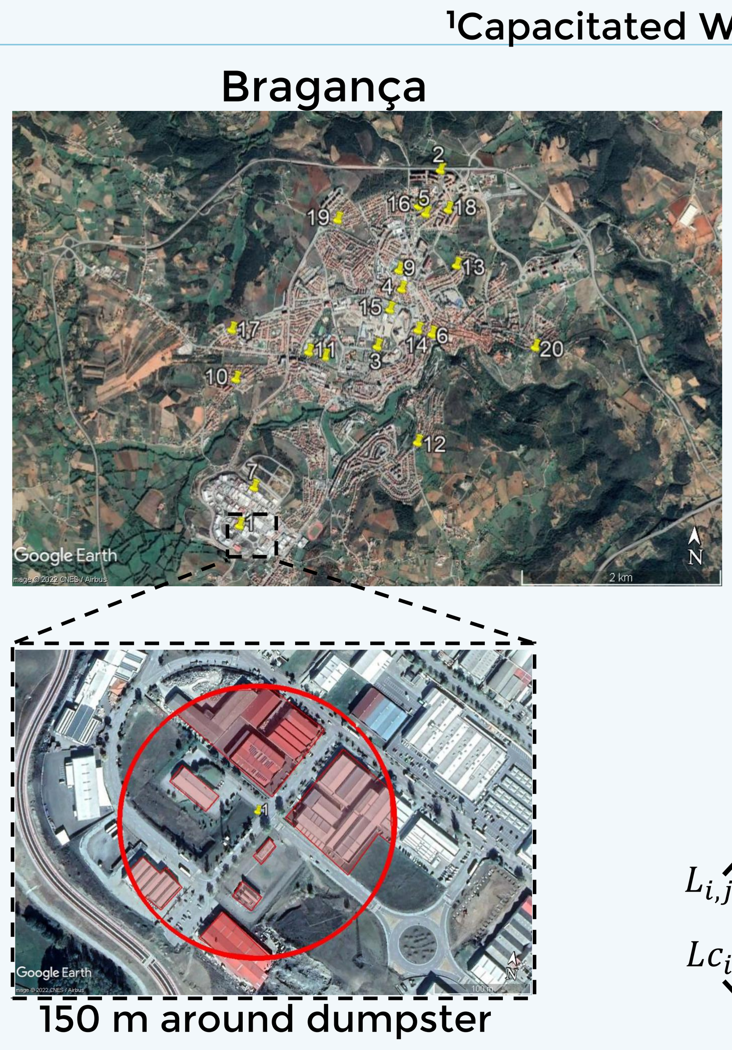
Google OR-Tools




- Selective collection of paper waste
- 20 dumpsters during 30 days were simulated
- Problem will be approached as CWCP[1]
- 3 trucks for waste collection (capacity = 16 m³)
- Dumpsters (capacity = 2.5 m³) locations are real
- Real trucks' consumption were considered

[1]Capacitated Waste Collection Problem




Days, $i = 1,\ldots, 30$

Dumpsters, $j = 1,\ldots, 20$

$$fv_j = \frac{FA_j}{TA} * \sigma_M$$

Filled area; Stochastic behavior; Filling velocity; Total area

$$L_{i,j} = L_{i-1,j} + fv_j$$

$$Lc_{i,j} = L_{i,j} * \frac{TV}{100}$$

Daily level **L** of dumpster **j** in day **i**

Total volume of the dumpster

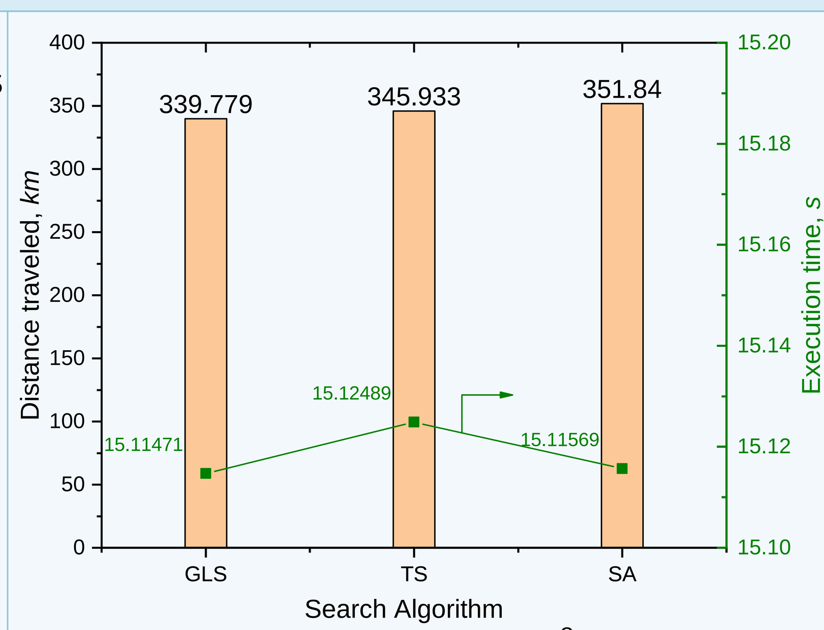
Daily volume **Lc** of dumpster **j** in day **i**

*Initial level (day 0) determined randomly*

### Formulation

**Objective:**
- Minimize total distance traveled

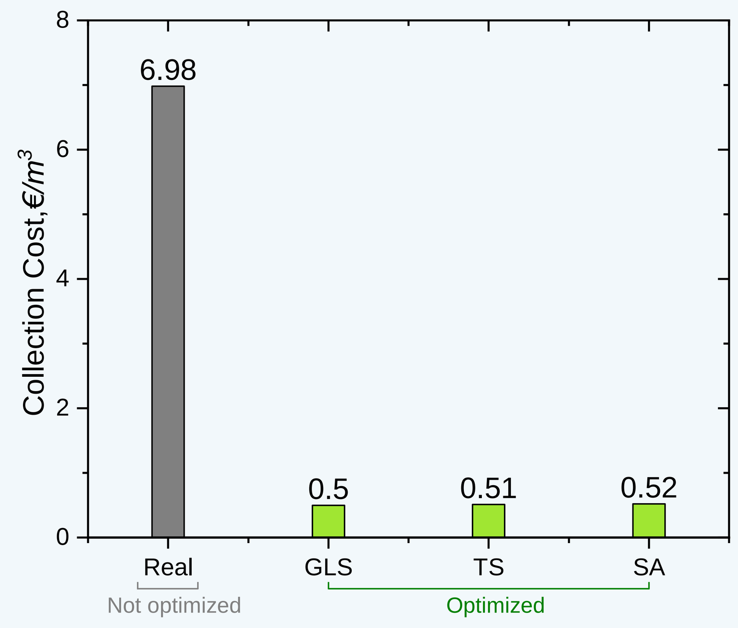
**Constraints:**
- Trucks have limited capacity
- Numer of trucks is limited and fleet is homogeneous
- Dumpsters are visited once and exactly once by one truck
- Trucks only collect one type of waste (*e.g.* paper)
- Each route begins and ends at the central depot

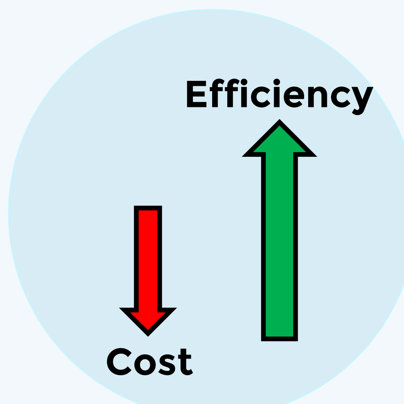



Remember: all 3 algorithms are optimizing routes, so no significant differences observed is not a bad result!

Our system is smaller than the real one, and data are scarce... How can we compare our results with real ones?

$$Collection\ cost\ (CC) = \frac{Total\ cost\ (€)}{Total\ load\ carried\ (m^3)}$$

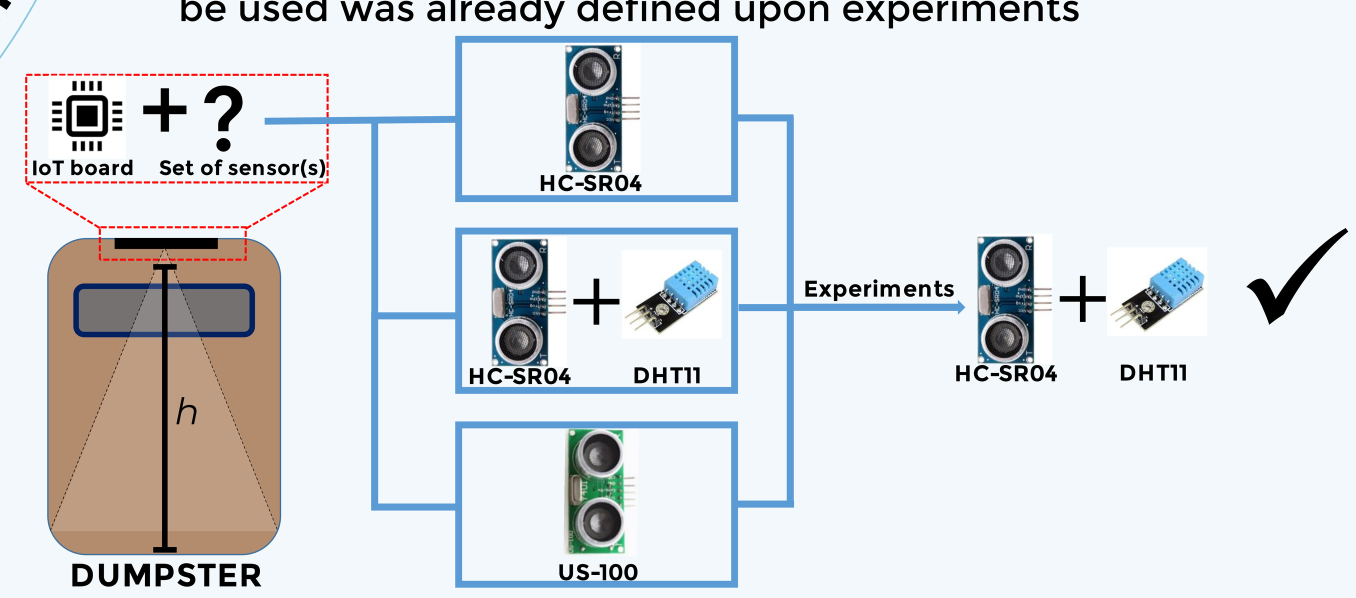


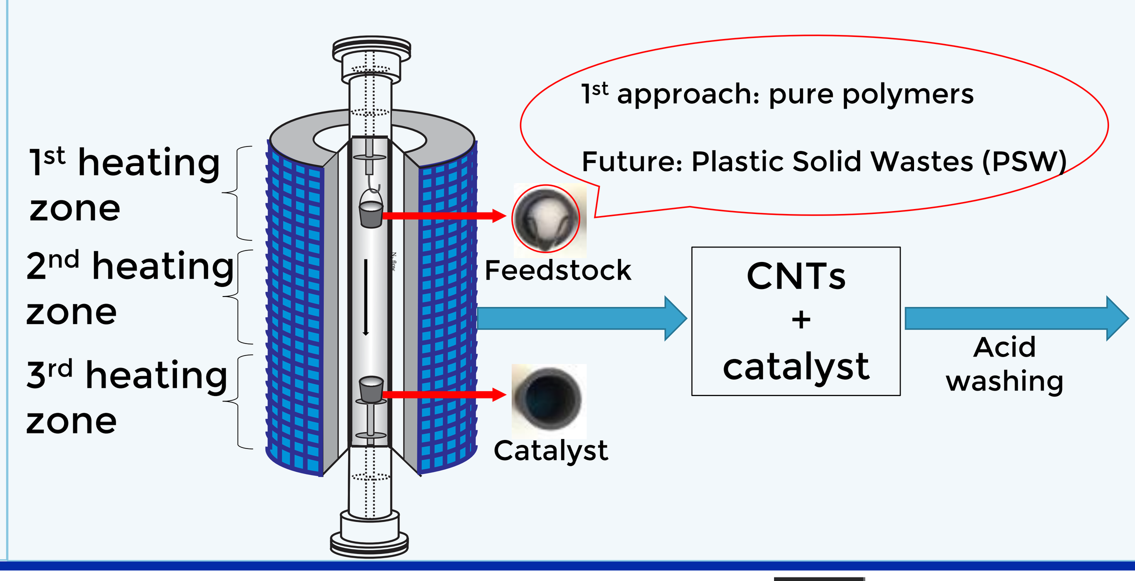

✓ **GLS is the best algorithm available in OR-tools for route optimization**

✓ **Current collection operations can be considerably optimized to save expenses**

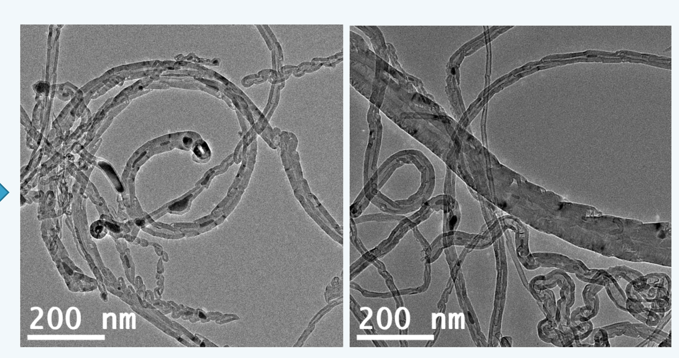
- In another study, we evaluated the role of upper threshold on decision making regarding route optimization. Spoiler alert: 90% was the best
- In the future, real time information regarding waste level will be employed to optimize routes. The set of sensors to be used was already defined upon experiments




**What about recycling technologies for plastic?**
**VALORIZATION THROUGH THEIR TRANSFORMATION INTO CARBON NANOTUBES**




With pure polymers we have CNTs!
Next step: try using PSW as feedstock





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