Computational Mathematics Model to Optimize Waste Collection

Delhi is among the world's most densely populated cities. It produces 9,000 metric tonnes of waste daily out of which only 35% is treated. The Municipal Corporation of Delhi is responsible for waste management in Delhi. The organization's functions on paper-work established decades ago. It fails to keep up to date with demographic and logistic changes. The lack of digitized data adds to the hurdles in open source solutions. This has significantly hampered the success of the Swachh Bharat Abhiyan (Clean India Movement).

We targeted the South Delhi region under the SDMC (South Delhi Municipal Corporation). We set up meetings with officials at the MCD and analyzed the intricacies of the situation. We realized that routes allocated to the trucks were not maintained due to regular changes in the road network. The only plausible solution is a software that integrates database management and route allocation.

We formalized the problem by breaking the continuous map into discrete nodes placed at society level collection sites. These sites are visited by the collection trucks. All trucks start at a central depot (the landfill) and perform multiple rounds in a day. An optimal solution would minimize fuel and time based on average traffic data. However, the problem is symmetric to the NP-Hard Capacitated Vehicle Routing Problem with Multiple Trips (CVRPMT).

We conducted field research. Based on our interactions with the route managers and truck drivers, we modeled an algorithm that captures their intuition. Our aim for an assistive system rather than an imposing scheduling software necessitated this. We did not take a data-driven approach as these have failed at practical scenarios primarily due to false causality.

We first model a differential equation to predict increase in waste demand at different sites. This is independently applied for different types of wastes such as food, metal, plastic where applicable. We propose a modular dustbin design based on geometric analysis for expansion of existing collection facilities. The Strong form of Mathematical Induction is used to prove a formula for the minimum number of Bins required to allocate the waste.

Truck routing is done by starting a round at a previously un-visited node (collection site). The next node is chosen iteratively by applying a linear cost function with unknown constants, which are discretely brute-forced so that the most optimal solution can be chosen. This is done till the truck capacity is met for that round. This is similar to the Depth First Search algorithm. The cost function ensures the number of trips extending far from the depot are minimized thus saving fuel costs. Assigning these rounds to different trucks reduces to the NP-Hard Load Balancing Problem. Instead, a common greedy heuristic is applied.

We integrated the Google Distances API and wrote a prototype in JavaScript. We simulated using dummy data to make optimizations. We are currently working towards obtaining a full dataset to test the algorithm. Moreover, similar systems can be applied in disaster relief, water shortage, postal delivery and so on.

Every year, solid waste adds significantly to a vast number of environmental problems ranging from water pollution to widespread diseases. It is thus imperative that a country that actively adopts initiatives like Digital India uses technology to improve the quality of life of its citizens. This will be

a significant step towards leading the whole world into a revolution.