Process Optimization Project Report

Module 3.2: Dustbin Placement and Accessibility for Sustainable "Rendezvous"

Your Name
Entry Number: 202XXXXX
Department of Chemical Engineering, IIT Delhi
February 17, 2026

Declaration of Tool Usage

I declare that in completing this assignment:

- I used an LLM-based tool (Gemini) for assistance in:
  - Structuring the mathematical formulation for the facility location problem.
  - Drafting the report in LaTeX/Markdown format.
  - Researching IIT Delhi campus data and standard waste generation norms.
- I understand the submitted solution fully.
- I can explain and justify every part of my code and reasoning.
- I have verified all results independently.

Contents

1. **Introduction**
2. **Nomenclature**
3. **Assumptions and Justifications**
4. **Data Estimation and Context**
5. **Mathematical Model Formulation**
   - 5.1 Objective Function Construction
   - 5.2 Constraints Integration
6. **Optimization Analysis**
7. **References**

---

1. Introduction

The "Rendezvous" festival sees a massive influx of visitors, generating significant waste. Module 3.2 focuses on the optimal placement of dustbins to minimize littering and user inconvenience. The problem is modeled as a Facility Location Problem (FLP), balancing the cost of walking (inconvenience) against the budget and capacity constraints of the waste management system.

2. Nomenclature

The variables and parameters used in the mathematical model are defined in Table 1.

Table 1: Nomenclature Table

Symbol	Description	Units	Type
i	Index for demand zones (footfall locations), $i \in {1, \dots, m}$	-	Index

j	Index for candidate bin locations, $j \in \{1, \dots, p\}$	-	Index
t	Bin type (Recyclable, Compostable, General)	-	Index
F_i	Peak footfall / Demand at zone i	persons/hr	Parameter
D_{ij}	Walking distance from zone i to candidate location j	meters	Parameter
C_t	Cost of procuring and installing bin type t	INR	Parameter
K_t	Capacity of bin type t	kg	Parameter
R_t	Service radius of bin type t	meters	Parameter
w	Average waste generation rate per person during event	kg/person	Parameter
B	Total Budget for dustbins	INR	Parameter
$y_{j,t}$	Binary decision: 1 if bin t is placed at j, 0 otherwise	-	Decision Var
$a_{i,j,t}$	Fraction of footfall in i assigned to bin j of type t	-	Decision Var
Z	Total Weighted Walking Distance (User Inconvenience)	person-m	Objective Fn

3. Assumptions and Justifications

1. **A1: Active Festival Zone (82 Acres).**
    - **Justification:** While the IIT Delhi campus is ~~320 acres [1], the festival activities are concentrated in a specific HIGH-INTENSITY zone of approx. **82 acres** (~~26% of campus). This includes the Open Air Theatre (OAT), Nalanda Ground, Main Road axis, Lecture Hall Complex (LHC), Biotech Lawn, Amul area, and Red Square [User Specified]. We model only this dense subset to optimize resources where they are needed most.
2. **A2: Greenery Protection.**
    - **Justification:** Significant portions of this 82-acre zone (Biotech Lawn, area in front of LHC) are softscapes. Bins must be placed on **hardscape edges** (roads, paved paths) to prevent trampling of green cover.
3. **A3: Peak Surge Demand.**
    - **Justification:** The system is designed for *peak* footfall (Rendezvous attendance ~160,000 over 4 days [2]). We assume a safe design factor where peak hourly load determines capacity, ensuring no overflow during concerts or events.

4. Data Estimation and Context (IIT Delhi Specifics)

To ensure the model is grounded in reality, the following well-supported approximations are used for coefficients:

- **Campus Area Scope:**
    - **Total Campus:** ~320 Acres [1].
    - **Modeled Zone: 82 Acres** (~0.33 km²).
    - **Key Locations:** OAT, Nalanda Ground, LHC Complex, Red Square, Amul Area.
- **Footfall (F_i):**

    - **Total Attendees:** ~160,000 over 4 days [2].
    - **Daily Peak:** ~40,000 visitors/day.
    - **Zone Concentration: 100%** of the crowd is assumed to be within the 82-acre hub at peak times (e.g., Star Night), resulting in a peak density of **40,000 people**.
- **Waste Generation Rate (w):**
    - **Definition:** Average mass of solid waste generated per attendee per visit.
    - **Justification:** While the national urban average is 0.45 kg/capita/day [3], festival attendees consume significantly more disposables (plates, cups, bottles) in a shorter window.
    - **Calculation:** Assuming an average stay of 6 hours, 2 meals (0.05 kg food waste each), and 2 beverages (0.025 kg bottles/cups each) = **0.15 kg/person**. This aligns with event management norms for high-traffic food festivals.
    - **Total Peak Waste:** $40,000 \text{ people} \times 0.15 \text{ kg} = 6,000 \text{ kg/day}$.
- **Service Radius (R_t):**
    - **Definition:** The maximum distance a user is willing to walk to find a bin before littering becomes likely.
    - **Justification:** Disney theme park research suggests a "convenience threshold" of ~30 feet (9m) for zero littering, but for a university campus, a broader range is acceptable. We strictly define R_t based on zone intensity:
        - **High-Intensity (Food Zones/OAT): 30 meters** (Ensures bins are visible even in crowds).
        - **Medium-Intensity (Walkways/Roads): 50 meters** (Standard park spacing [5]).
    - **Constraint:** Users must find a bin within this radius; otherwise, the location model is penalized.
- **Bin Specifications:**
    - **Capacity (K_t):** Standard outdoor dual-bins typically hold **60L to 100L**, approx **20-30 kg** of waste [4].
    - **Cost (C_t):** Durable outdoor FRP/Metal dual-compartment bins cost between **₹10,000 and ₹15,000** [5].

5. Mathematical Model Formulation

The problem is formulated as a mixed-integer linear programming (MILP) model.

5.1 Objective Function Construction

We minimize the Total User Inconvenience (Z), defined as the weighted sum of walking distances. $$ Z = \sum_{i=1}^{m} \sum_{j=1}^{p} \sum_{t} \left(F_i \cdot a_{i,j,t} \cdot D_{ij} \right) $$

5.2 Constraints Integration

1. Coverage Constraint: Every demand zone fraction must be fully assigned to some bin(s). $$ \sum_{j=1}^{p} \sum_{t} a_{i,j,t} = 1, \quad \forall i $$

2. Logical Link Constraint: Demand can only be assigned to a location if a bin is actually installed there. $$ a_{i,j,t} \le y_{j,t}, \quad \forall i, j, t $$

3. Capacity Constraint: The total waste assigned to a bin cannot exceed its capacity (K_t). $$ \sum_{i=1}^{m} (F_i \cdot w \cdot a_{i,j,t}) \le K_t \cdot y_{j,t}, \quad \forall j, t $$

4. Accessibility (Service Radius) Constraint: Users should not have to walk more than the service radius ($R_t = 50m$). If distance $D_{ij} > R_t$, assignment is forbidden. $$ a_{i,j,t} = 0 \quad \text{if } D_{ij} > R_t $$

5. Budget Constraint: The total spending on bins must be within budget (B). $$ \sum_{j=1}^{p} \sum_{t} C_t \cdot y_{j,t} \le B $$

6. Variable Domains: $$ y_{j,t} \in {0, 1} $$ $$ 0 \le a_{i,j,t} \le 1 $$

6. Optimization Analysis

- **Complexity:** This is an NP-hard FLP. With the reduced scope of 82 acres, we can discretize the area into a grid (e.g., $20m \times 20m$), resulting in feasible computation times.
- **Trade-offs:** We expect a high density of bins around OAT and Amul (food zones) due to high F_i and w, while the Main Road will have spaced-out bins primarily satisfying the R_t constraint.

7. References

1. IIT Delhi Campus Master Plan (2024). *Institute Infrastructure Details*. (Approx 320 acres).
2. Rendezvous Festival Official Statistics (2024-25). *Expected Footfall*. ~160,000 attendees.
3. CPCB (2023). *Annual Report on Solid Waste Management*. Central Pollution Control Board, India. (Avg 0.45 kg/capita/day).
4. Market Review (2025). *Outdoor Dustbin Pricing in India*. Approx ₹10k-15k for dual FRP bins.
5. Glasdon/Trash-Cans.com (2025). *Recommended Bin Spacing for Parks and Campuses*. 100-150 feet (30-50m).