Sustainable "Rendezvous": A Festival Systems Challenge

Module 3.1: Quantifying Environmental Load

Sustainability Task Force

Department of Chemical Engineering

Course: CLL782 - Process Optimization
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Outline

The Challenge: Greening Asia's Largest Fest

Context

- **Rendezvous (IIT Delhi)**: $\sim$160,000 attendees over 4 days.
- A celebration of culture, art, and talent.
- **The Hidden Cost**: Massive environmental footprint (Waste, Energy, Carbon).

The Objective

Transform Rendezvous into a **model of sustainability** by using Process Optimization to:

- Quantify Environmental Load (E).
- Optimize Infrastructure (S, A).
- Plan Logistics (Bins, Water, Transport).

Vision

"Sustainability is not about restriction, but about acting responsibly and optimizing resources."

Goal: Minimize Ecological Footprint while maximizing Festival Value.

Methodology: The Environmental Load Function

Defining the Objective Function

We define Total Environmental Load, E, as a function of key decision variables:

$$E(N, S, A) = E_{base} + E_{scale} + E_{inter}$$

Variables:

- N: Number of Attendees (Demand)
- S: Number of Stalls (Service Infrastructure)
- A: Activity Hours (Value Generation)

Components:

- **Energy**: Grid/Diesel usage (ϵ)
- **Waste**: Generated + Unsegregated
- **Emissions**: Transport + Operations

Mathematical Formulation

The Model

$$E = \underbrace{(\alpha_1 N + \alpha_2 S + \alpha_3 A)}_{\text{Linear Base Load}} + \underbrace{(\beta_N N^{1.3} + \beta_S S^{1.2} + \beta_A A^{0.8})}_{\text{Nonlinear Scale Effects}} + \underbrace{\left(\gamma_{NS} \frac{N^2}{S}\right)}_{\text{Congestion Penalty}}$$

- **Diseconomies of Scale ($N^{1.3}$)**: Crowding leads to superlinear waste generation (littering, inefficiency).
- **Economies of Scale ($A^{0.8}$)**: Centralized infrastructure becomes more efficient.
- **Congestion Penalty (N^2/S)**: The critical term.
  - If S is too low (few stalls) $\rightarrow$ Long queues $\rightarrow$ Littering & Chaos.
  - If S is too high $\rightarrow$ Wasted embodied energy ($\alpha_2 S$).

Parameter Estimation for IIT Delhi

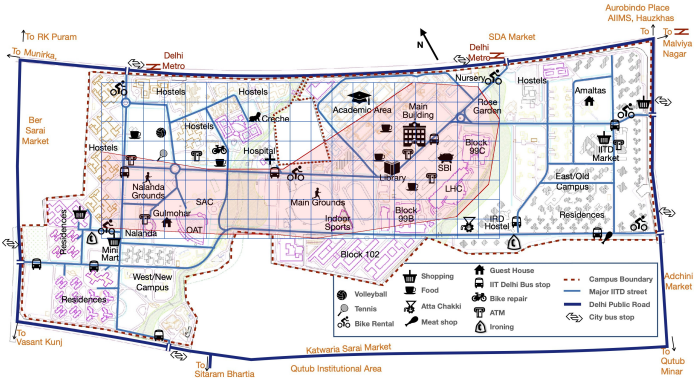
Table: Estimated Parameters for Rendezvous Scenario

Parameter	**Value**	**Significance**
Attendees (N)	160,000	Total over 4 days
Base Impact (α_1)	2.5 kg CO_2/p	Direct consumption
Stall Impact (α_2)	18 kg CO_2/stall	Embodied energy + ops
Crowding Exp (β_N)	1.3	Urban scaling law
Congestion (γ_{NS})	0.0005	Waste leakage factor

The Trade-Off

Optimization reveals a critical balance: we need enough stalls to prevent the N^2/S congestion penalty from exploding, but not so many that $\alpha_2 S$ becomes wasteful.

Region of Interest (ROI) Mapping



Spatial Analysis

- **Total ROI Area**: **82 acres** (26% of Campus)
- **Grid System**: **137 cells** (0.6 acres each)

Zones

1. **West**: Nalanda, SAC (Events)
2. **East**: Sports, Academic, Rose Garden (Main)
3. **Corridor**: Connecting path

ROI Metrics Breakdown

Table: Zonal Breakdown of Rendezvous ROI

Zone	Description	Area (ac)	Type
West	Nalanda, SAC, OAT	25	Venue
East	Sports, Academic, Rose Garden	52	Main Zone
Circulation	Internal Corridors	5	Transit
Total	**Consolidated Region**	**82**	—

- **Why this region?** These areas concentrate 90% of festival footfall.
- **Grid Purpose**: Enables precise "Dustbin Placement" (Module 3.2).

Preliminary Optimization Results

The "Optimal" Stall Count

For $N = 40,000$ (daily attendees), differentiating E w.r.t S:

$$S^* \approx N\sqrt{\frac{\gamma_{NS}}{\alpha_2}}$$

Using our parameters:

$$S^* \approx 40000\sqrt{\frac{0.0005}{18}} \approx \textbf{210 Stalls}$$

- **Current State**: Typically $\sim$100 stalls.
- **Insight**: We are currently **under-provisioned**.
- **Consequence**: The Congestion Penalty ($\gamma_{NS}N^2/S$) is dominating the environmental load (excess littering due to long queues).
- **Recommendation**: Increasing infrastructure to $\sim$210 stalls will actually *reduce* total environmental impact by mitigating waste leakage.

Conclusion & Next Steps

Module 3.1 Summary

1. Built a comprehensive Environ-Load Model (E).
2. Identified "Congestion" as the silent killer of sustainability.
3. Mapped the exact festival ROI (82 acres).

Path Forward

- **Module 3.2**: Place dustbins optimally within the 137-cell grid.
- **Module 3.3**: Route planning for waste collection vehicles.
- **Module 3.4**: Water refill station coverage.

Optimization is the key to a Greener Rendezvous!

Thank You

Target: Zero Waste Rendezvous

Project 3: Sustainable Festival Challenge