A Linear Optimization Model for Chapter-Level Resource Allocation

Sugar4Smiles | Operational Efficiency Brief

1. Problem

Sugar4Smiles distributes approximately 500 birthday kits per month across five chapters (Houston, New Jersey, Austin, Nashville, Dallas). Kit allocation across chapters has historically been set informally, without a systematic way to weigh per-chapter cost differences against actual need. Field observation suggested two specific inefficiencies: Nashville has been consistently oversupplied relative to demand, while New Jersey has been consistently undersupplied. This brief develops a linear programming model to reallocate a fixed monthly kit volume across chapters in a way that minimizes total misallocation — defined as the sum of unmet need (shortfall) and unused surplus (waste) — rather than simply minimizing cost.

2. Why Misallocation, Not Cost, Is the Right Objective

An initial version of this model minimized total dollar cost subject to holding total kit volume constant. That formulation produced a monthly savings of roughly $7, an economically negligible result that does not reflect the organization's actual operating problem. Per-chapter costs range narrowly, from $4.90 to $6.80 per kit, so cost-only optimization has little room to act. The more meaningful inefficiency in the data is distributional: kits sitting unclaimed in one chapter while another chapter cannot meet demand. The model below optimizes for service level first, using cost only as a secondary tiebreaker between allocations that serve need equally well.

3. Model

For each chapter *i*, let x_i be the monthly kit allocation, d_i be estimated demand, s_i be surplus above demand, and u_i be shortfall below demand. The model minimizes total surplus and shortfall across all chapters, subject to allocations summing to the current total monthly volume (500 kits) and to per-chapter capacity bounds reflecting realistic growth limits (volunteer availability, local sourcing capacity). Solved as a linear program via SciPy's HiGHS solver.

4. Data & a Note on Demand Estimates

Current allocation and per-kit cost figures reflect actual chapter operations. Demand figures for New Jersey and Nashville are directional estimates based on chapter-level observation (consistent under- and over-supply, respectively), not measured waitlist or intake data. Houston, Austin, and Dallas demand is assumed equal to current allocation, as no over/under-supply signal has been observed for those chapters. These estimates should be replaced with measured figures — pantry partner waitlist counts or chapter lead intake reports — as that data becomes available.

Chapter	Current Allocation	Cost/Kit	Estimated Demand	Optimized Allocation	Shortfall
Houston	300	$5.00	300	300	0
New Jersey	100	$6.80	165	112	53
Austin	50	$5.50	50	50	0
Nashville	25	$6.40	13	13	0
Dallas	25	$4.90	25	25	0

5. Results

Reallocating Nashville's estimated surplus into New Jersey reduces total monthly misallocation (shortfall plus waste) from 77 kits to 53 kits — a 31% reduction — at a cost increase of roughly $5 per month, effectively unchanged from the current $2,737.50 monthly budget. New Jersey's shortfall is not fully eliminated: under the fixed 500-kit monthly volume, reallocation alone cannot close the full gap between New Jersey's estimated demand (165) and its allocation. Fully meeting New Jersey demand would require increasing total monthly kit volume, not just redistributing the existing volume — a distinct finding from the reallocation result, and a natural input into budget or chapter-growth planning.

6. Limitations

This is a first-pass model built to test whether a reallocation-based approach outperforms a cost-only approach, which it does. Its main limitation is that two of five demand figures are estimated rather than measured. The model also holds total monthly kit volume fixed; it does not yet model the cost or logistics of scaling total volume up, which would be needed to fully resolve New Jersey's shortfall. Extending the model with real intake/waitlist data and a variable total-volume case are the two clear next steps.