Vehicle Routing for the American Red Cross

Based on a paper by
Dr. Jinxin Yi
Carnegie Mellon University

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Introduction

- The American Red Cross (ARC) has 36 Blood Services Divisions nationwide
- This work focuses on the “bring-back” operation for each division
- Blood collection vehicles collect whole blood at prescheduled sites for about six hours and then return to headquarters
- At headquarters, whole blood is separated into components

Introduction

- The most sensitive component is platelets – used for transplants, radiation treatments, and chemotherapy
- For platelets, whole blood must be processed within eight hours after donation
- The ARC seeks to route vehicles from headquarters to sites and back, in order to obtain the desired amount of platelets while minimizing transportation costs
- This is a traditional vehicle routing problem, except the number of stops per route is very small

Additional Considerations

- Blood is not allowed to stay in a vehicle more than six hours
- The later in the day a site is visited, the more blood there is to bring back to headquarters
- So, the amount of blood picked up at a site is time-dependent
- Next, we discuss the solution approach

Solution Approach

- First, we generate all feasible routes
- Second, we optimize start times for each route to maximize total amount collected
- Third, many inferior routes are removed
- Finally, we choose the best subset of routes using integer programming

Comments

- Since each route has a small number of sites, there are not too many of them

- The authors worked with 178 randomly generated problems with 99 sites each and the number of feasible routes was always $\leq$ 76,455

- Consider two routes, A and B, with

  A: Depot → A → B → C → Depot, length = 360, amount collected = 240

  B: Depot → B → A → C → Depot, length = 350, amount collected = 250

- Route A is inferior to Route B and it can be removed

Integer Programming Model Definitions

- Remove/delete all infeasible routes
- Model definitions

  c_r = the length of route r

  d_r = the collection amount for route r

  LB = minimum daily collection amount

$$x_r = \begin{cases} 1 & \text{if route } r \text{ is chosen} \\ 0 & \text{otherwise} \end{cases}$$

$$z_{ir} = \begin{cases} 1 & \text{if route } r \text{ visits site } i \\ 0 & \text{otherwise} \end{cases}$$

Integer Programming Model

- Min $\sum_r c_r x_r$

  subject to:

  $$\sum_r z_{ir} x_r \le 1, \text{ for all } i \quad (1)$$

  $$\sum_r d_r x_r \ge \text{LB} \quad (2)$$

  $$x_r \in \{0,1\} \quad (3)$$

- Constraint (1) guarantees that no site is visited more than once
- Constraint (2) represents the minimum collection requirement

Integer Programming Model

- To speed up the solution process, additional constraints (called cutting planes) were added to the model
- The entire procedure was implemented on a Spar20 workstation with Cplex 6.5 as the IP solver
- All 178 problems were solved optimally
- The average time to solve the IP was 9 minutes
- The max time to solve the IP was almost 1.5 hours

Application to the ARC

- This solution approach was applied to the ARC's Connecticut Region in Feb. 2000
- On Feb. 1, 2000 there were 12 collection sites
- There are five routes in the optimal solution

Route #1: Depot → K → Depot
Route #2: Depot → L → M → Depot
Route #3: Depot → A → G → H → Depot
Route #4: Depot → B → C → D → Depot
Route #5: Depot → F → E → J → Depot

Results

- The same analysis was applied for the entire month of Feb. 2000
- Travel distance was reduced by nearly 60%, on average
- A typical blood division spends several million dollars per year on the bring-back operation
- The project was viewed as a major success