VIRGINIA COMMONWEALTH UNIVERSITY

INFO 645 - PRESCRIPTIVE ANALYTICS

Team Project

Realignment of Regional Office for RAM Wireless

Submitted by:

Group-06

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Date of Submission: 12-05-2024

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Executive Summary

In this project, we were tasked with solving an optimization problem related to assigning stores to regional offices. The problem involves balancing multiple factors such as travel costs, geographic proximity, and the operational capacity of each office. Our goal was to determine the most cost-effective assignments while ensuring that all operational constraints were met.

We are a group of students from Virginia Commonwealth University, currently enrolled in the Decision Analytics program. This project was assigned as part of our Prescriptive Analytics coursework, where we worked collaboratively over a period of six weeks to analyze, model, and optimize the assignment process.

1. Problem Description:

RAM Wireless tasked us with evaluating the alignment of its stores to regional offices to minimize operational costs while ensuring workload feasibility. The company operates multiple stores across Virginia, supported by four regional offices: Staunton, Richmond, Warrenton, and Tappahannock. These offices provide essential services such as inventory, payroll, hiring, marketing, and merchandising.

As the company has grown, inefficiencies have emerged in the current allocation system, including excessive travel costs, workload imbalances, and underutilization of some offices. The current nearest-office approach assigns stores to their geographically closest office, which minimizes travel distances but fails to account for the limited-service capacity of each office, leading to overburdened offices and reduced service quality.

The goal of this project is to develop a model that optimizes the assignment of 50 stores to regional offices while minimizing travel and salary costs. The model must respect geographic boundaries, office capacity, and potential travel restrictions such as maximum distance or travel time. The solution aims to ensure that the hours required to service each store do not exceed the available capacity at its assigned office. Travel costs include both mileage costs at $0.585 per mile and employee salary costs at $26 per hour of travel time, while respecting capacity constraints for the five key service areas at each office.

2. Model Development

We approached the problem using an optimization model built with AMPL, a mathematical modeling language designed for large-scale optimization. The model aimed to minimize total travel and salary costs, incorporating both mileage and employee salary costs. Sets were defined to represent stores, offices, and service areas, while parameters captured distances, travel times, service hours required by stores, hours available at offices, and the number of trips needed per year. A binary decision variable indicated whether a store was assigned to a specific office. Constraints were incorporated to ensure that each store was assigned to exactly one office, that the workload at each office did not exceed its available capacity, and that the decision variables were binary and non-negative, making the model suitable for real-world implementation.

After solving the initial model, geographic inconsistencies were identified, where some stores were assigned to distant offices, resulting in inefficiencies. To address these issues, we implemented two remedies. First, we applied geographic constraints by adding limits on distance and travel time to promote more geographically feasible assignments. However, these constraints had no significant impact, as the original assignments were already within the defined limits. Second, we introduced manual adjustments, specifically reassigning stores like Stafford_County to their geographically closer offices, which improved both cost efficiency and geographic alignment. The initial model resulted in a total cost of $195,479.31, optimized purely for cost but not considering geographic feasibility. By applying geographic constraints, we found no change in total cost, indicating that the initial assignments were within the defined limits. However, applying manual adjustments reduced the total cost to $194,130.69, demonstrating that targeted manual interventions can provide significant improvements.

Our findings revealed that while the original solution minimized costs, it resulted in geographically inefficient assignments. The geographic constraints had no impact, as the initial assignments were already feasible. However, manual adjustments provided a meaningful cost reduction while improving geographic alignment.

Based on these results, we recommend a hybrid approach: Applying geographic constraints to ensure baseline feasibility and using targeted manual adjustments to address specific geographic anomalies. Future work could explore more sophisticated methods, such as dynamic penalties for distant assignments, to further optimize both cost and geographic feasibility. This project illustrates how optimization can effectively balance cost efficiency with operational practicality, offering valuable insights for real-world logistics and planning.

Presentation of the Model

The objective of the optimization model is to minimize the total travel and salary costs associated with the assignment of stores to regional offices. The travel costs are calculated based on both mileage costs (at a rate of $0.585 per mile) and salary costs (at a rate of $26 per hour of travel time). The model ensures that each store is assigned to exactly one regional office, while also respecting the available hours for each service area at each office. Additionally, the assignment must account for potential travel restrictions, such as maximum distance or travel time, ensuring both operational feasibility and cost efficiency.

Data:

Regional Offices (R): {Staunton, Richmond, Warrenton, Tappahannock}

Stores (S): {Albemarle County, Amherst County, Augusta County, ..., York County}

Service Areas (A): {Inventory, Payroll, Hiring, Marketing, Merchandising}

Travel Parameters:

$mileage\_rate = average\ cost\ per\ mile = 0.585$

$hourly\_rate = average\ employee\ hourly\ rate = 26$

$mi_{ij} = The\ distance\ from\ store_j\ to\ regional\ office_i\ (in\ miles),\ i \in R\ and\ j \in S$

$t_{ij} = The\ travel\ time\ from\ store_j\ to\ regional\ office_i\ (in\ hours),\ i \in R\ and\ j \in S$

$hours\_avail_{ik} = Annual\ hours\ available\ for\ area_k\ at\ regional\ office_i\ ,\quad k \in A\ and\ i \in R$

$hours\_req_{jk} = Annual\ hours\ required\ for\ area_k\ at\ store_j,\quad k \in A\ and\ j \in S$

$mi\_cost_{ij} = Mileage\ cost\ between\ regional\ office_i\ and\ store_j,\quad j \in S\ and\ i \in R$

$= mileage_{ij} * mileage\_rate\ ,\ for\ j \in S\ and\ i \in R$

$salary\_cost_{ij} = Salary\ cost\ per\ trip\ between\ reginal\ office_i\ and\ store_j,\quad j \in S\ and\ i \in R$
$= time_{ij} * hourly\_rate,\qquad j \in S\ and\ i \in R$

$trips_{jk}$ = $Number\ of\ annual\ trips\ required\ for\ each\ area_k\ at\ store_j,\quad j \in S\ and\ k \in A$

$Total\_travel\_cost$ = $The\ overall\ travel\ cost.$

Decision Variables:

The decision variables are binary:

$$x_{ij} = 1\ , if\ store\ j\ is\ assigned\ to\ regional\ office\ i$$

$$x_{ij} = 0\ , if\ store\ j\ is\ not\ assigned\ to\ regional\ office\ i$$

Where: $i \in R\ (set\ of\ regional\ offices)$

$j \in S\ (set\ of\ stores)$

Algebraic Formulation:

The goal is to minimize the total travel cost, which includes both mileage and salary costs. The total cost is calculated based on the number of trips required per service area, multiplied by the respective travel costs (mileage and salary), and the binary decision variables x_{ij}.

$$\text{Minimize} \sum_{j\in S}\sum_{i\in R}\sum_{k\in A} \text{trips}_{jk} \cdot (2 \cdot \text{mi}_{ij} + 2 \cdot \text{salary\_cost}_{ij}) \cdot x_{ij}$$

Where:

- $\text{mi}_{ij} = \text{mileage}_{ij} \cdot \text{mileage\_rate}$
- $\text{salary\_cost}_{ij} = \text{travel\_time}_{ij} \cdot \text{hourly\_rate}$

Constraints:

Assignment Constraint:

Each store must be assigned to exactly one regional office:

$$\sum_{i \in R} x_{ij} = 1, \quad \forall j \in S$$

Feasibility Constraint:

For each activity at each regional office, the total required hours for service, combined with the additional hours for travel time, must not exceed the available hours at the office:

$$\sum_{j \in S} \left(\text{hours\_req}_{jk} + 2 \cdot \text{travel\_time}_{ij} \cdot \text{trips}_{jk} \right) \cdot x_{ij} \leq \text{hours\_avail}_{ik}, \quad \forall i \in R, \forall k \in A$$

Manual Adjustment for Specific Assignments:

For specific stores, such as Stafford County, we may force the assignment to a specific office to improve geographic alignment. This is implemented as a constraint:

$$X_{Warrenton}, Stafford\_County \ = 1$$

Binary Decision Variables:

The decision variables x_{ij} are binary, representing if store j is assigned to regional office i:

$$x_{ij} \in \{0, 1\}, \quad \forall i \in R, \forall j \in S$$

Non-Negativity and Balance:

Ensure that the total number of available hours at each regional office is balanced with the required hours:

$$\text{time\_balance}_{ik} = \text{hours\_avail}_{ik} - \sum_{j \in S} \left(\text{hours\_req}_{jk} + 2 \cdot \text{travel\_time}_{ij} \cdot \text{trips}_{jk} \right) \cdot x_{ij},$$

$$\forall i \in R, \forall k \in A$$

Results

The original solution achieved a total cost of **$195,479.31**, optimizing for travel and salary costs. However, geographic inconsistencies were observed, such as Stafford_County being assigned to Richmond instead of the geographically closer Warrenton. This indicates that the optimization focused purely on cost minimization without incorporating geographic feasibility.

To address these issues Manual Adjustments have been made. Explicitly reassigning Stafford_County to Warrenton improved geographic alignment, reducing the total cost to **$194,130.69**. This remedy demonstrates that slight manual interventions can enhance both cost-efficiency and geographic feasibility.

The full AMPL code for this optimization model can be accessed through the provided Colab link:

https://colab.research.google.com/drive/1JSdX5NyiXaCvE4FUAhH59GdB3HnWRGxO?usp=sharing

Assumptions:

- Distances and travel times between stores and regional offices are assumed to be accurate and consistent, based on average conditions.
- Each store must be assigned to exactly one regional office.
- Mileage costs ($0.585 per mile) and hourly rates ($26 per hour) are constant across all offices and stores, with no variation in vehicle types, gas prices, or employee wages.
- The available hours at each regional office and the hours required by each store for each service area are fixed and accurately reflect current operational capacity, without accounting for fluctuations due to staffing changes or growth in service demand.

- The model prioritizes minimizing costs (travel and salary), assuming this approach aligns with the organization's strategic goals, even if it results in geographically suboptimal assignments.

Recommendation:

- The new store-to-office assignments should be used as the baseline for realignment, offering improved cost efficiency and workload balance. However, reassess assignments for stores located in distant offices to improve geographic practicality, moving them to closer offices where feasible. The new assignments should be implemented gradually to minimize disruptions, allowing employees to adapt while maintaining service quality. Regular evaluations should be conducted to identify any further areas for improvement.

- RAM Wireless should also consider increasing the capacity of offices in high-demand areas, such as Richmond, to reduce the need for geographically inconvenient assignments and improve operational efficiency.

- A hybrid approach is recommended, using geographic constraints as a baseline to ensure practical feasibility, and applying targeted manual adjustments where needed to address specific geographic or operational challenges, ensuring cost savings and better alignment with real-world logistics.

- This approach ensures both operational efficiency and improved geographic alignment for RAM Wireless.

Conclusion:

In conclusion, the model effectively balanced cost minimization, geographic alignment, and operational feasibility, providing a practical and scalable solution for RAM Wireless. The results show the importance of combining automated optimization with manual adjustments to address real-world logistical challenges. Future improvements could focus on refining the model by incorporating dynamic penalties for inefficient assignments or exploring more advanced techniques for capacity management, ultimately leading to even more optimized solutions for similar problems.

Appendix:

interactions with a generative AI:

https://docs.google.com/document/d/1SfB8sguNreCUFM3YtSqoT67qEvPzl2kCPqIg9tyU5tg/edit?usp=drive_link

https://chatgpt.com/share/6750fbaf-07ac-800a-8499-3406dfdd8020

https://copilot.cloud.microsoft/?fromCode=cmcv2&redirectId=1359E5FA4DDE4BAB8CB9D319FB6FECAD&noredirect=1&auth=2

Dataset:

https://docs.google.com/spreadsheets/d/1for1E7zCxgjuM1FXBmCVIADnVilci14r/edit?usp=drive_link&ouid=109039323993197012834&rtpof=true&sd=true