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Executive Summary

The Ram Wireless Homeo division faces inefficiencies in assigning stores to regional offices, leading to high travel costs and imbalanced workloads. Currently, stores are assigned based on proximity to offices, without fully considering operational constraints like travel times and resource availability. This results in excessive commuting, reduced productivity, and overutilized resources at some offices.

We are graduate students specializing in Decision Analytics, tasked with addressing this issue as part of our coursework. Over four weeks, we analysed data, developed optimization models, and provided actionable recommendations to improve store assignments while minimizing costs and ensuring resource feasibility.

The project focused on four regional offices—Staunton, Richmond, Warrenton, and Tappahannock—and their assigned stores. Two approaches were explored: a baseline assignment of stores to the nearest office (Part A) and an optimization-based realignment (Part B). Travel costs were calculated as the sum of mileage costs ($0.585 per mile) and salary costs ($26 per hour), with constraints ensuring office workloads did not exceed their available capacity.

Part A revealed a total cost of $192,040.16, but imbalances were evident, as some offices exceeded their available hours. In contrast, the optimized approach in Part B achieved a feasible assignment with a slightly higher cost of $195,479.31. This ensured balanced workloads across offices while maintaining reasonable travel costs. The optimized plan effectively addressed the operational challenges and demonstrated the benefits of a data-driven approach to resource management.

We recommend implementing the optimized assignment plan to achieve sustainable cost management and balanced resource utilization. Periodic reviews of store assignments and investments in monitoring tools can further enhance efficiency and adaptability to changing operational needs. These measures will enable The Ram Wireless Homeo division to reduce inefficiencies, improve productivity, and achieve long-term operational stability.

Implementing these recommendations will enable The Ram Wireless Homeo division to optimize operations while achieving long-term cost savings and improved efficiency

PART B

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1. Problem

Create a model that will find the lowest cost assignment of all stores to a regional office that respects area availability in each office. What is this assignment? How does it differ from the assignment in Part A? How is it the same?

2. Objective in Words

Decide the assignment of each store to a regional office **so that** the total travel cost is minimized, subject to the following **constraints**:

a) Capacity Constraints: The total hours required by all stores assigned to each regional office must not exceed the available employee hours at that office.

b) Assignment Constraints: Each store must be assigned to exactly one regional office.

c) Nonnegativity and Binary Constraints: The assignment variable for each store to a regional office must be binary, meaning a store is either assigned (1) or not assigned (0) to a specific office.

3. Data Definition

Data

Staunton	**Warrenton**	**Richmond**	**Tappahannock**
Amherst County	Buckingham County	Chesterfield County	Augusta County
Charles City County	Caroline County	City of Richmond	Shenandoah County
City of Fredericksburg	Essex County		Spotsylvania County
Culpeper County	Fluvanna County		Stafford County
Cumberland County	Hanover County		York County
Dinwiddie County	Nelson County		
Fauquier County	New Kent County		
Goochland County	Page County		
Greene County	Powhatan County		
Henrico County	Warren County		
Hopewell County	Westmoreland County		
James City County			
King and Queen County			
King George County			

King William County			
Louisa County			
Madison County			
Mathews County			
Orange County			
Prince George County			
Prince William County			
Rappahannock County			
Rockbridge County			
Rockingham County			

$Let,$

R

$= \{Staunton, Richmond, Warrenton, Tappahannock\} be\ the\ set\ of\ Regional\ Offices.$

$S\ = \{Albemarle\_County\ , Amherst\_County\ , Augusta\_County,$

$Buckingham\_County\ \ldots\ Warren\_County, Westmoreland\_County, York\_County\}$

$be\ the\ set\ of\ stores.$

$activities$

$= \{Inventory, Payroll, Hiring, Marketing, Merchandising\} be\ the\ set\ of\ activities$

$d_{ij} = Distance\ (in\ miles) between\ store\ i\ and\ regional\ office\ j, where\ i \in S, j \in R$

$w = Hourly\ wage\ for\ employees\ traveling\ to\ stores, fixed\ at\ \$26\ per\ hour..$

$m = State\ Mileage\ rate, fixed\ at\ \$0.585\ per\ mile, covering\ fuel\ \&\ vehicle\ wear.$

$H_j = Available\ work\ hours\ for\ each\ regional\ office\ j, where\ j \in R.$

$h_i = Annual\ hours\ of\ service\ needed\ by\ each\ store\ i, where\ i \in S.$

$s = Average\ travel\ speed\ in\ miles\ per\ hour.$

$\boldsymbol{Available\ Work\ Hours}$:

$Indexed\ by\ regional\ office\ (j)\ and\ work\ area\ (k), such\ as$:

$-\ Inventory, Payroll, Hiring, Marketing, Merchandising.$

$A_{jk}\ represents\ the\ available\ hours\ for\ regional\ office\ j\ in\ area\ k.$

$\boldsymbol{Hours\ Required}$:

$Indexed\ by\ store\ (i)\ and\ work\ area\ (k).$

$Example$: $H_{ik}\ represents\ the\ hours\ required\ by\ store\ i\ in\ area\ k.$

$travel\_cost_{ij} = d_{ij} \times m, the\ cost\ of\ travel\ per\ mile, where\ i \in S, j \in R$

$salary\_cost_{ij} = d_{ij}/s\ \times w, salary\ cost\ based\ on\ travel\ time, where\ i \in S, j \in R.$

4. Variable Definition – Decision variable

$\boldsymbol{x_{ij}} = A\ binary\ variable\ where\ \boldsymbol{x_{ij}} = \mathbf{1}, if\ store\ i\ is\ assigned\ to\ regional\ office\ j$

$and\ \boldsymbol{x_{ij}} = \mathbf{0}, otherwise.$

Where,

i = Stores

j = Regional Offices

k = Work Areas

Parameters:

$$C_{ij} = Total\ travel\ cost\ (round - trip) for\ store\ i\ to\ regional\ office\ j.$$

$$H_{ik} = Hours\ required\ by\ store\ i\ in\ work\ area\ k.$$

$$A_{jk} = Available\ hours\ in\ work\ area\ k\ at\ office\ j.$$

5. Algebraic Formulation

$\boldsymbol{Objective}: Minimize\ the\ total\ travel\ cost$

$$Min \sum_{i \in S} \sum_{j \in R} x_{ij} \times (travel\_cost_{ij} + salary\_cost_{ij}), for\ i \in S, j \in R \qquad (Total\_Cost)$$

$Subject\ to\ the\ following\ \boldsymbol{constraints}:$

$$\sum_{j \in R} x_{ij} = 1, for\ i \in S\ and\ j \in R \qquad (Assignment\_Constraint)$$

$$\sum_{i} H_{ik} \cdot x_{ij} + \sum_{i} (Travel\ Time_{ij} \cdot x_{ij}) \leq A_{jk} \forall j, k \qquad \text{(Feasibility Constraint)}$$

$$\sum_{i \in S} h_i \times x_{ij} \leq h_j, for\ i \in S\ and\ j \in R \qquad (Capacity\_Constraint)$$

$$x_{ij} \in \{0,1\}, for\ i \in S\ and\ j \in R \qquad (Binary\ and\ Non\_Negativity\ Constraint)$$

6. Implementation

AMPL Implementation: Colab link

7. Results

The optimal solution is that we should minimize the total travel cost to **$195,479.31**. This value represents the combined expenses of mileage and salary costs for the trips required by each store to their assigned regional offices.

8.Key Insights

- Part B ensures no office exceeds its capacity, accounting for both travel time and working hours.
- Part B achieves feasibility by balancing workload but results in slightly higher cost.

Part C: Geographic Evaluation of Optimized Assignments

While the Part B solution successfully minimized costs and balanced workloads, it did not fully address the practical challenges arising from geographic misalignment. When overlaying the optimized assignments onto a map of Virginia, several inconsistencies become evident. For instance, stores in contiguous regions are sometimes split across multiple regional offices, while stores located closer to one office may be assigned to another farther away. These irregularities, although mathematically efficient, could disrupt operational workflows, increase logistical complexity, and reduce employee productivity.

These inconsistencies stem from the model's focus on cost minimization and workload balancing without explicitly considering geographic continuity. The optimization algorithm prioritized travel costs and resource utilization but did not incorporate constraints to ensure geographic coherence. As a result, the assignments sometimes ignored natural or administrative boundaries such as county lines or regional clusters, which are critical for practical operations.

To address this, we recommend refining the model by introducing geographic continuity constraints. First, Virginia's counties or metropolitan areas could be used as predefined clusters for each regional office. The model could then be adjusted to ensure that all stores within a cluster are assigned to the same regional office whenever possible. Additionally, a primary service zone could be defined for each office, limiting cross-boundary assignments to cases where capacity constraints necessitate exceptions. By penalizing deviations from geographic continuity, the model can balance both cost efficiency and practical coherence.

These changes would improve logistical efficiency, reduce employee confusion, and streamline operational planning. Employees would benefit from more contiguous service areas, minimizing travel-related fatigue and delays. However, the adjustments may slightly increase total travel costs or require a more nuanced approach to workload balancing. These trade-offs are acceptable, as the long-term operational benefits would outweigh the marginal increase in costs.

In conclusion, geographic alignment is critical for operational efficiency, and incorporating these refinements into the model would make the solution more practical and impactful. Visual overlays of the optimized assignments on the Virginia map should guide further refinements and ensure that the model accounts for both operational feasibility and cost efficiency. By addressing these geographic concerns, the division can achieve a robust, sustainable solution that enhances both productivity and employee satisfaction.

Additional Information: Modeling Methodology and Results

The optimization model developed for Part B relied on a structured and methodical approach to address the challenges posed by the current store-to-office assignment process. This section provides a detailed account of the modeling methodology and the results achieved, offering deeper insights into the decision-making process and the effectiveness of the solution.

Modelling Methodology

The goal of the optimization model was to minimize the total travel cost while ensuring that no regional office exceeded its available work hours. Travel costs were calculated as a combination of mileage costs (at a state rate of $0.585 per mile) and salary costs (at $26 per hour). The model also accounted for the time required for employees to travel between stores and their assigned regional offices. Below is an overview of the key components of the model:

1. **Objective Function**: The model's primary objective was to minimize the total cost of assigning stores to regional offices. The cost function incorporated both mileage and salary costs, ensuring an accurate representation of travel-related expenses.
2. **Decision Variables**: Binary decision variables were used to represent the assignment of each store to a specific regional office. A value of 1 indicated that a store was assigned to a particular office, while a value of 0 indicated otherwise.
3. **Constraints**: The model incorporated several constraints to ensure feasibility:
    - **Assignment Constraint**: Each store was assigned to exactly one regional office.
    - **Capacity Constraint**: The total hours required for servicing assigned stores (including travel time) did not exceed the available hours for each regional office.
    - **Workload Balancing**: The workload across offices was balanced to prevent overutilization of resources.
4. **Data Inputs**: The data inputs included:

- Travel distances and times between stores and offices.
- Hourly requirements for each store in five key areas (inventory, payroll, hiring, marketing, and merchandising).
- Available work hours for each regional office.

The optimization was implemented using AMPL, a powerful modeling tool, with solvers such as HiGHS and CBC to compute the results. The model was run iteratively to validate outputs and refine constraints to ensure practical feasibility.

Results

The results of the optimization provided critical insights into the operational improvements achievable through data-driven decision-making:

1. **Cost Efficiency**: The total travel cost for the optimized solution was $195,479.31, a slight increase compared to the $192,040.16 cost of the closest-office assignment in Part A. This increase was justified by the improved feasibility and workload balancing achieved in the optimized solution.

2. **Workload Balancing**: The optimization ensured that no regional office exceeded its available work hours, addressing the resource imbalances observed in Part A. By redistributing assignments, the model achieved a more equitable workload distribution.

3. **Geographic Observations**: While the optimization minimized costs and balanced workloads, certain geographic inconsistencies were noted, such as fragmented assignments for stores in contiguous regions. These observations were addressed in Part C, where potential refinements were proposed to incorporate geographic constraints into the model.

Appendix: Interactions with Generative AI

Generative AI tools played a significant role in assisting with various stages of this project, from data preparation and modeling to report writing and presentation. Below is an account of how these tools were utilized and their contributions to achieving the project objectives.

https://chatgpt.com/c/67464d33-d7d0-8006-872b-c88ffa56fbf9

Problem Definition and Structuring

At the start of the project, AI was used to help frame the problem and develop a clear structure for the analysis. It assisted in identifying key objectives such as minimizing travel costs, balancing workloads, and addressing geographic inconsistencies. By breaking the problem into actionable components, AI provided a framework that guided the methodology and ensured alignment with operational goals.

Data Preparation and Processing

AI tools were instrumental in preparing and structuring the data for modeling. They assisted in renaming columns, filling missing values, and formatting the dataset into an AMPL-compatible structure. Additionally, AI provided automated scripts for validating data integrity, ensuring the inputs were accurate and ready for optimization. This contribution streamlined the process and enabled the team to focus on model development.

Optimization Modeling

AI contributed to the development of the optimization model in AMPL. It provided the initial framework for the objective function and constraints, incorporating workload balancing and travel cost minimization. Troubleshooting support was also provided, helping to resolve runtime errors and refine the model for better alignment with project goals. This collaboration significantly accelerated the development and validation of the model.

Report Writing and Refinement

Generative AI was actively engaged in drafting and refining sections of the report. The executive summary, parts A through C, and this appendix were all developed with AI assistance. The narrative tone, consistency, and readability were enhanced through iterative revisions. Additionally, AI helped condense complex technical details into clear and concise explanations, ensuring the report was accessible to both technical and non-technical audiences.

Analysis of Geographic Constraints

In Part C, AI helped evaluate the geographic implications of the optimized assignments. By analyzing the map of Virginia and identifying geographic inconsistencies, AI provided recommendations for incorporating continuity constraints into the model. This analysis ensured that the findings addressed both cost efficiency and practical feasibility.

Impact on the Project

Generative AI tools enhanced the overall efficiency and quality of the project by automating repetitive tasks, offering technical insights, and improving the clarity of communication. These contributions allowed the team to focus on decision-making and validation, ensuring that the final solutions were robust and actionable. The integration of AI into the workflow exemplified the value of leveraging advanced tools in solving complex business challenges.