Project Phase I

Ram Wireless, a Virginia-based company with numerous store locations, depends on regional offices to support services such as inventory management, payroll, hiring, local marketing, and merchandising. As the company has expanded geographically, inefficiencies have surfaced in the assignment of stores to regional offices. This has led to increased travel time for employees, impacting productivity, cost-efficiency, and overall employee satisfaction.

Part A – Problem

Vance and Melissa at Ram Wireless aim to assign each store to the nearest regional office based purely on mileage. This allocation disregards any cost constraints and focuses solely on distance. Once the stores are assigned, the goal is to calculate the total travel cost of the allocation and assess its feasibility.

Part B – Problem

Melissa Jones, the COO, and Vance Larson, a regional manager, are seeking a realignment of store assignments to the regional offices in Staunton, Richmond, Warrenton, and Tappahannock. The main goal is to minimize travel costs by balancing travel distances and workloads. They have engaged Verve Consulting to analyze and optimize these assignments, aiming to reduce travel time and expenses while adhering to each office's capacity constraints.

Data

Hours Available

	Inventory	Payroll	Hiring	Marketing	Merchandising
Richmond	3025	1225	1750	3675	5000
Tappahannock	5550	3250	1200	1600	3400
Warrenton	2500	3375	1325	850	825
Staunton	3450	9100	1700	1850	3550

- **Average Mileage Cost**: $0.585 per mile
- **Average Employee Hourly Wage**: $26 per hour

Let

$$C = \text{Set of regional offices}, C = \{\text{Staunton}, \text{ Richmond}, \text{ Warrenton}, \text{ Tappahannock}\}$$

$$S = \text{Set of stores, with each store represented as an element (e.g., Albemarle County).}$$

$$A = \text{Set of support areas (activities)}, A = \{\text{Inventory}, \text{ Payroll}, \text{ Hiring}, \text{ Marketing}, \text{ Merchandising}\}$$

Decision Variables

Let

x_{ij} = *Is a binary variable indicating whether* $store_j$ *is assigned to* $office_i$, *for* $j \in S$ *and* $i \in C$

$$x_{ij} \in \{0,1\}, \quad j \in S \text{ and } i \in C$$

Parameters

- **Distance and Time**:

$\mathrm{mileage_{ij}}$: *Distance in miles from store* j *to regional office* i, *for* $i \in C$ *and* $j \in S$.

$\mathrm{time_{ij}}$: *time in hours from the store* j to regional office i, for i ∈ C and j ∈ S.

- **Cost Rates:**
  - Mileage rate = 0.585: The cost per mile.
  - Hourly rate = 26: Employee hourly wage.

- **Hours and Requirements:**

$hours\ available_{ih}$ = *annual hours avaliable for activity* h *at regional office* i, *for* $h \in A$ and $i \in C$

$hours\ required_{jh}$ = *annual hours required for activity* h *at store* j, *for* $h \in A$ *and* $j \in C$

- **Trips**:

$trips_{jh}$ = *number of annual trips required for each activity* h *at store* j *for* $j \in C$ *and* $h \in A$

- **Derived Costs**

  Mileage Cost:

$$mileage\ cost_{ij} = mileage_{ij} \times mileage\ rate$$

Salary Cost

$$salary\ cost_{ij} = time_{ij} \times hourly\ rate$$

Objective in Words

Part A:

Decide how to assign each store to the closest regional office based on mileage, so that the total mileage is minimized while satisfying the following constraints:

- Each store is assigned to exactly one regional office.
- Nonnegativity constraints.

Part B:

Decide the optimal assignment of each store to the nearest regional office to minimize the total travel distance, ensuring that:

- Each store is allocated to one and only one regional office.
- Total hours required for each activity at each regional office must not exceed the available hours for that activity at the office – Resource Capacity constraint.
- All values remain non-negative.

Algebraic Formulation

Part A:

Optimization model

$$minimize \sum_{j \in S} \sum_{i \in C} \sum_{h \in A} trips_{jh} * 2 * \left(mileage_{cost_{ij}} + salary_{cost_{ij}}\right) .* x_{ij}$$

$$s.t. \quad \sum_{i \in C} x_{ij} = 1, \qquad j \in S \quad (assigment\ constriant)$$

$$x_{ji} \in \{0,1\}, j \in S\ and\ i \in C \qquad (Nonnegativity\ and\ binnary\ Constraint)$$

Total Travel Cost:

$$total\ travel\ cost = \sum_{j \in S} \sum_{i \in C} \sum_{h \in A} 2 * trips_{jh} . \left(mileage_{cost_{ij}} + salary_{cost_{ij}}\right) . x_{ij}$$

Part B:
Optimization model

$$minimize \sum_{j\in S}\sum_{i\in C}\sum_{h\in A} trips_{jh} * 2 * \left(mileage_{cost_{ij}} + salary_{cost_{ij}}\right) .* x_{ij}$$

$$s.t. \quad \sum_{i\in C} x_{ij} = 1, \qquad j \in S \quad (assigment\ constriant)$$

$$x_{ji} \in \{0,1\}\ , j \in S\ and\ i \in C \qquad (Nonnegativity\ and\ binnary\ Constraint)$$

$$\sum_{j\in S} hours_{required_{jh}}.\ x_{ij} + \sum_{j\in S} 2 * travel_{time\ jh} * trips_{jh}.\ x_{ij} +\leq \sum_{j\in S} hours_{available_{ih}},$$
$$i \in C,\ \ j\ \in A\ and\ h \in A\ (Resource\ Capacity\ Constraint)$$

Total Travel Cost:

$$total\ travel\ cost = \sum_{j\in S}\sum_{i\in C}\sum_{k\in A} 2 * trips_{jk}\ .\left(mileage_{cost_{ij}} + salary_{cost_{ij}}\right).x_{ij}$$

Feasibility check:

$$\sum_{j\in S} hours\_required_{jk}.\ x_{ij} \leq hours\_avaiable_{ik}, i \in C\ and\ h \in A$$

RESULT

Part A

The optimal solution based on the minimum distance allocation; each store is assigned to the nearest regional office as follows:

County	ALLOCATION OF RO - Part A
Albemarle	Staunton
Amherst	Staunton
Augusta	Staunton
Buckingham	Staunton
Caroline	Tappahannock
Charles City	Richmond
Chesterfield	Richmond
City of Fredericksburg	Warrenton
City of Richmond	Richmond
Culpeper	Warrenton
Cumberland	Richmond
Dinwiddie	Richmond
Essex	Tappahannock
Fauquier	Warrenton
Fluvanna	Staunton
Goochland	Richmond
Greene	Warrenton
Hanover	Richmond
Henrico	Richmond
Hopewell	Richmond
James City	Richmond
King and Queen	Tappahannock
King George	Tappahannock
King William	Tappahannock
Louisa	Richmond
Madison	Warrenton
Mathews	Tappahannock
Nelson	Staunton
New Kent	Richmond
Orange	Warrenton
Page	Warrenton
Powhatan	Richmond
Prince George	Richmond
Prince William	Warrenton
Rappahannock	Warrenton
Rockbridge	Staunton
Rockingham	Staunton
Shenandoah	Warrenton
Spotsylvania	Warrenton
Stafford	Warrenton
Warren	Warrenton
Westmoreland	Tappahannock
York	Tappahannock

resulting in an optimal total cost of **$192040.16**.

Part B

The optimal solution for Office Realignment Project is to assign:

County	ALLOCATION OF RO - Part B
Albemarle	Staunton
Amherst	Staunton
Augusta	Staunton
Buckingham	Staunton
Caroline	Tappahannock
Charles City	Richmond
Chesterfield	Richmond
City of Fredericksburg	Tappahannock
City of Richmond	Richmond
Culpeper	Warrenton
Cumberland	Richmond
Dinwiddie	Richmond
Essex	Tappahannock
Fauquier	Warrenton
Fluvanna	Richmond
Goochland	Richmond
Greene	Staunton
Hanover	Richmond
Henrico	Richmond
Hopewell	Richmond
James City	Richmond
King and Queen	Tappahannock
King George	Tappahannock
King William	Tappahannock
Louisa	Richmond
Madison	Staunton
Mathews	Tappahannock
Nelson	Staunton
New Kent	Richmond
Orange	Warrenton
Page	Warrenton
Powhatan	Richmond
Prince George	Richmond
Prince William	Warrenton
Rappahannock	Warrenton
Rockbridge	Staunton
Rockingham	Staunton
Shenandoah	Warrenton
Spotsylvania	Tappahannock
Stafford	Richmond
Warren	Warrenton
Westmoreland	Tappahannock
York	Tappahannock

an optimal total cost of **$ 195479.31**.

SUMMARY OF STEPS TO ACHIEVE THE OPTIMIZED SOLUTION – PROJECT PHASE 1

Calculation of Costs

- **Mileage and Salary Costs**: Excel formulas were used to calculate the mileage cost for each store-to-regional-office route at $0.585 per mile and salary costs based on travel time and an hourly rate of $26. The formulas were:
    - **Mileage Cost**: $= Mileage * Mileage\ Rate$
    - **Salary Cost**: = $Travel\ Time\ (hrs) * Hourly\ Rate$
      These were combined to determine the total transportation cost for each store-to-office assignment.
- **Total Cost Computation**: The total transportation cost was calculated by summing mileage and salary costs for each store-to-regional-office pairing:
    - **Total Cost**: $= Mileage\ Cost + Salary\ Cost$
      This data was then organized for optimization.

Initial Assignment Decision

- **Binary Decision Variables**: A column was added to Excel for binary decision variables (1 for assignment, 0 for no assignment). These variables were crucial for the optimization process, determining the store-to-office assignments.

Optimization with Excel Solver

- **Solver Setup**: Excel Solver was configured to minimize total transportation costs while ensuring each store was assigned to exactly one regional office and all resource constraints were met.
- **Objective Function**: The objective was to minimize the sum of total costs weighted by the binary decision variables:
    - **Objective**: Minimize SUM(Product of Total Costs and Decision Variables) Solver aimed to find the optimal store-to-office assignments with the lowest cost.
- **Constraints**: Constraints were applied to ensure:
    - Each store was assigned to one regional office (sum of binary variables = 1).
    - Total service hours at each office did not exceed available hours.
- **Solver Execution**: Solver adjusted the decision variables to find the optimal assignments, minimizing costs while adhering to constraints.

Regional Office Allocation Comparison

- **Consistency**: Most counties maintained the same regional office assignment in both Part A and Part B (e.g., Staunton for Albemarle, Amherst, and Augusta). Some counties, like the City of Fredericksburg and Spotsylvania, had different assignments between the two parts.
- **Geographic Shifts**: Some counties shifted regional offices in Part B, with trends toward Richmond or Tappahannock (e.g., Fluvanna moves from Staunton to Richmond). These shifts suggest a reevaluation of proximity or other factors.
- **Overall Trends**: Richmond is the most frequently assigned regional office, followed by Staunton and Warrenton, with some variations in Part B, particularly for counties in the eastern and southern regions.