Ride Allocation Optimization

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Decision Variables

- $t_{ij} \in \{0, 1\}$: Binary decision variable indicating if driver j is assigned to passenger i.
- $d_{ij}^k \in \{0, 1\}$: Binary variable indicating if driver j is assigned to area k for rider i.
- D_k: Number of drivers allocated to area k, where $k = 1, 2, \ldots, K$.

Parameters

- N_r^k: Number of riders in area k.
- N_d^k: Number of drivers in area k.
- H_k: Historical ride data for area k.
- C_{ij}^k: Cost of assigning driver j to rider i in area k (based on distance, preferences, etc.).
- P_k: Past ride count for area k.
- R_j: Rating of driver j.
- α, β, γ: Weights for balancing demand, cost, and quality.
- f_{ij}: Binary value indicating whether driver j satisfies passenger i's preferences.
- d_{ij}: Distance between passenger i and driver j.
- s_j: Status of driver j ($s_j = 0$ if available, $s_j = 1$ if unavailable).
- p_{ij}: Revenue contribution of assigning driver j to passenger i.
- c_{ij}: Cancellation likelihood score for pairing passenger i with driver j.
- e_j: Emission score of driver j's vehicle (lower is better).
- λ_k: Minimum percentage of demand to satisfy in area k.
- w_i: Normalized weight representing how early passenger i booked:

$$w_i = \frac{\text{latest\_time} - \text{booking\_time}_i}{\text{latest\_time} - \text{earliest\_time}}$$

Objective Functions

1. **Maximize Total Assignments:**

$$Z_1 = \sum_{i=1}^{n} \sum_{j=1}^{m} f_{ij} \cdot (1 - s_j) \cdot t_{ij}$$

2. **Minimize Assignment Costs:**

$$Z_2 = \sum_{i=1}^{n} \sum_{j=1}^{m} d_{ij} \cdot (1 - s_j) \cdot f_{ij} \cdot t_{ij}$$

3. **Maximize Driver Ratings:**

$$Z_3 = \sum_{i=1}^{n} \sum_{j=1}^{m} f_{ij} \cdot (1 - s_j) \cdot r_j \cdot t_{ij}$$

4. **Maximize Assignments Based on Booking Time:**

$$Z_4 = \sum_{i=1}^{n} \sum_{j=1}^{m} w_i \cdot f_{ij} \cdot t_{ij}$$

5. **Maximize Revenue:**

$$Z_5 = \sum_{i=1}^{n} \sum_{j=1}^{m} p_{ij} \cdot t_{ij}$$

6. **Minimize Driver Workload Deviation:**

$$Z_6 = \sum_{j=1}^{m} \left(\frac{\sum_{i=1}^{n} t_{ij}}{n} - u_j \right)^2$$

7. **Minimize Cancellation Probability:**

$$Z_7 = \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} \cdot t_{ij}$$

8. **Promote Eco-Friendly Rides:**

$$Z_8 = \sum_{i=1}^{n} \sum_{j=1}^{m} e_j \cdot t_{ij}$$

9. **Prioritize Subscription Users:**

$$Z_9 = \sum_{i \in \text{premium}} \sum_{j=1}^{m} p_{ij} \cdot t_{ij}$$

Constraints

1. **One Driver per Passenger:**

$$\sum_{j=1}^{m} t_{ij} \leq 1 \quad \forall i \in \{1, 2, \ldots, n\}$$

2. **One Passenger per Driver:**

$$\sum_{i=1}^{n} t_{ij} \leq 1 \quad \forall j \in \{1, 2, \ldots, m\}$$

3. **Driver Availability:**

$$s_j = 0 \quad \text{if driver is available, else } s_j = 1$$

4. **Driver Allocation Limit:**

$$\sum_{k=1}^{K} D_k \leq M$$

5. **Demand Satisfaction:**

$$D_k \geq \lambda_k \cdot N_r^k, \quad \forall k$$

6. **Driver Assignment to One Area:**

$$\sum_{k=1}^{K} d_{ij}^k \leq 1, \quad \forall i, j$$

7. **Binary Decision Variables:**

$$t_{ij},\, d_{ij}^k \in \{0, 1\}, \quad \forall i, j, k$$