Decision Variables

1. x_{ik}: Binary decision variable indicating the truck serves the customer from warehouse i to k (1 if true, 0 if false)
2. d_{kj}: Binary decision variable indicating the drone is dispatched from the truck at node k to serve the customer j (1 if true, 0 if false)
3. y_{ik}: Binary decision variable indicating the truck visits node k when serving customers from warehouse i
4. z_{kj}: Binary decision variable indicating the drone visits node k when serving customer j
5. $T_{\text{truck}_{ik}}$: Time taken by the truck to travel from warehouse i to node k and serve customer j
6. $T_{\text{drone}_{kj}}$: Time taken by the drone to travel from node k to serve customer j
7. p_{ij}: Binary variable indicating package delivery from node i to j
8. $C_{\text{package}_{ij}}$: Cost for delivering a package from node i to j
9. β: Weight parameter for package delivery cost in the objective function

Objective Function

Minimize:

$$Z = \alpha_T \sum_k x_{ik} C_{\text{truck}_{ik}} + \alpha_D \sum_{k,j} d_{kj} C_{\text{drone}_{kj}} + \beta \sum_{k,j} p_{kj} C_{\text{package}_{kj}} + \lambda \sum_k (T_{\text{truck}_{ik}} + T_{\text{drone}_{kj}})$$

Constraints

1. $\sum_i x_{ik} + \sum_j d_{kj} = 1$ (Serve either by truck or drone)
2. $T_{\text{truck}_{ik}} = \frac{\text{Distance}_{\text{truck}_{ik}}}{\text{Speed}_{\text{truck}}}$ (Truck Time Constraint)
3. $T_{\text{drone}_{kj}} = \frac{\text{Distance}_{\text{drone}_{kj}}}{\text{Speed}_{\text{drone}}}$ (Drone Time Constraint)
4. $x_{ik} \geq d_{kj}$ (Drone Dispatch Constraint)
5. $\sum_j x_{ik} = y_{ik}$ (Mark nodes visited by the truck)
6. $\sum_j d_{kj} = z_{kj}$ (Mark nodes visited by the drone)

Where:

- x_{ik} is a binary variable indicating whether the truck traverses the link between warehouse i and the customer k.
- d_{kj} is a binary variable indicating whether the drone is dispatched from the truck at node k to serve the customer j.
- y_{ik} is a binary variable indicating whether the truck visits node k when serving customers from warehouse i.
- z_{kj} is a binary variable indicating whether the drone visits node k when serving customer j.
- $T_{\text{truck}_{ik}}$ is the time taken by the truck to travel from warehouse i to node k and serve customer j.
- $T_{\text{drone}_{kj}}$ is the time taken by the drone to travel from node k to serve customer j.
- $C_{\text{truck}_{ik}}$ is the cost associated with the truck serving the customer from warehouse i to k.
- $C_{\text{drone}_{kj}}$ is the cost associated with the drone serving the customer from node k to j.
- α_T is the unit variable cost for the truck.
- α_D is the unit variable cost for the drone.
- λ is a weight parameter for the time component in the objective function.
- p_{ij}: Binary variable indicating package delivery from node i to j.
- $C_{\text{Package}_{ij}}$: Cost for delivering a package from node i to j.
- β: Weight parameter for package delivery cost in the objective function.