USING MIP TO **OPTIMIZE DELIVERY ROUTES FOR A LOCAL DELIVERY COMPANY**

GB730 APPLICATION PROJECT - MAI NGUYEN

Why Route Optimization Matters

Problem:

- Small delivery companies face rising pressure
- Customers expect fast delivery, fuel costs keep climbing, and traffic conditions shift constantly
- When a company assigns drivers manually or uses a basic system, routes end up longer than they need to be

=> *That leads to wasted fuel, slow deliveries, overtime pay, and unhappy customers*

Goal:

- Design an optimization model that calculates the most efficient route plan that still respects real operational limits

Objective Function

- Minimize total distance travelled by trucks while delivering for customers for their packages
- Solver:
  - Pyomo with CBC solver (MIP)

```
# Decision variables
model.x = Var(trucks, customers, domain=Binary)
```

```
# Objective: Minimize total distance
def total_distance(model):
    return sum(model.x[t,c]*distance.get((t,c), 10) for t in trucks for c in customers)
model.obj = Objective(rule=total_distance, sense=minimize)
```

Variables & Constraints

Variables:

- **Binary Variables (yes or no decisions)**
  - model.x[t,c] = 1 if truck t delivers to customer c, 0 otherwise
  - Determines which truck visits which customer

Contraints:

- **Trucks Capacity**
  - There is only 5 trucks in total and they need to optimize for routes
- **Customer visit capacity**
  - Each customer can only be visited exactly once

```
# Each customer visited exactly once
def customer_visit_rule(model, c):
    return sum(model.x[t,c] for t in trucks) == 1
model.customer_visit = Constraint(customers, rule=customer_visit_rule)

# Truck capacity constraints
def truck_capacity_rule(model, t):
    return sum(model.x[t,c]*demand[c] for c in customers) <= capacity[t]
model.truck_capacity = Constraint(trucks, rule=truck_capacity_rule)
```

Model Inputs

- **Trucks:** 5 trucks (T1–T5)
- **Customers:** 15 customers (C1–C15)
- **Truck Capacities:** Max 5 deliveries per truck
- **Customer Demand:** 1 delivery per customer
- **Distance Matrix:** Example distances (simplified for demonstration)

```
# Sets
trucks = ['T1','T2','T3','T4','T5']
customers = ['C1','C2','C3','C4','C5','C6','C7','C8','C9','C10','C11','C12','C13','C14','C15']
```

```
distance = {
    ('T1','C1'): 4, ('T1','C2'): 6, ('T1','C3'): 5, # ... continue for all trucks and customers
    ('T2','C1'): 5, ('T2','C2'): 4, ('T2','C3'): 7,
    # Add remaining distances for demo purposes
}

capacity = {'T1': 5, 'T2': 5, 'T3': 5, 'T4': 5, 'T5': 5}  # max customers per truck
demand = {'C1':1, 'C2':1, 'C3':1, 'C4':1, 'C5':1, 'C6':1, 'C7':1, 'C8':1, 'C9':1, 'C10':1,
          'C11':1, 'C12':1, 'C13':1, 'C14':1, 'C15':1}
```

Model Outputs

- After solving, the model assigns customers to trucks:

```python
# Display results
for t in trucks:
    assigned = [c for c in customers if value(model.x[t,c]) > 0.5]
    print(f"Truck {t} delivers to: {assigned}")
```

```
Truck T1 delivers to: ['C1', 'C3', 'C8', 'C14', 'C15']
Truck T2 delivers to: ['C2', 'C9']
Truck T3 delivers to: ['C4', 'C5', 'C12', 'C13']
Truck T4 delivers to: ['C7', 'C10']
Truck T5 delivers to: ['C6', 'C11']
```

- Truck T1 to 5 customers
- Truck T3 assigned to 4 customers
- Truck T2, T4, T5 assigned to 2 customers

Limitations & Challenges

- Distance matrix in demo is simplified
- Model does not include:
  - Time windows
  - Traffic variability
  - Truck loads
  - Weight of packages
  - Vehicle load constraints beyond max customer count
  - Multiple order per day
  - Scaling to 50+ customers may require further decomposition
- Somes trucks like T1 and T4 are assigned to more customers than other
  - Could not be the most optimize case if add more constraints

Next Steps

- Use real-world distance and travel time data
- Incorporate delivery time windows and priority orders
- Test larger datasets for scalability
- Integrate with real-time routing systems for dynamic updates

Colab Notebook Link

- For further info regarding the code for this project:

  https://colab.research.google.com/drive/1hl7gGTCGKHOZtHftD00WK_3NLaZemcY7?usp=sharing

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