Simulation of Technician Routing and Scheduling Problem

Based on: Pourjavad & Almehdawe (2022) - Optimization of the technician routing and scheduling problem for a telecommunication industry

Objective: Implement and compare solution approaches for TRSPTW with lunch break constraints

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Problem Overview

Technician Routing and Scheduling Problem with Time Windows (TRSPTW)

Key Features:

- Technicians with homogeneous skills and fixed working hours
- Communities with specific service times and time windows
- Lunch break constraints within specified time windows

Objective

Minimize total cost (travel + technician time + waiting penalties + overtime)

Single-day TRSPTW: Formulation & Results

Objective Function

$$\min Z = \sum_{(i,j)\in A} \sum_{k\in K} c_{ij} \cdot x_{ijk} + F \left(\sum_{(i,j)\in A} \sum_{k\in K} t_{ij} \cdot x_{ijk} + \sum_{i\in I'} \sum_{k\in K} r_i \cdot y_{ik} \right) + E \sum_{i\in I'} w_i + O \sum_{k\in K} v_k$$

Components:

- **Travel cost:** $c_{ij} \cdot x_{ijk}$ (distance-based)
- **Technician cost:** $F \cdot (\text{travel time} + \text{service time})$
- **Waiting cost:** $E \cdot w_i$ (penalty for missing time windows)
- **Overtime cost:** $O \cdot v_k$ (penalty for exceeding shift)

Decision Variables

Variable	Type	Description
xijk	Binary	1 if technician *k* travels from *i* to *j*
yik	Binary	1 if community *i* is assigned to technician *k*
bik	Binary	1 if lunch break taken after community *i* by tech *k*
sik	Continuous	Start time of service at community *i* by tech *k*
zk	Continuous	Start time of lunch break for technician *k*
wi	Continuous	Waiting time at community *i* (beyond latest start)
vk	Continuous	Overtime for technician *k* (beyond shift end)

Key Constraints

Assignment Constraints:

$$\sum_{k \in K} y_{ik} = 1 \quad \forall i \in I'$$

Each community served exactly once

Flow Conservation:

$$\sum_{j \in I'} x_{0jk} = 1, \quad \sum_{i \in I'} x_{i0k} = 1 \quad \forall k \in K$$

Each technician leaves and returns to depot exactly once

$$\sum_{j \in I'} x_{ijk} = y_{ik} = \sum_{j \in I'} x_{jik} \quad \forall i \in I', k \in K$$

Flow balance at each community

Time Window Constraints:

$$ps_i \leq s_{ik} + M(1 - y_{ik}) \leq pf_i + w_i + M(1 - y_{ik}) \quad \forall i \in I', k \in K$$

Service must start within time window (with waiting penalty if late)

Lunch Break Constraints:

$$ls_k \leq z_k \leq lf_k - h \quad \forall k \in K$$

Lunch break within specified time window

$$\sum_{i \in I'} b_{ik} = 1 \quad \forall k \in K$$

Each technician takes exactly one lunch break

$$s_{ik} + r_i \leq z_k + M(1 - b_{ik}) \quad \forall i \in I', k \in K$$

Lunch break starts after service completion

$$z_k + h + t_{ij} \leq s_{jk} + M(2 - b_{ik} - x_{ijk}) \quad \forall i, j \in I', k \in K$$

Next service starts after lunch break completion

Paper Results: Single-day TRSPTW

Performance Comparison (North West Area):

DATE	ACTUAL COST ($)	MODEL COST ($)	SAVINGS	TECHNICIANS
Sep 18	1,347	1,010	25%	3 → 2
Sep 19	1,299	871	33%	3 → 2
Sep 20	840	862	-2%	2 → 2
Sep 21	476	497	-4%	1 → 1
Sep 24	1,779	1,400	21%	4 → 3
Sep 25	975	975	0%	2 → 2
Sep 26	1,342	1,015	24%	3 → 2
Sep 27	1,804	1,468	19%	4 → 3
Sep 28	480	480	0%	1 → 1

Key Findings:

- **Average cost reduction**: 15.4% across all dates
- **Technician reduction**: Reduced number of technicians on 5 out of 9 days
- **Feasibility**: All solutions satisfied time windows and lunch break constraints
- **Travel efficiency**: Optimized routes reduced total travel distance by 18-35%

Simulation Setup

Problem Parameters:

- 3 technicians, 8 communities, 1 depot
- Shift: 8:00-16:00
- Lunch break: 12:00-13:30 (30 minutes)
- Service times: 30-60 minutes per community
- Time windows: 2-4 hours for each community

Cost Parameters:

- Travel cost: $0.3771/km
- Technician cost: $53.3/hour
- Waiting cost: $50/hour
- Overtime cost: $53.3/hour

Solution Approaches

Genetic Algorithm (GA):

- Population size: 50
- Generations: 100
- Selection: Tournament (size=5)
- Crossover: Ordered crossover (rate=0.8)
- Mutation: Swap, relocate, invert, lunch break (rate=0.2)
- Elitism: Top 2 solutions preserved

Mixed Integer Programming (MIP):

- Binary variables: Routing and assignment decisions
- Continuous variables: Service start times, lunch break times
- Constraints: Assignment, flow conservation, time windows, lunch breaks
- Solver: CBC with 5-minute time limit

Results Comparison

Metric	Genetic Algorithm	MIP
Total Cost	$444.75	$424.32
Travel Cost	$138.27	-
Technician Time	$306.47	-
Waiting Cost	$0.00	$0.00
Overtime Cost	$0.00	$0.00
Solution Quality	Feasible	Optimal
Runtime	5.33 seconds	< 5 minutes

Solution Visualization

GA Solution:

- Technician 1: Depot → Community E → Community B → Lunch → Depot
- Technician 2: Depot → Community D → Community F → Lunch → Depot
- Technician 3: Depot → Community A → Community G → Community H → Lunch → Community C → Depot

MIP Solution:

- Technician 1: Depot → Community B → Lunch → Community C → Depot
- Technician 2: Depot → Community A → Lunch → Depot
- Technician 3: Depot → Community D → Community E → Community G → Community H → Lunch → Community F → Depot

Key Findings & Discussion

Performance Comparison

- MIP found optimal solution with 4.7% lower
- GA provided good feasible solution much faster (5.33 seconds vs. 5 minutes)
- Both solutions satisfied all constraints (no waiting time or overtime)

Insights

- For small instances, MIP provides optimal solutions within reasonable time
- GA may scales better for larger problems
- Lunch break constraints significantly impact routing decisions

Conclusion & Future Work

Conclusion:

- Successfully implemented both GA and MIP approaches for TRSPTW
- Validated the paper's approach through simulation
- Demonstrated the importance of lunch break constraints in technician scheduling

Coding

All coding and description will find in github repository

[mknishat/TRSPTW: This repository implements a Genetic Algorithm (GA) and Mixed Integer Programming (MIP) to solve the Single-day TRSPTW problem based on the paper by Pourjavad & Almehdawe (2022)]

THANK YOU