# Metaheuristic Approaches for Optimizing the MinMax Multiple Traveling Salesman Problem

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## Introduction

The MinMax Multiple Traveling Salesman Problem (mTSP) is a complex combinatorial optimization challenge where multiple salesmen must visit a set of cities exactly once, returning to a central depot. The objective is to minimize the maximum tour length among all routes. This variant of the classical Traveling Salesman Problem (TSP) is NP-hard and requires advanced algorithmic strategies to compute near-optimal solutions efficiently. In this study, we explore and compare two bio-inspired metaheuristics: Ant Colony Optimization (ACO) and Particle Swarm Optimization (PSO).

## Methods

I. Ant Colony Optimization (ACO):

Employs 50 ants over 1000 iterations. Ants construct solutions by probabilistically selecting the next city based on pheromone intensity and heuristic visibility. Each tour is refined with a 2-opt local search and a 3-opt-like procedure to improve solution quality and mitigate premature convergence. Pheromone trails are updated based on individual ant performance and the global best solution. Parameters α and β are dynamically tuned to balance exploration and exploitation.

II. Particle Swarm Optimization (PSO):

The algorithm consists of five swarms, each with 50 individuals. Each individual updates its position by combining inertia, cognitive memory, and social interaction. Velocity is formed by selecting scaled and shuffled swap operations from each vector. A hill-climbing procedure is triggered when a swarm stagnates to refine solutions locally.The inertia weight gradually decreases from 1.0 to 0.4 to balance exploration and exploitation.

## Results

TABLE I: Performance summary on the berlin52 test instance

| #Sm. | Algorithm | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| 2 | ACO | 4342.84 | 27.35 | 4288.36 | 4361.19 |
| | PSO | 4439.50 | 328.38 | 4128.93 | 4893.80 |
| | Reference | [4049.05, 4110.21] | — | — | — |
| 3 | ACO | 2863.12 | 22.69 | 2842.18 | 2877.79 |
| | PSO | 3027.85 | 78.27 | 2900.36 | 3112.93 |
| | Reference | [2753.63, 3244.37] | — | — | — |
| 5 | ACO | 2198.89 | 75.67 | 2112.08 | 2296.49 |
| | PSO | 2015.23 | 220.41 | 1791.31 | 2295.35 |
| | Reference | [1671.69, 2441.39] | — | — | — |
| 7 | ACO | 2508.62 | 4.48 | 2504.96 | 2514.17 |
| | PSO | 1595.23 | 108.32 | 1452.56 | 1737.60 |
| | Reference | [1272.06, 2440.92] | — | — | — |

The algorithms were tested on four standard TSP instances (eil51, berlin52, eil76, and rat99) with 2, 3, 5, and 7 salesmen configurations, repeating each run 30 times. ACO consistently produced solutions closer to known reference values with lower standard deviation but had a higher execution time. PSO executed faster but showed greater solution variability. For the berlin52 dataset, ACO produced more stable solutions, while PSO showed stronger performance in specific configurations (e.g., 5 and 7 salesmen), albeit with higher variability.

## Discussion and Conclusions

ACO generally outperforms PSO in solution quality and stability but requires longer runtimes. PSO offers faster execution, making it suitable for applications where quick, approximate solutions are acceptable.

Future work includes developing hybrid methods that combine ACO's quality with PSO's efficiency, optimizing ACO's local search, and packaging the codebase for educational adoption.

## References


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