Urban Transit Route Optimization

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Introduction

- Public transport route design is a key problem in urban mobility planning.
- The Transit Network Design Problem (TNDP) balances passenger service quality and operational cost.

- This work studies heuristic and multi-objective optimization approaches using a benchmark transit network.

Problem Statement

- Given:
- - A transport network with stops and links
- - An origin–destination demand matrix

- Find a set of transit routes that minimizes:
- - Average passenger travel time (ATT)
- - Total route length (TRT)

Mathematical Formulation

- The transport network is represented as a graph $G = (V, E)$.

- Decision variable:
- $R = \{R1, \ldots, Rk\}$ — set of transit routes.

- Objectives:
- $ATT = \Sigma D\_ij \cdot T\_ij / \Sigma D\_ij$
- $TRT = \Sigma \text{length}(r), r \in R$

Problem Complexity

- The TNDP is NP-hard.
- The number of possible route combinations grows exponentially.

- Exact optimization is infeasible for realistic networks.
- Therefore, heuristic and metaheuristic methods are required.

Solution Framework

- The proposed solution follows three main stages:

- 1. Candidate route generation
- 2. Passenger assignment and evaluation
- 3. Route set optimization

- This framework follows modern TNDP literature.

Candidate Route Generation

- Candidate routes are generated using the K-shortest paths algorithm (Yen’s algorithm).
- Routes are computed for OD pairs with the highest demand, producing a limited but realistic candidate set.

Passenger Assignment

- A transit graph is constructed with:
- - Nodes representing (stop, route) states
- - Edges representing route movements and transfers

- Passengers choose shortest paths using Dijkstra’s algorithm.
- Unserved OD pairs incur a penalty cost.

Optimization Methods

- Greedy heuristic:
- - Iterative route addition
- - Weighted-sum objective

- NSGA-II:
- - Multi-objective genetic algorithm
- - Non-dominated sorting
- - Pareto front approximation

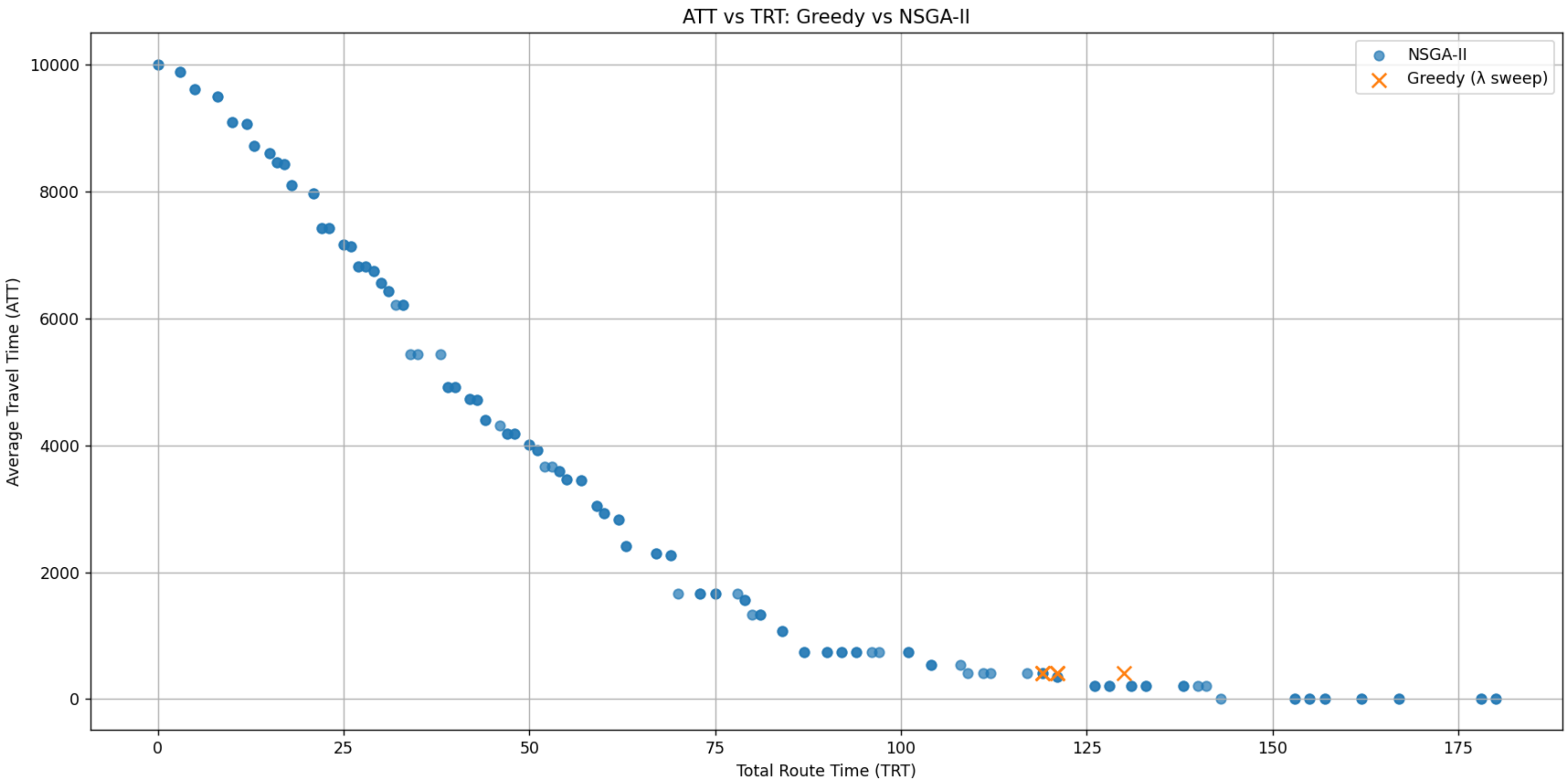
Experimental Setup

- Benchmark network: Mandl
- - 15 stops
- - 42 links

- Candidate routes: ~80
- Constraints on the maximum number of routes
- Evaluation metrics: ATT and TRT

Results: ATT vs TRT

- The plot highlights the ability of NSGA-II to capture a wide range of trade-off solutions.



Discussion

- NSGA-II provides a rich approximation of the Pareto front.

- The greedy heuristic approximates only a limited portion of the trade-off surface but serves as a strong baseline method.

Conclusions

- A complete TNDP pipeline was implemented.
- Greedy and NSGA-II approaches were compared.
- NSGA-II demonstrates clear advantages in multi-objective optimization.

- The results are consistent with existing research.

Future Work

- Possible extensions include:
- - Route frequency optimization
- - User equilibrium assignment
- - Application to large-scale networks
- - Parallel evaluation techniques