Mechanical & Industrial Engineering
UNIVERSITY OF TORONTO

Master Project

Solving Dynamic Vehicle Routing Problems using Inverse Optimization

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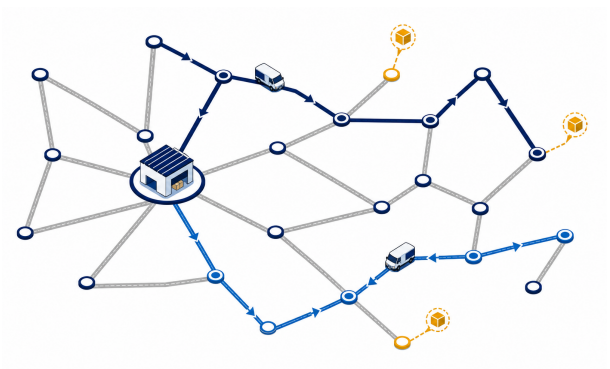
Context

The Vehicle Routing Problem (VRP) determines how a fleet of vehicles should deliver packages from a central depot to a set of customers. Each vehicle has limited capacity, and some deliveries must be completed within specific time windows. The usual objective is to minimize total travel distance or operating cost.



In the Dynamic Vehicle Routing Problem (DVRP), not all delivery requests are known at the start. New requests arrive while vehicles are already travelling. When this happens, the routes must be updated quickly. A good routing method should handle new requests without creating long detours or unnecessary changes to the existing plan.

Strong optimization heuristics can find efficient routes when all requests are known. Machine-learning methods can learn patterns from previous delivery data, but they do not automatically produce feasible routes. This project will combine both approaches. Inverse Optimization will learn useful routing preferences from good past solutions, while a VRP heuristic will use those preferences to construct feasible routes.

The learning method studied in this project is *Inverse Optimization* (IO), a form of supervised learning tailored to decision-making systems. Standard supervised learning observes input–output examples and fits a parameterized predictor. IO adds structure: it assumes that the observed output is itself the solution of an optimization problem whose objective or parameters are unknown.

For the DVRP, an input describes the information available at a decision time—for example, the current vehicle locations, accepted requests, remaining capacity, and time. The corresponding output is the routing action selected by an expert solver or a high-performing policy. IO uses these examples to learn the parameters of an optimization model that reproduces the expert's decisions.

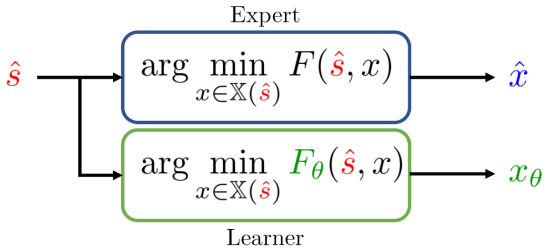


Figure 1: In IO, the parameter θ is tuned so that the learner's decision x_θ matches the expert decision $\hat{x}$.

This is a natural bridge between prediction and routing. Instead of asking a learning model to construct a complete route directly, the learned parameters express what the routing optimizer should value, such as travel time, route flexibility, geographic balance, or the ability to absorb future requests. A state-of-the-art heuristic then handles feasibility and combinatorial search.

The main research question is whether the learned optimization model improves dynamic routing compared with static or short-sighted heuristics. The methods will be compared using total travel distance, number of served requests, computation time, and performance on different request patterns.

Project tasks

The project can roughly be divided into the following parts:

1. Perform a literature review on Inverse Optimization and static and dynamic Vehicle Routing Problems.

2. Reformulate the Dynamic VRP as an Inverse Optimization problem, defining the observable state, expert decisions, and learnable objective parameters.

3. Develop an algorithm that combines the learned IO model with state-of-the-art heuristic methods for the static VRP.

4. Implement and evaluate the algorithm using simulated and real-world delivery data, and compare it with standard static and dynamic routing baselines.

The ideal candidate has some experience with Python and an interest in optimization, machine learning, or transportation systems. Familiarity with operations research, vehicle routing, mathematical optimization, or data analysis is helpful but not required.

Application: Please submit your CV, unofficial transcript, and a short paragraph describing your interest in the project by email to p.mohajerinesfahani@utoronto.ca and donya.jafari@mail.utoronto.ca.

Start Date: Fall 2026 / Winter 2027

Research Areas: Operations Research, Applied Machine Learning, Information Engineering, Transportation and Logistics