Solving Matching Problems in Practical Applications Using JuMP

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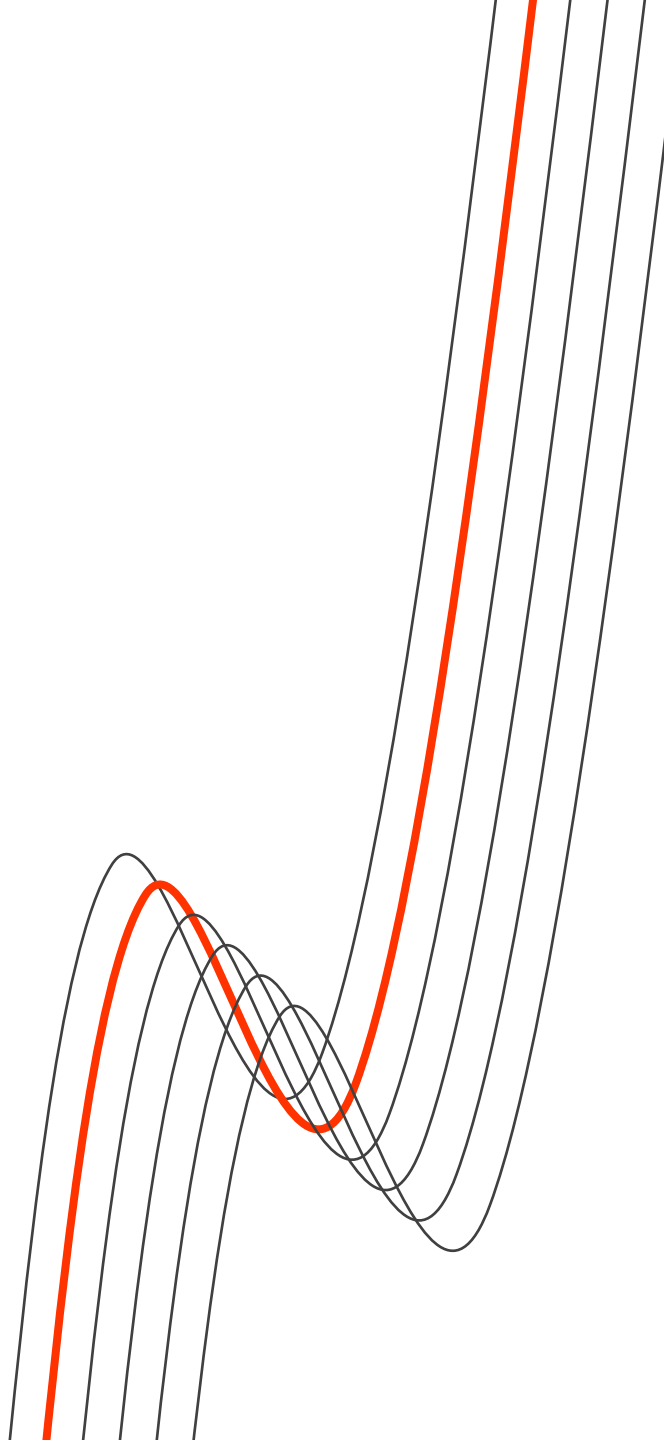
JuMP-dev 2024, Montreal, Canada

Optimal Solutions™

JUMP



About Optimal Solutions

Optimal Solutions is an OR consultancy. We work on integer programming, discrete-event simulation, and other data-driven strategies to help clients make their operational decisions.

- Partners with IBM, Gurobi, and FICO
- We have experience in airlines, food and beverage, chemicals, and many more industries.

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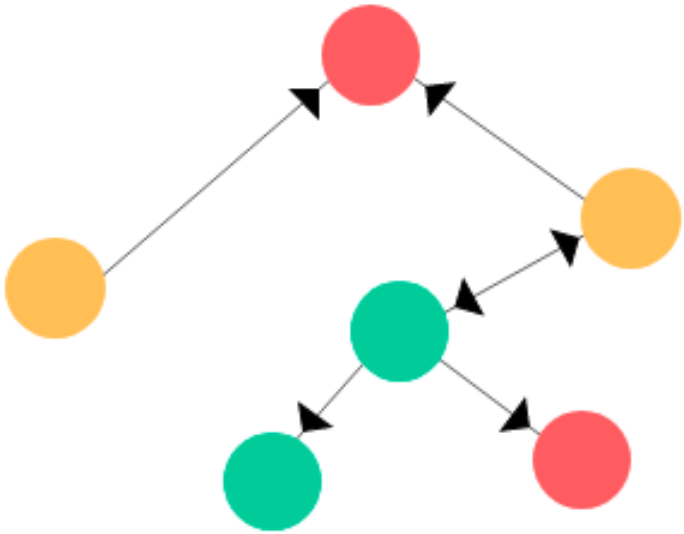
Project background

Work done in early 2023

Confidential large client with a large transportation network consisting of

- Hundreds of terminals
- A fleet with many vehicle types

Client's first optimization model modeled JuMP!



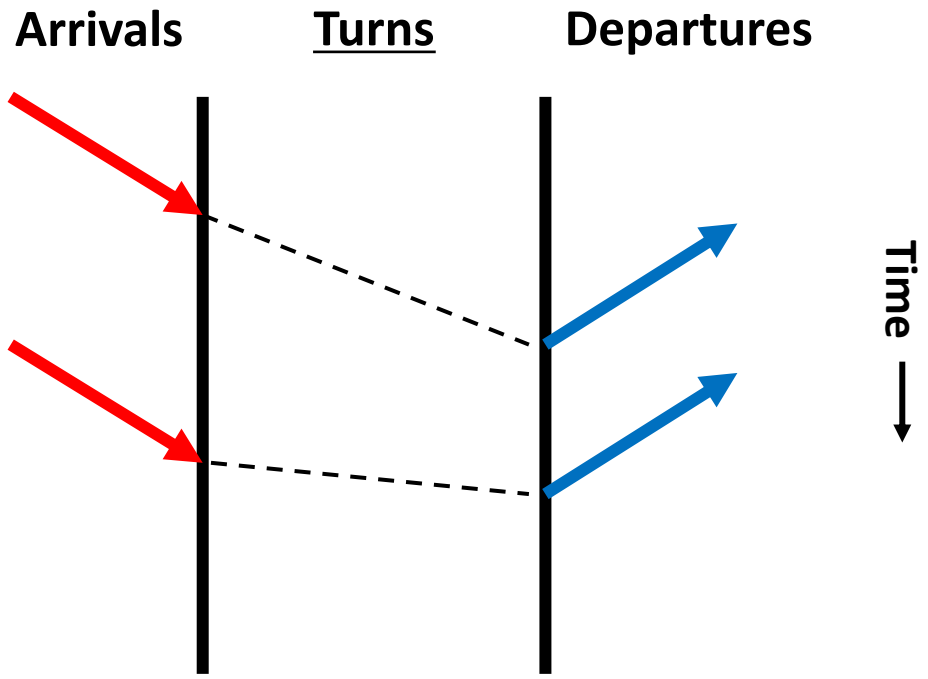
Turns

Every trip has been defined

- Origin, destination, departure time, arrival time, vehicle type

A turn is a matching between two trips

Turns connect trips into a sequence, defining the full itinerary of each vehicle

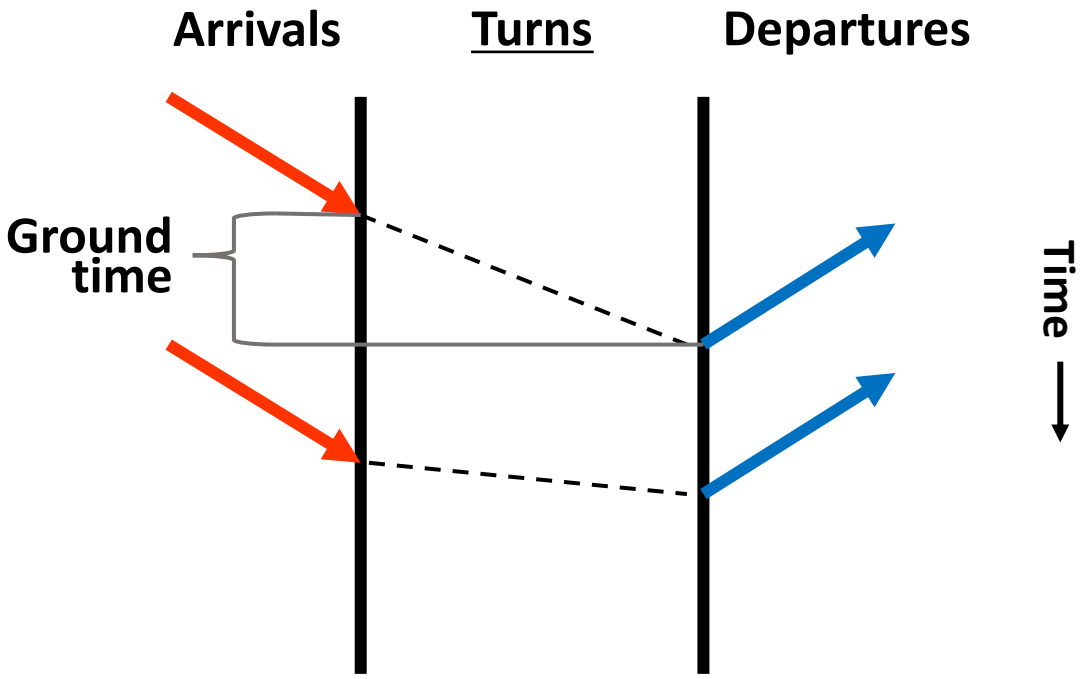


Ground Time

Turns also define the amount of ground time between each trip

Ground time is a valuable but constrained resource

- Ground time acts as a kind of padding, preventing arrival delays from cascading into the next trip
- However, ground time also means inefficient use of the vehicles. Too much ground time, and the fleet may not be large enough to cover the schedule



Problem Statement

Optimize ground time allocation by building turns strategically.

Allocate more ground time to trips that have a higher likelihood of delay.

Optimize adherence to *ground time rules*

"I would like trips leaving from **Montreal** to **Boston** of vehicle type **XT560** between **4pm and 7pm** to have an extra **10** minutes of ground time."

All while adhering to constraints related to fleet size, maintenance requirement, etc.

Approaches

Incumbent approach

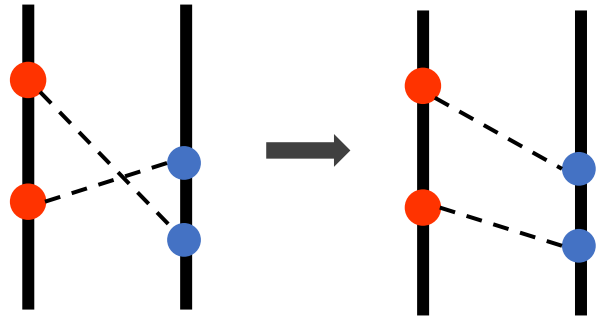
- Simple LIFO 👎

Approach 1: Retiming model Slow but effective

- Add a ground time objective to an earlier model which also has the power to retime and refleet
- Has the power to shift the network in order to satisfy the ground time rules

Approach 2: Turn building Less effective but fast

- Purely optimize turns, trips are static
- No dependencies across terminals
  - Enforce fleet size constraint by minimizing total ground time
- Doesn’t interfere with any of the other objectives in the retiming model



Enter JuMP!

Execute turn building by solving dozens of integer programs

- One per terminal per vehicle type

Data preprocessing, lots of problems, each one easy for the solver

→ High model build time relative to the solve time

So we introduced our client to JuMP! Moving away from docplex (python) to JuMP lead to significant speed improvement

Challenges

Converting developers is one thing, but what about business managers?

Employees

- Legacy employee experience
  - Decades of combined employee experience in C++ to go to waste?
- New hiring
  - Much easier to find candidates with experience in more established programming languages. It's changing, but it's a risk

Industry

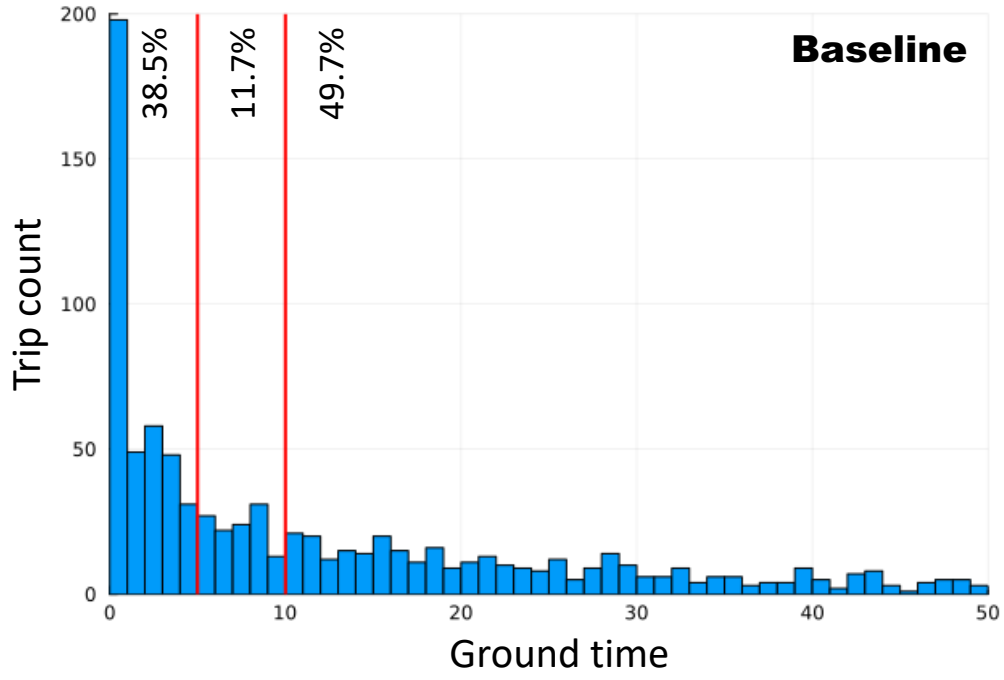
- Competition
  - Extra drive to get ahead, but little mercy for a wrong choice
- Legacy
  - Industry that is already criticized for using legacy technology. Drive and excitement for trying something new, but also fear of getting once again entrenched in something that may not stand the test of time.

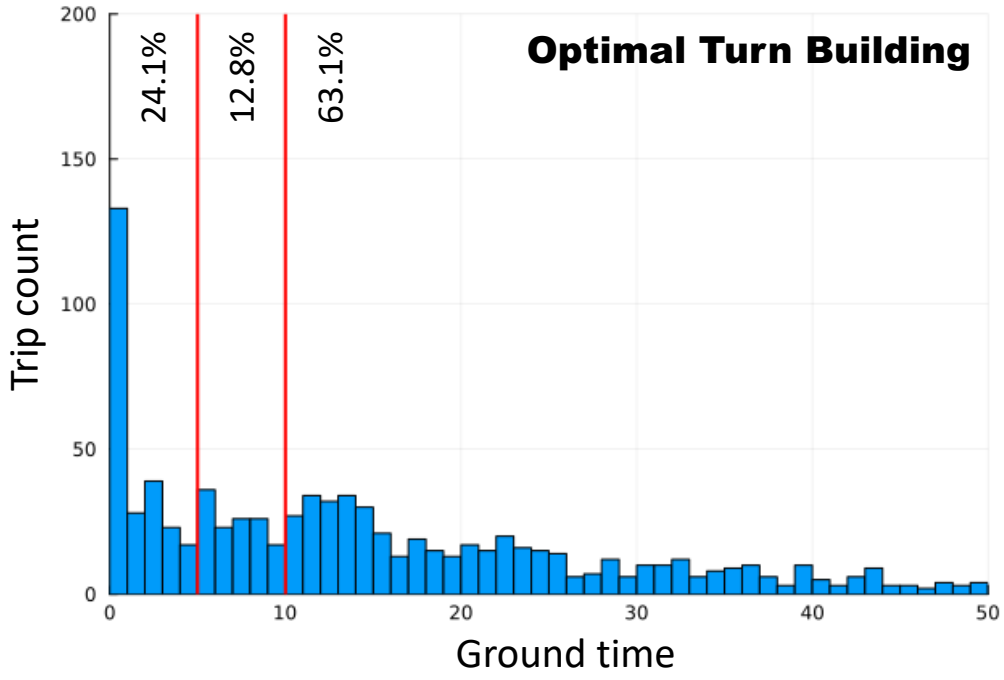
Results

Optimal turn building lead to an additional 16% of trips that satisfy their ground time rule

- 13%-19% across four different test schedule, runtime of 4-10 seconds

Ground time distributions – July 19





Turn Building Use Cases

Save time

Even when the retiming model is set to aggressively optimize ground time, turn building can match half that benefit in just seconds

Performance boost

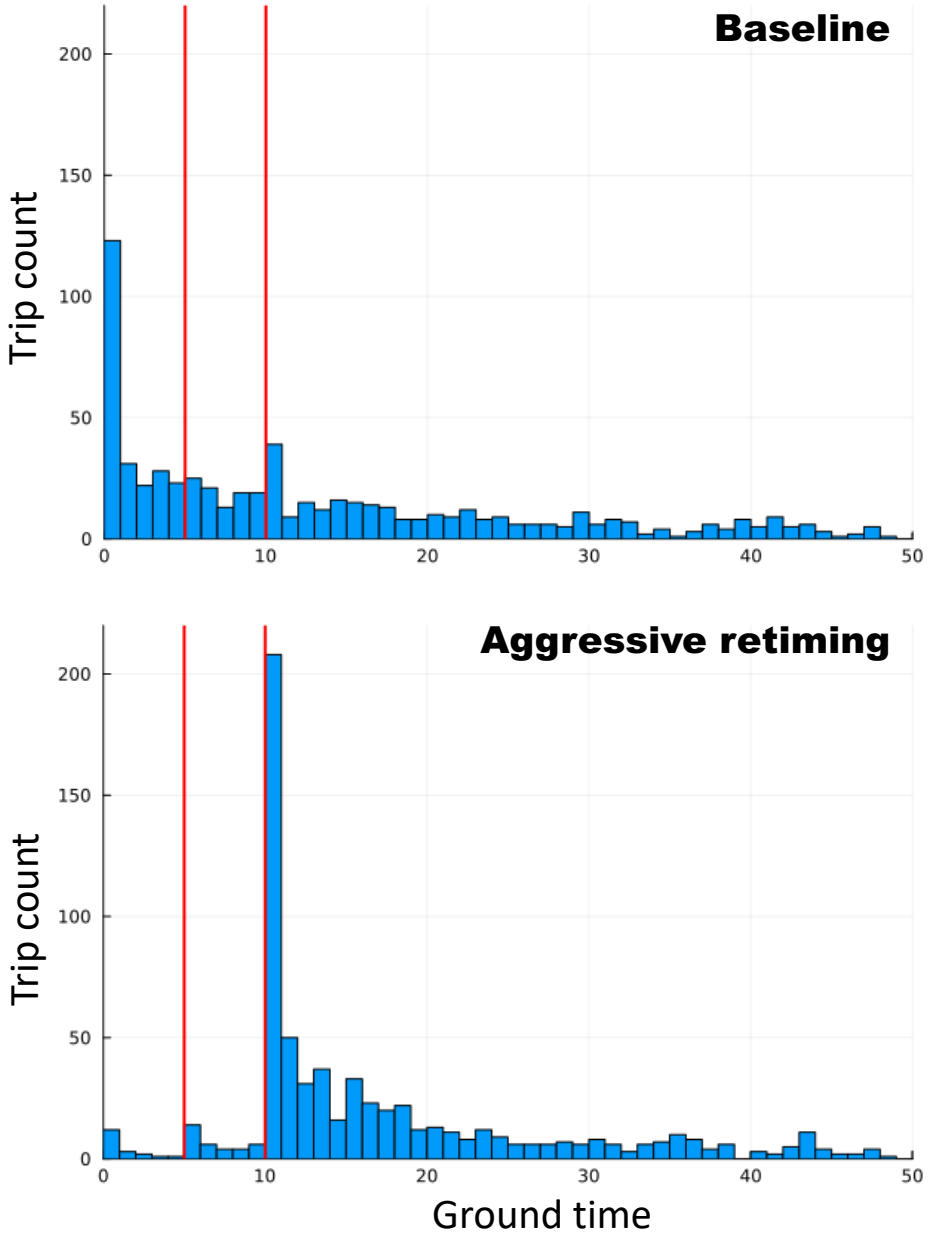
The retiming model does not always solve to optimality, so turn building can usually squeeze out an additional 5% of ground time compliance

- Without compromising other objectives

Mar22

GT in Retiming model 6min – 9min	JuMP Turn Building 4sec – 10sec	GT Compliance
No	No	64.2%
No	Yes	80.3%
Yes	No	95.3%
Yes	Yes	95.5%

+16%



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