Order up! How do I deliver it?

Build on-demand logistics apps with Python, OR-Tools, and DecisionOps

Ryan O'Neil · December 6, 2023 · PyData Global

🖐 Thanks for coming! You can follow along here:

github.com/ryanjoneil/2023-pydata-global-order-up

We'll cover this

Ryan O'Neil

CTO at Nextmv

Optimization AI, early music, cats.

🧮 Minimal models for on-demand delivery

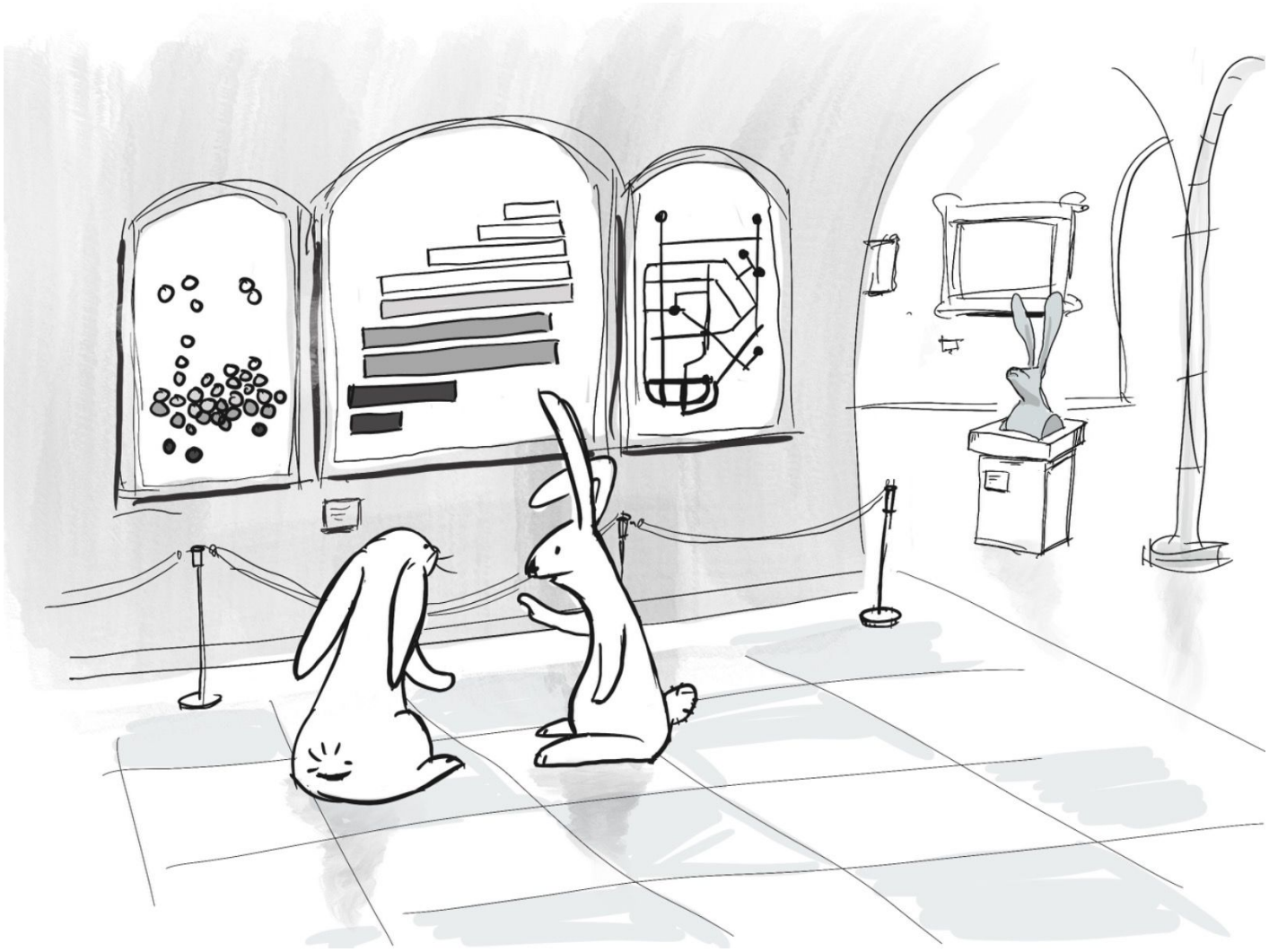
What they are, how they work together

🔨 Model data and code

Solve all the things with Python and OR-Tools!

🚀 Test, deploy, and operate

How to rely on these models in a real environment



💡 An optimization library is the Swiss army knife of a decision stack. It may be your **most useful tool**.

🚜 Today’s example: The Farm Share Company

- Consumer delivery service for farm-based goods
- Started with manual, siloed processes
- We’re scaling and want tighter integration
- Monthly forecasting, weekly scheduling, daily route planning

Inputs, outputs, and approaches for today

Demand forecast

QUESTION
How many orders?

INPUT
Historical order volume

OUTPUT
Forecast order volume

APPROACH
- LAD regression

Shift scheduling

QUESTION
What drivers are available?

INPUT
Required workers
Worker availability

OUTPUT
Driver shift assignments

APPROACH
- MIP

Vehicle routing

QUESTION
What are the driver routes?

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Available drivers
Actual orders (stops)

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Driver route assignments

APPROACH
- CP-SAT

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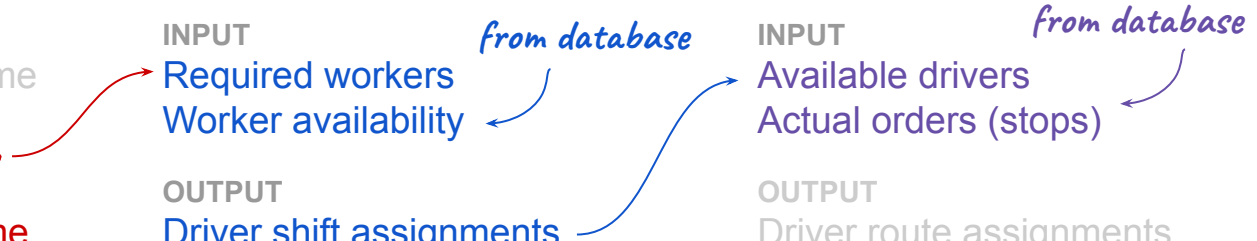
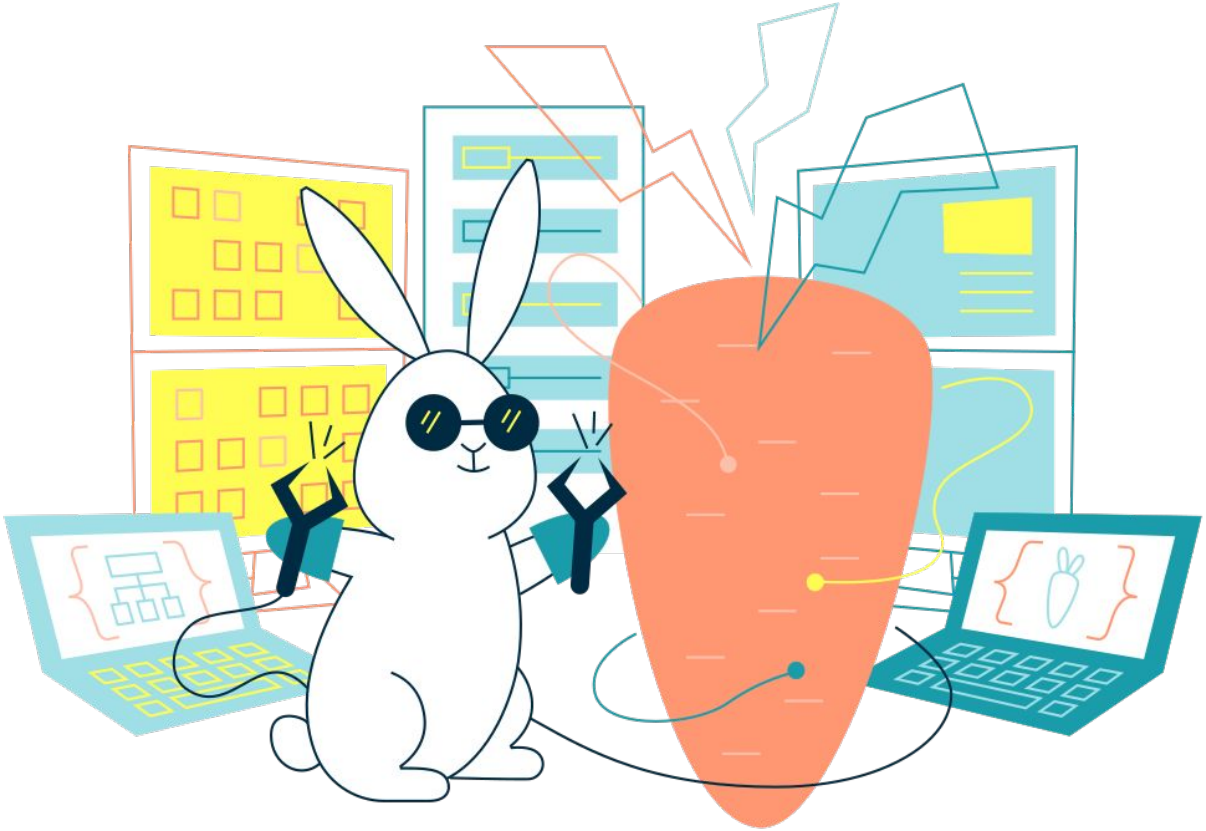
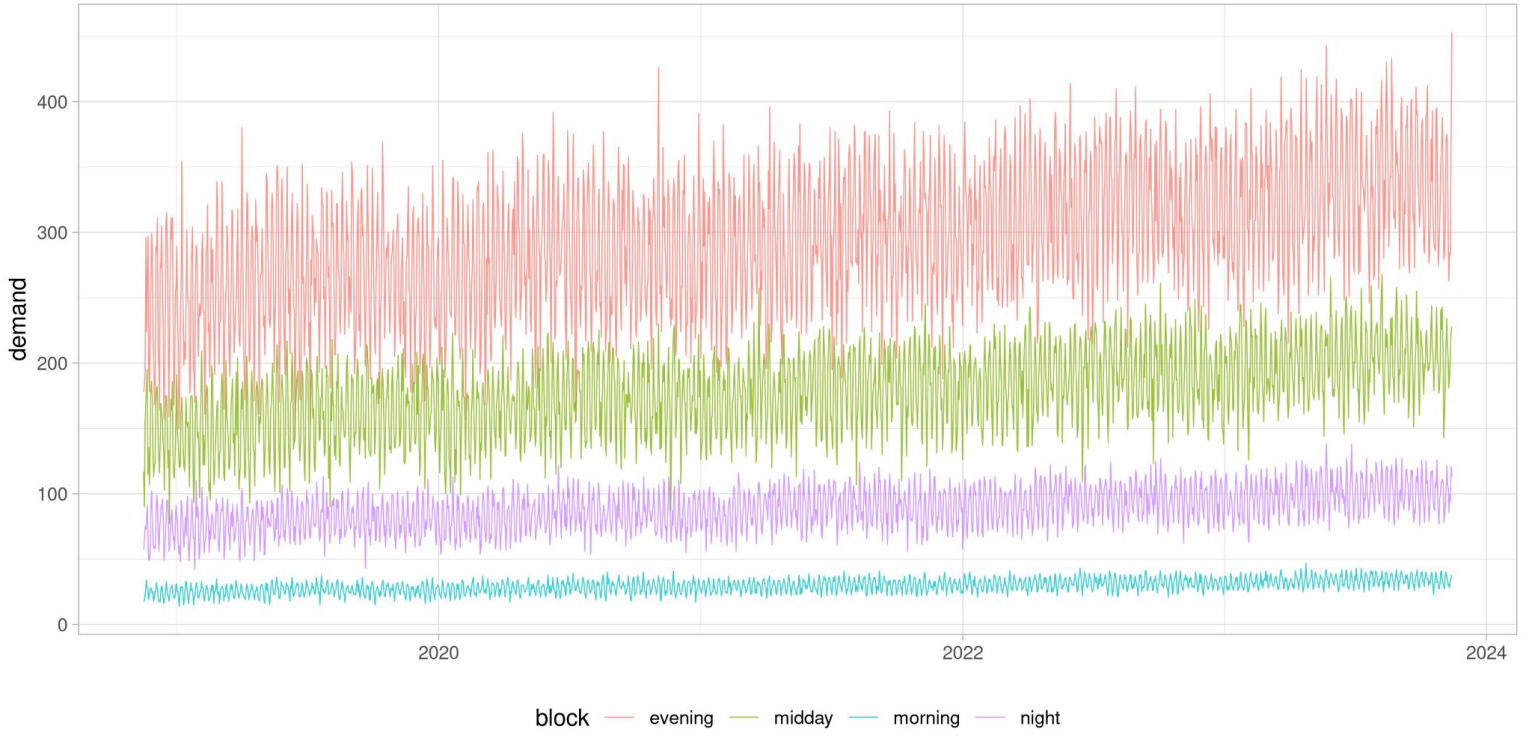


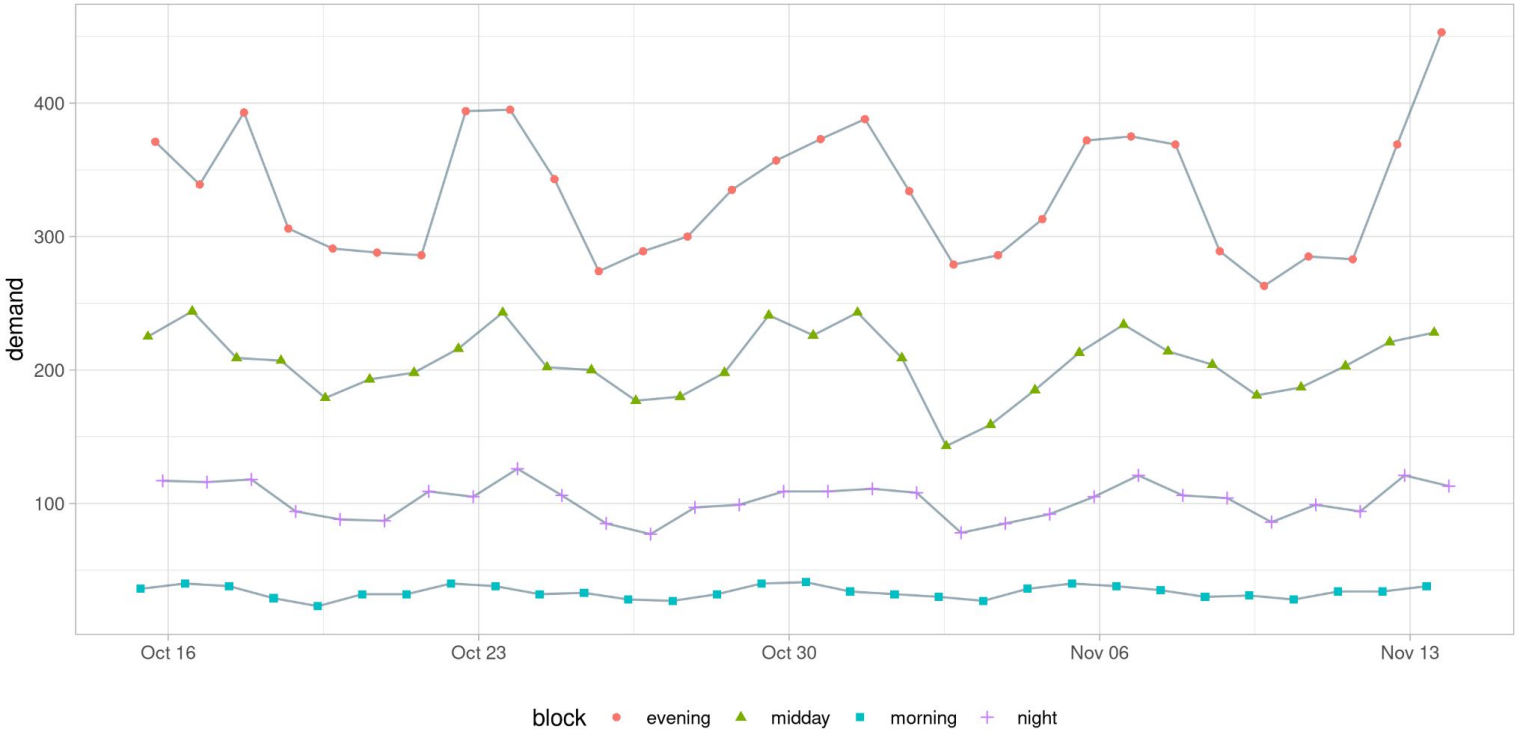
forecasting model



Input: order volume data

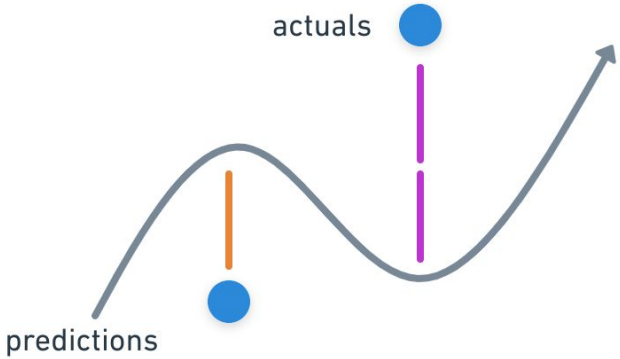


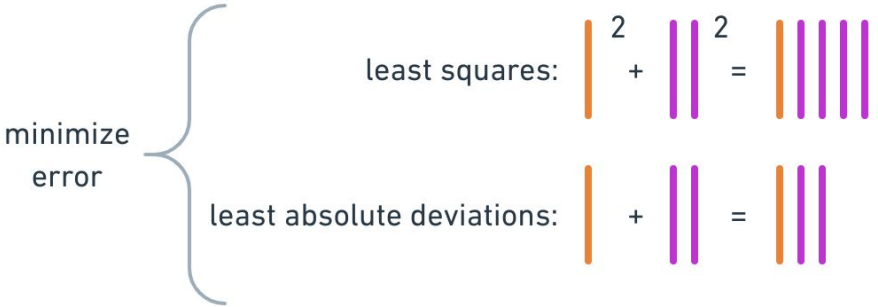
Input: recent order volume data



🤔 Why LAD?

- Robust to outliers
- Customizable
- Can model it as a linear program!





🔍 An optimizer's view of regression

A and **b** are inputs
x is a vector of reals

objective $\min f(x) = \|Ax - b\|$

norm of the residuals

🔍 An optimizer's view of regression

$$\min f(x) = \|Ax - b\|$$

Least squares

$$\min f(x) = \|Ax - b\|^2$$

Analytical solution

LAD

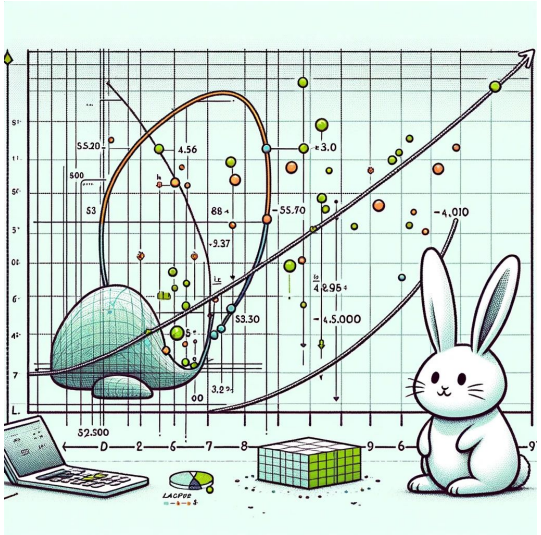
$$\min f(x) = |Ax - b|$$

Algorithm

$$\begin{aligned} \min \quad & 1^\mathsf{T} z \\ \text{s.t.} \quad & z \geq Ax - b \\ & z \geq b - Ax \end{aligned}$$

🗿 Features

- Offset
- Daily trend
- Seasonal trend
- Solar cycle trend
- Weekly trend

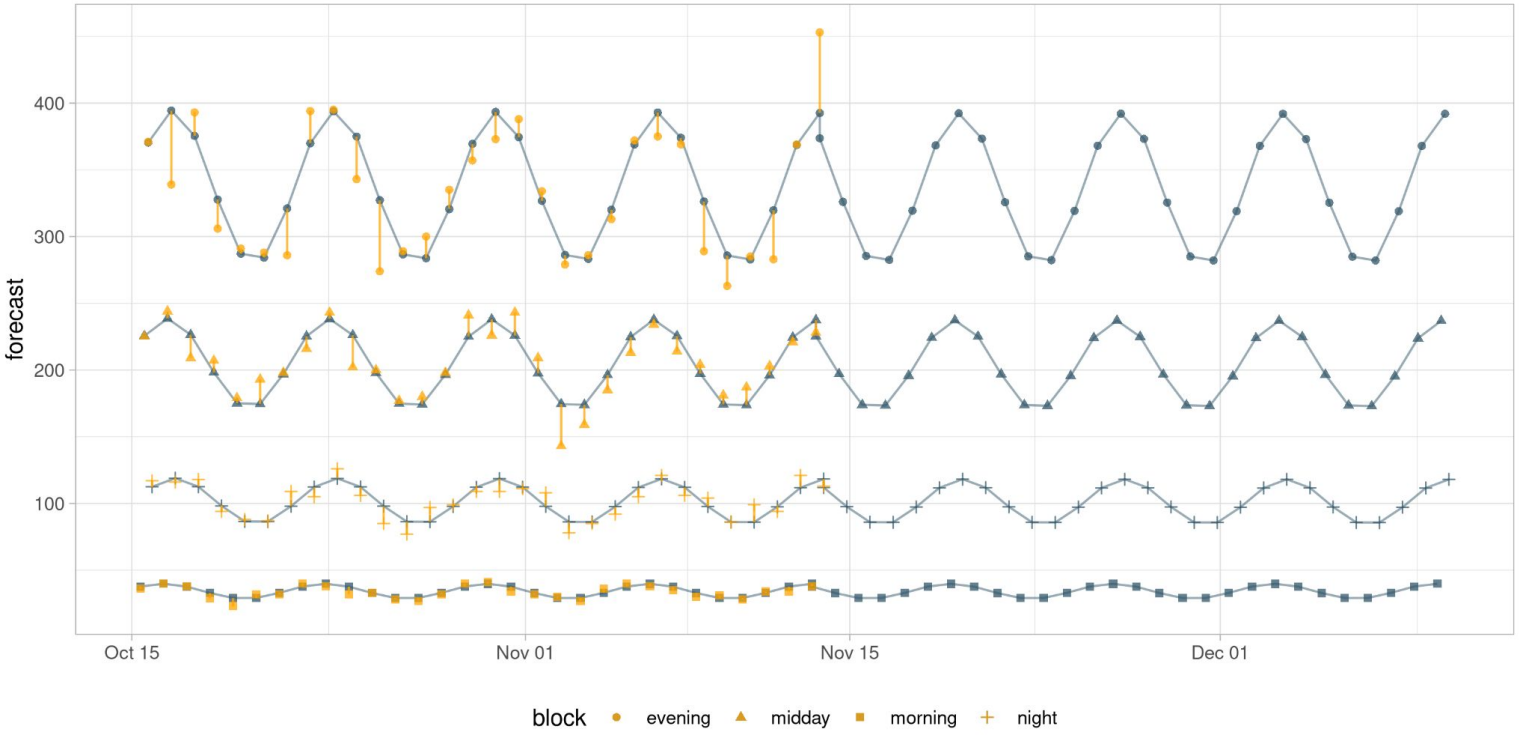


For more details, see:

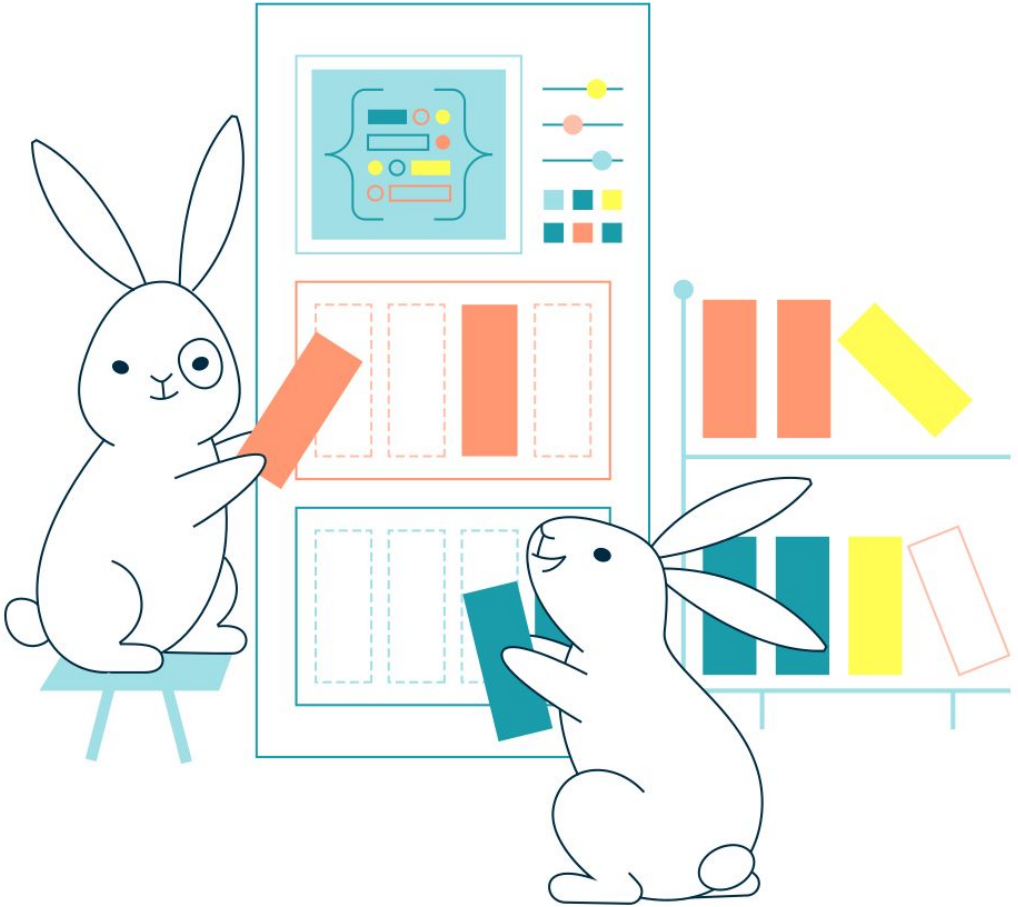
Robert Vanderbei
“Local Warming”

forecasting speedrun

🔮 Output: demand forecast

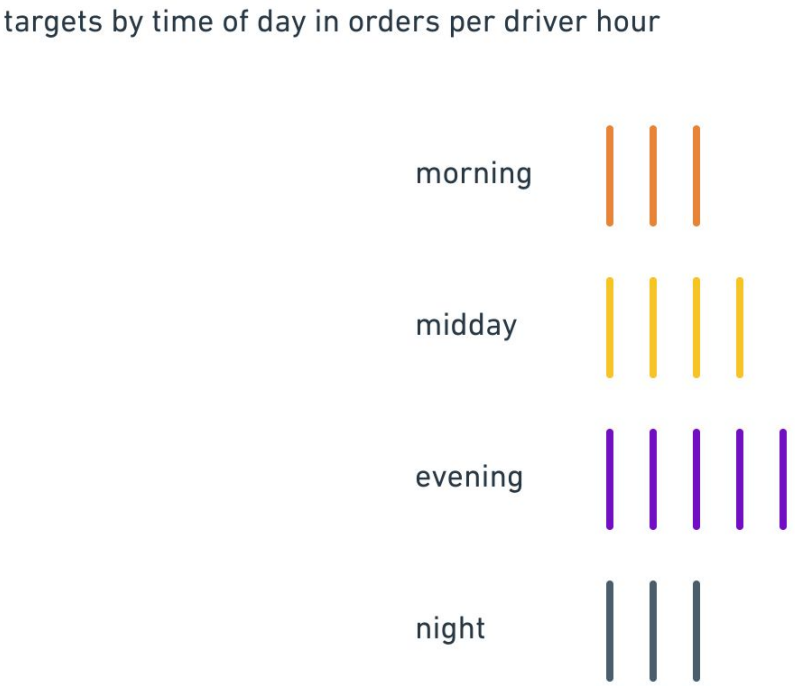


scheduling model



💸 Overstaffing costs money.

😡 Understaffing infuriates users.



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```
min penalty(over)  * overstaffing +
    penalty(under) * understaffing
```

📋 One scheduling model of many

$$\min \quad \sum_h (p_o o_h + p_u u_h) \qquad \text{oversupply and undersupply}$$

$$\text{s.t.} \quad s_h = \sum_{i \in W_h} w_i \qquad \forall\ h \quad \text{supply per hour}$$

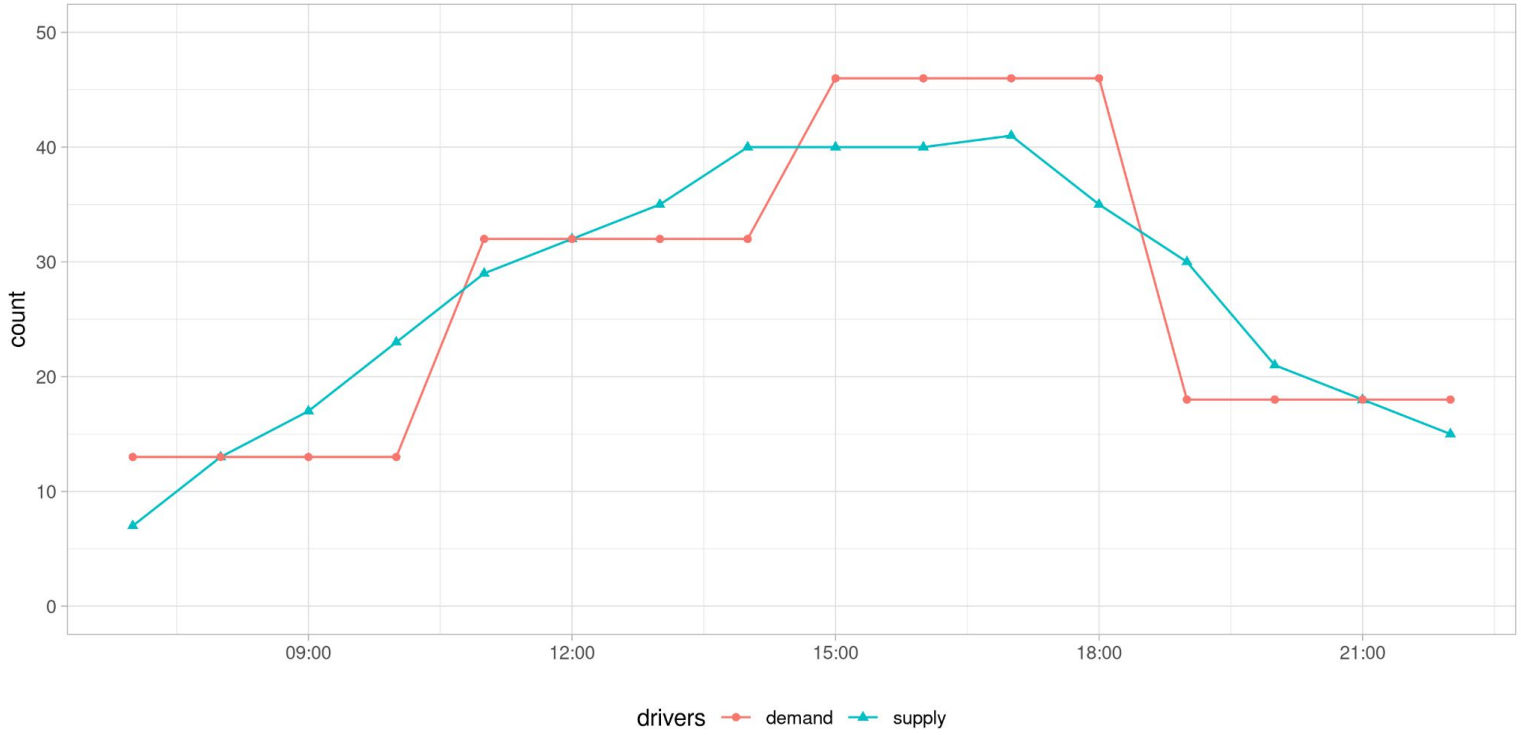
$$o_h \geq d_h - s_h \qquad \forall\ h \quad \text{oversupply per hour}$$

$$u_h \geq s_h - d_h \qquad \forall\ h \quad \text{undersupply per hour}$$

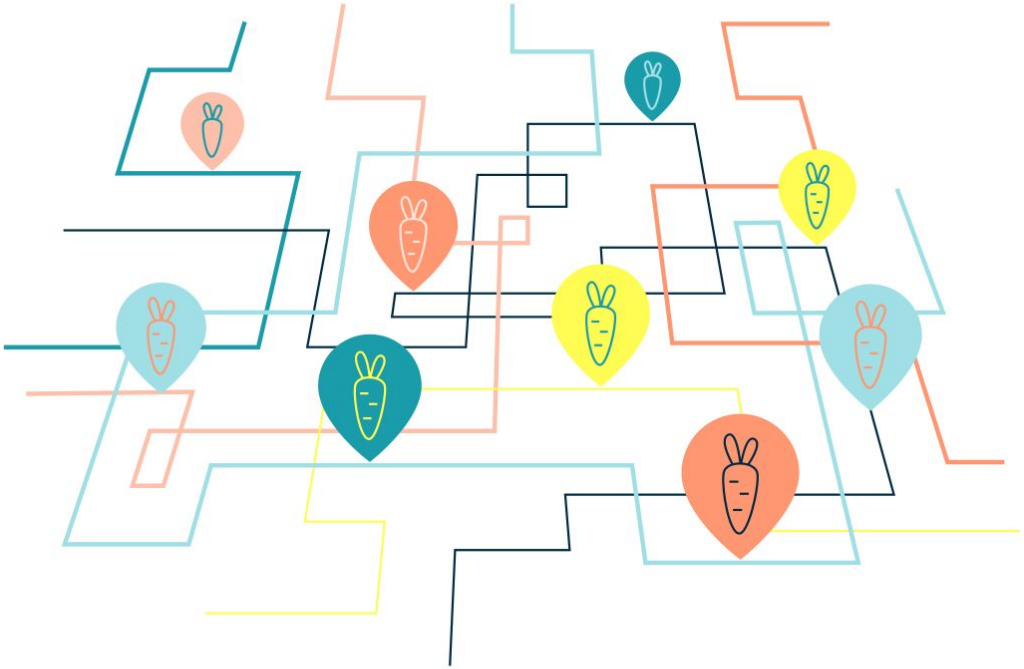
$$w \in \{0,1\}^{|W|}$$

scheduling speedrun

Output: driver schedule

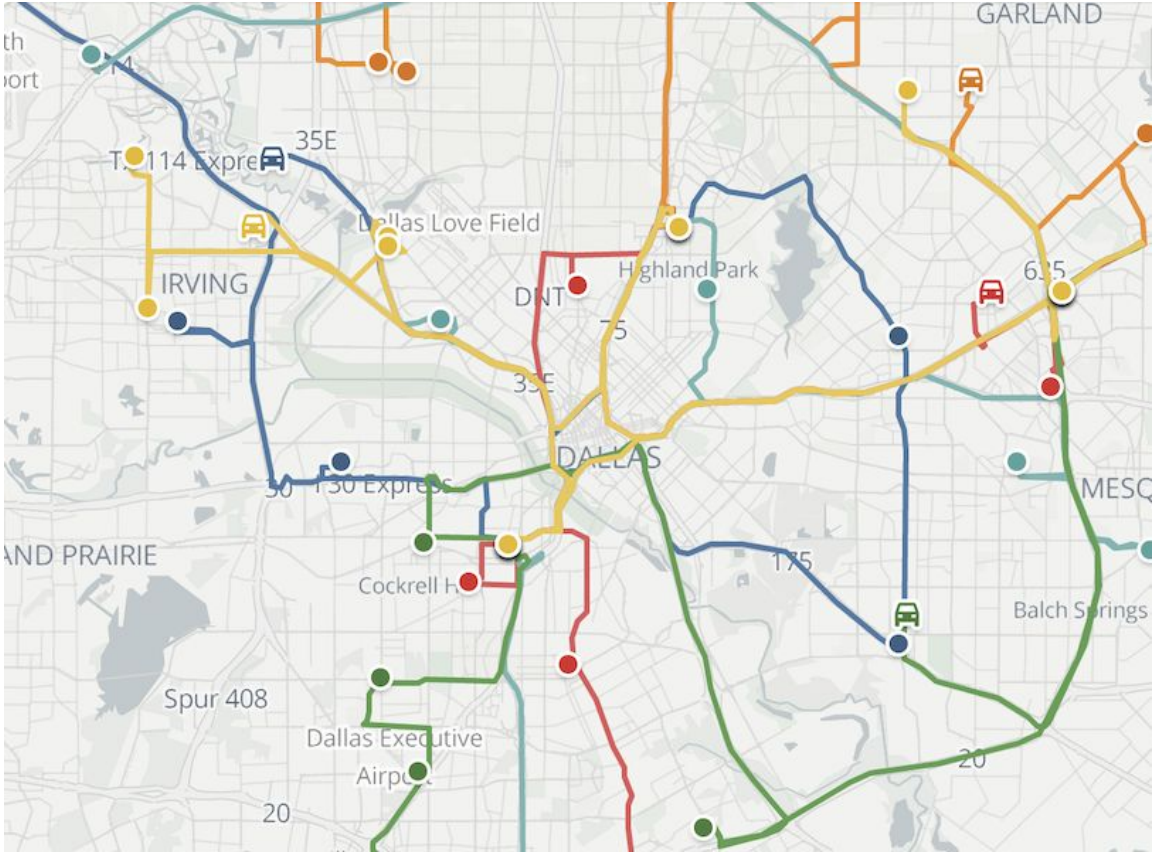


routing model



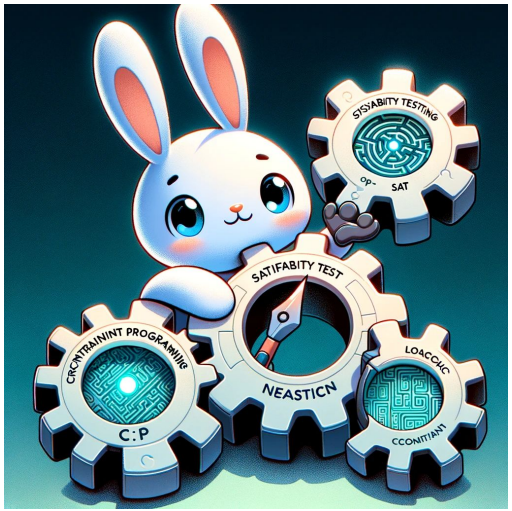
💸 Drive time and distance cost money.

😡 Missed and late deliveries infuriate users.



OR-Tools's CP-SAT is a hybrid solver

- Constraint Programming +
- Satisfiability +
- Local search



For more details, see:

"Search is Dead, Long Live Proof" and "A Constraint Programming Toolkit for Local Search"

routing speedrun

🌮 Summary

- Forecasting, scheduling, and routing are the 3 “starter models” you need in on-demand delivery.
- Optimization underlies many (if not most) decision models.
- It’s worth the time spent learning how to use them. They are frequently (and unexpectedly) useful.

💪 Exercises

- Use the same input data with another forecasting tool, like Prophet or Orbit.
- Change the scheduling model to use OR-Tools's scheduling APIs instead of MIP.
- Try a different routing solver based on MIP or Nextroute.

QUESTIONS?