Gurobi Connect

Gurobi Applications in

Supply Chain

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GUROBI OPTIMIZATION

Supply Chain Optimization

STRATEGIC

- Network Design
- Transportation Selection
- Supplier Selection
- Yield and Revenue Management*
- Capacity Planning*

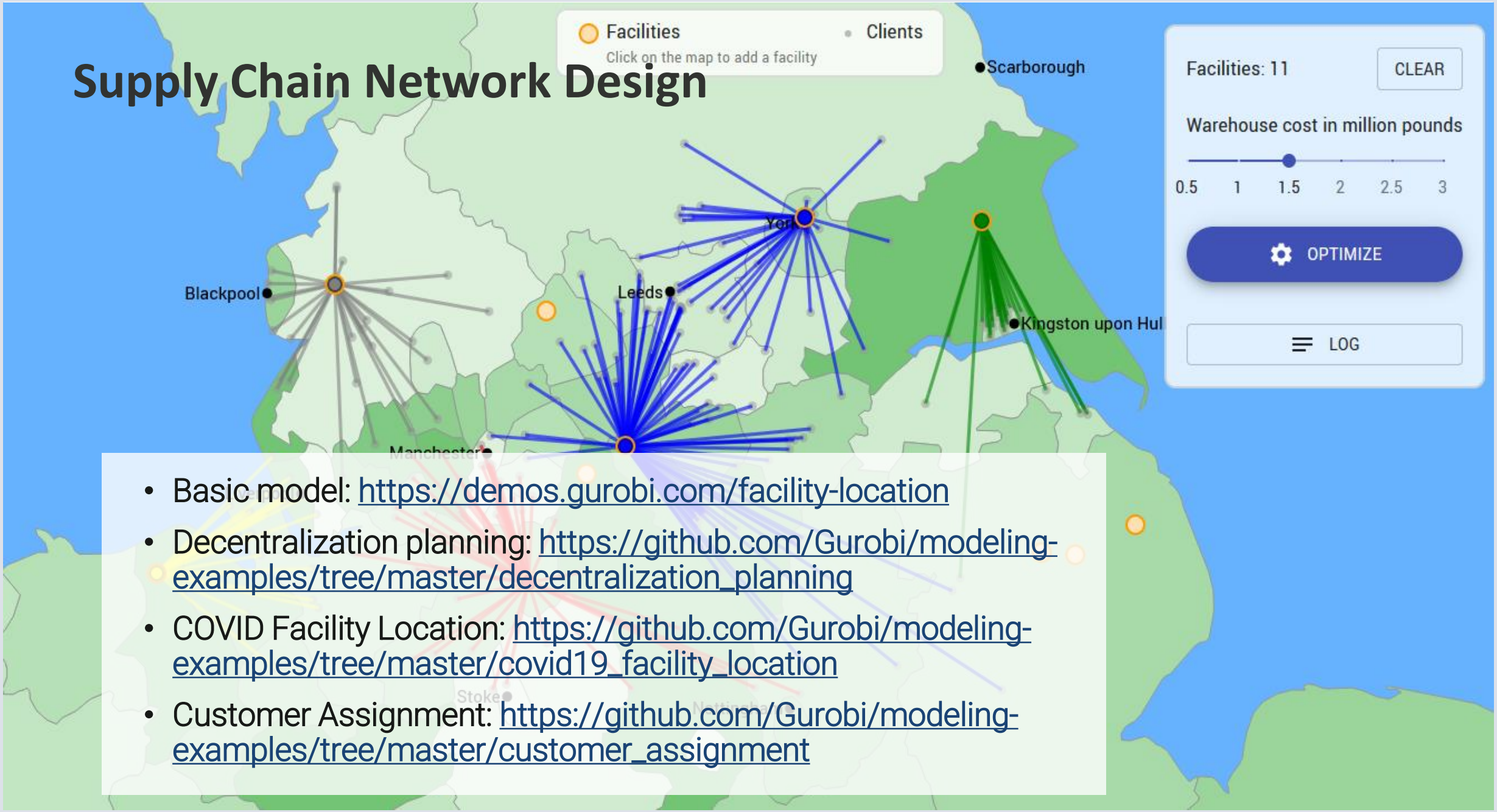
TACTICAL

- Inventory Optimization*
- Maintenance Planning / Predictive Maintenance*
- Production Planning
- Supply Planning
- Order Fulfillment Planning
- Inventory Location

OPERATIONAL

- Vehicle Routing
- Workforce Scheduling / Rostering
- Resource Allocation*/ Utilization
- Shipment Routing
- Real-Time Dispatching
- Cutting Stock
- Blending
- Packaging

Supply Chain Network Design



- Basic model: https://demos.gurobi.com/facility-location
- Decentralization planning: https://github.com/Gurobi/modeling-examples/tree/master/decentralization_planning
- COVID Facility Location: https://github.com/Gurobi/modeling-examples/tree/master/covid19_facility_location
- Customer Assignment: https://github.com/Gurobi/modeling-examples/tree/master/customer_assignment

Compare to Machine Learning

GUROBI OPTIMIZATION

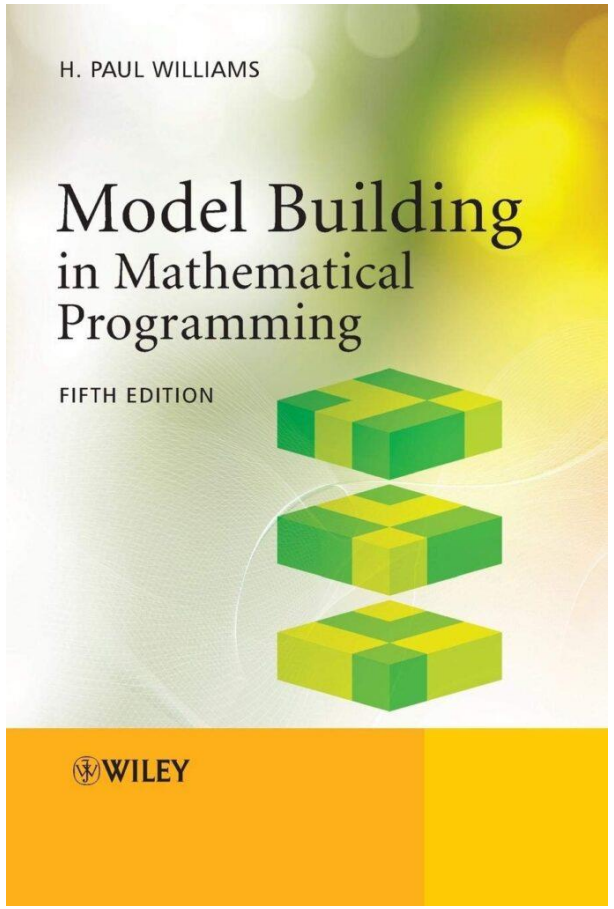
- Model developers: please don't try to draw parallels
- Mathematical optimization (MO) is very different
  - Speaking a new language

Machine Learning	Math Programming
Models take different forms	Model always *describes* the solution
Models are trained	No training involved. Model is static.
Meaning of data is extracted by the model	Meaning of data must be known up front
Result is a description or prediction	Result is a prescription
Finds a viable solution	Finds the best solution
Highly distributed on common architectures	Proprietary parallelization/distribution
Mines data for insights	Uses data verbatim

Mathematical Modeling Reference

- Comprehensive, high-level reference for model types and techniques:
  - Publisher ： Wiley; 5th edition
  - Language ： English
  - Paperback ： 432 pages
  - ISBN-10 ： 1118443330
  - ISBN-13 ： 978-1118443330
- Caution: This is based on old, slow solvers.
  - Solvers can do more now.
  - New problem types possible today

https://www.amazon.com/dp/1118443330?ref_=cm_sw_r_cp_ud_dp_8KQ5C5HTAW5K6Z6TGVQ9



Our History

For context, let's take a step back and look at how we got started.

1940s & 50s

Underlying solver technology first introduced

1970s

Solver technology becomes commercially viable

1987

Dr. Bob Bixby co-founds CPLEX Optimization

1990s

Solver applications grow increasingly powerful and practical

2008

Dr. Bixby, Dr. Rothberg, and Dr. Gu co-found Gurobi Optimization

2012

Gurobi solves 11 previously unsolvable problems

2014

The NFL adopts Gurobi for its complex scheduling problems

2019

The U.S. FCC uses Gurobi to generate US $20 billion in revenue

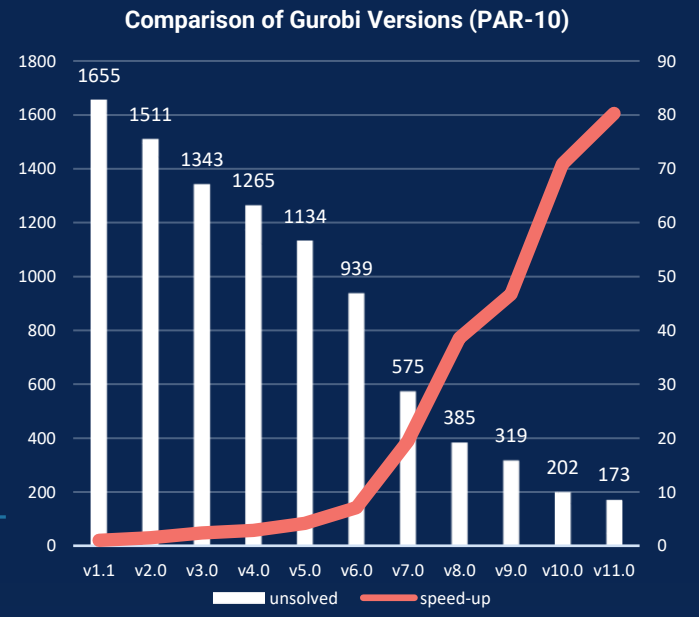
2020

SAP partners with Gurobi to expand its solving capabilities

2023

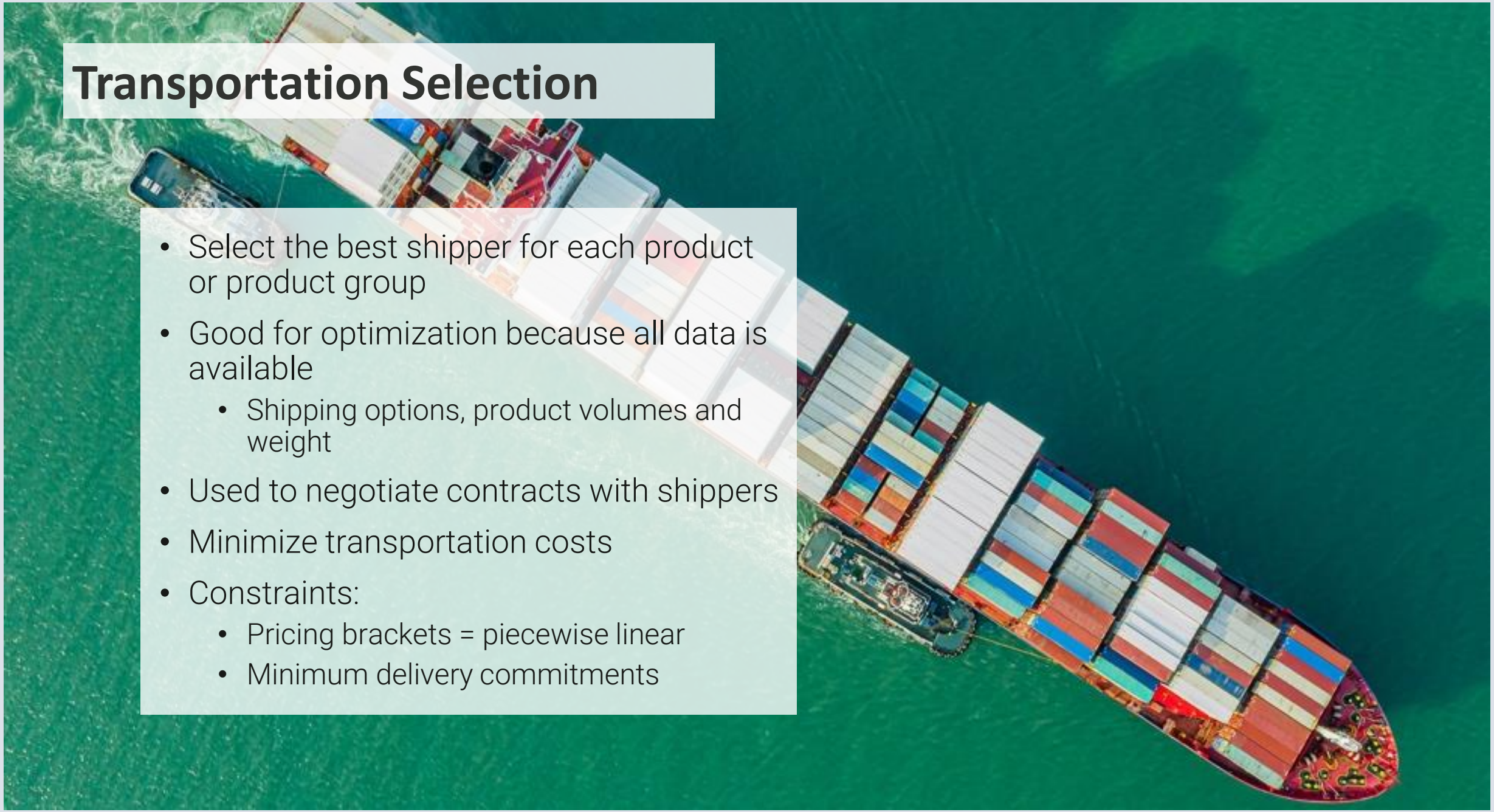
Gurobi acquires October Sky

Gurobi's solver achieves 80x speed improvement since version 1.1



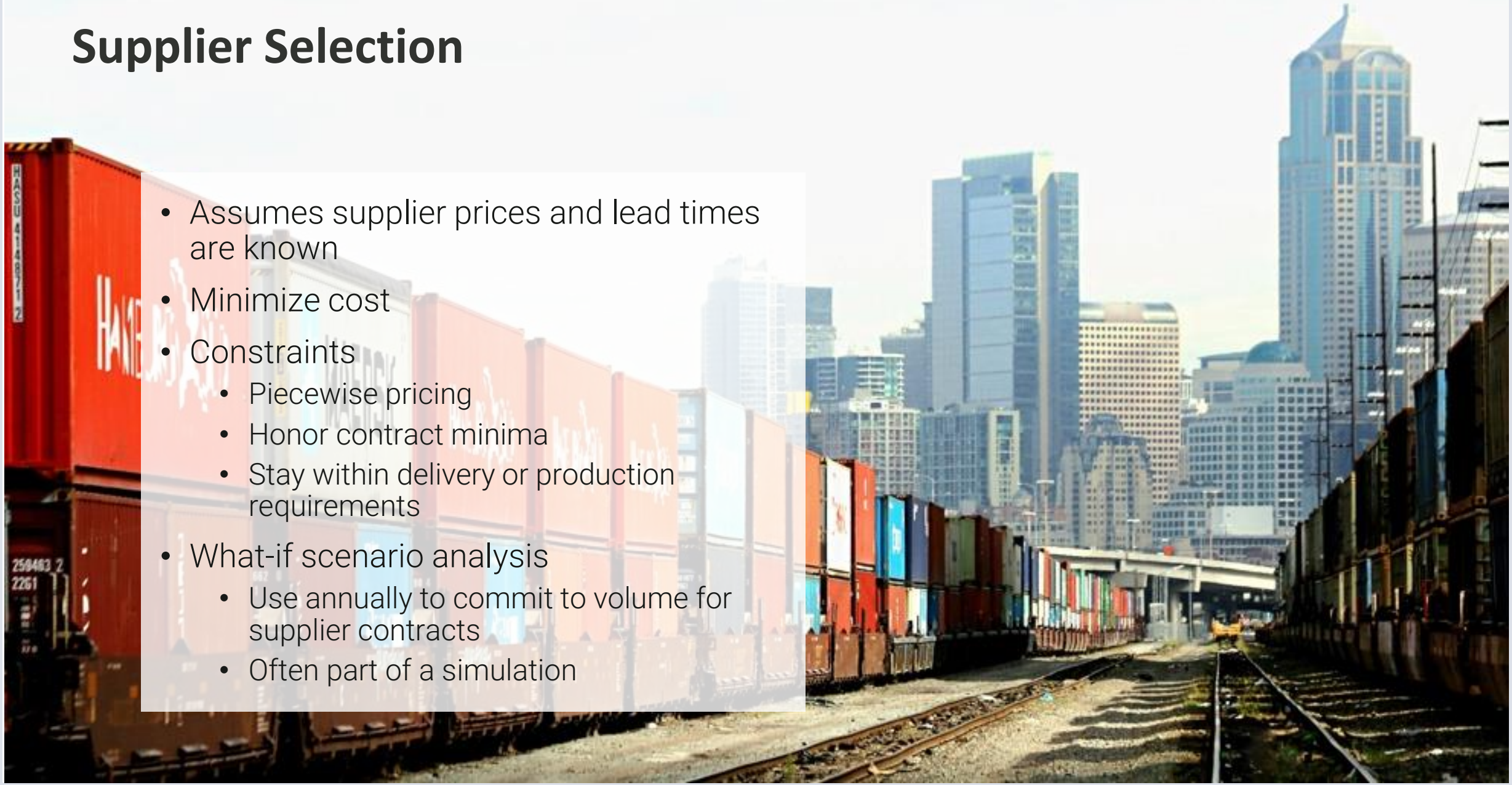
GUROBI OPTIMIZATION

Transportation Selection



- Select the best shipper for each product or product group
- Good for optimization because all data is available
  - Shipping options, product volumes and weight
- Used to negotiate contracts with shippers
- Minimize transportation costs
- Constraints:
  - Pricing brackets = piecewise linear
  - Minimum delivery commitments

Supplier Selection



- Assumes supplier prices and lead times are known
- Minimize cost
- Constraints
  - Piecewise pricing
    - Honor contract minima
    - Stay within delivery or production requirements
- What-if scenario analysis
  - Use annually to commit to volume for supplier contracts
  - Often part of a simulation

Yield/Revenue Management

- Manage pricing to maximize revenue
- Usually applies to time-limited resource
  - Example: airline ticket pricing
- Requires good predictions of customer behavior
- Use gurobipy-machinelearning
  - Integrate ML predictor and linear program into one model
  - https://pypi.org/project/gurobi-machinelearning/

Capacity Planning

- Determine capacity needed for various levels of demand
- Minimize costs
  - Labor
    - Honor contracts, laws or rules
  - Machinery
    - Factor in service periods
  - Facilities
- Scenario analysis – what-if tool
- Nice to integrate this into a simulation
- Examples:
  - Virtual assembly line

Inventory Restock Levels

- Set restock levels for all items in inventory
  - Often relative to a usage or sales forecast
- Minimize inventory investment or maximize order fill levels
- Data
  - Vendor lead times
  - Item cost
  - Vendor order minima
- Common constraints
  - Honor allowed lead times for each item
- Scenario analysis
  - Consider various demand levels

Maintenance Planning / Predictive Maintenance

- Decide when to work on machinery
- Minimize maintenance costs
- Inputs
  - Predictive maintenance model
  - Required maintenance schedules
  - Available labor, labor laws, contracts, and rules
- Constraints
  - Meet production plans
  - Do not exceed available labor

Production Planning

- Decide what to produce from a factory or group of factories
- Minimize costs, maximize revenue, profits, or customer satisfaction.
- Inputs
  - Demand predictions ← ML saves the day
  - Existing orders
- Constraints
- This can now be operational
  - Near-real-time in some factories (5 min)
- Multi-period production planning: https://github.com/Gurobi/modeling-examples/tree/master/farm_planning

Order Fulfillment Planning

- Determine how to fulfill a batch of orders
- Minimize fulfillment costs, maximize customer satisfaction
- Inputs
  - Maximum allowed delivery times
  - Costs – labor, rent or capital costs, etc.
  - Vendor lead times by facility
- Constraints
  - Inventory
  - Available facility capacity
  - Available labor

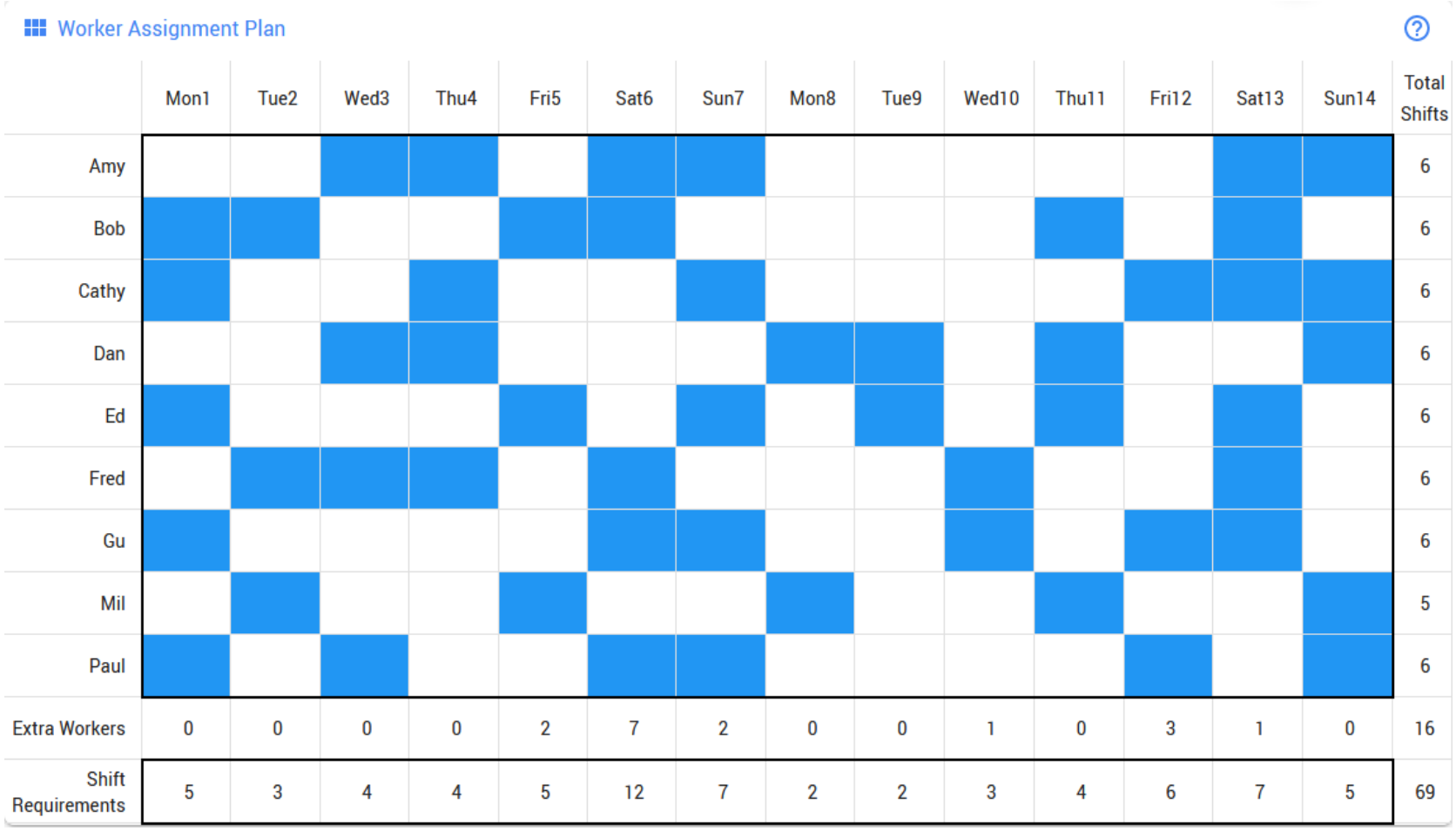
Inventory Location

- Two common uses:
  - Position inventory to minimize fulfillment costs
  - Move inventory to support marketing efforts
- Maximize revenue, minimize costs
- Constraints
  - Maintain restock levels
  - Meet expected customer demand at all locations
    - Consider event schedule from marketing – increased demand

Vehicle Routing

- Schedule visits (e.g., deliveries) for a fleet of vehicles and drivers
- Minimize cost or delivery time, or maximize customer satisfaction
- Usually includes time windows
- Difficult to solve
  - First determine acceptable MIP Gap
  - Requires column generation
  - Often uses heuristics for column generation or finding a MIP Start
- Resources:
  - Webinar: https://www.gurobi.com/events/how-to-synchronize-complex-routing-operations-synched-vrps-with-gurobi/
  - Technician routing: https://github.com/Gurobi/modeling-examples/tree/master/technician_routing_scheduling

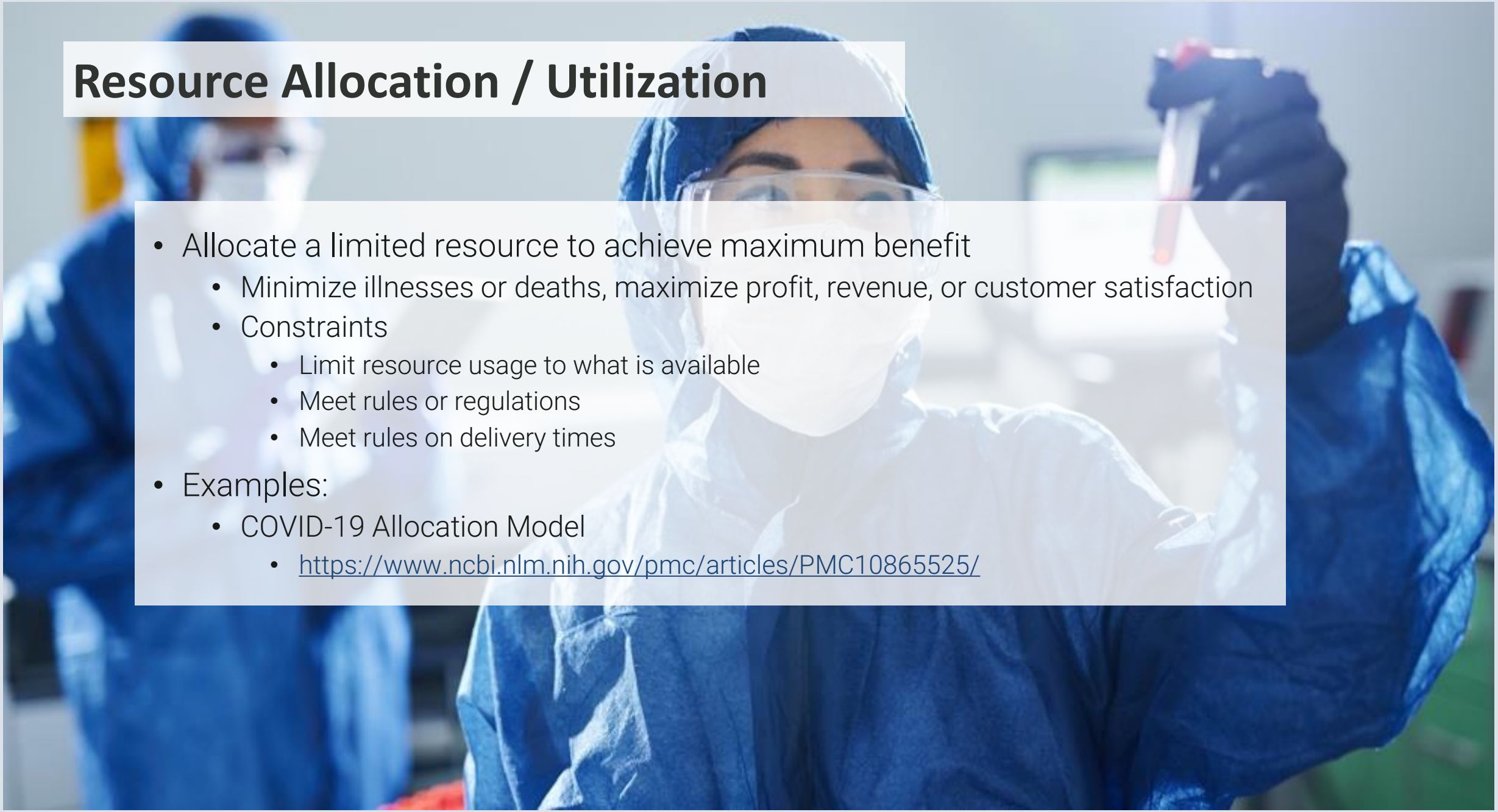
Workforce Scheduling / Rostering



	Mon1	Tue2	Wed3	Thu4	Fri5	Sat6	Sun7	Mon8	Tue9	Wed10	Thu11	Fri12	Sat13	Sun14	Total Shifts
Amy			■	■		■	■						■	■	6
Bob	■	■			■	■					■		■		6
Cathy	■			■			■					■	■	■	6
Dan			■	■				■	■		■			■	6
Ed	■				■		■		■		■		■		6
Fred		■	■	■		■				■			■		6
Gu	■					■	■			■		■	■		6
Mil		■			■			■			■			■	5
Paul	■		■			■	■					■		■	6
Extra Workers	0	0	0	0	2	7	2	0	0	1	0	3	1	0	16
Shift Requirements	5	3	4	4	5	12	7	2	2	3	4	6	7	5	69

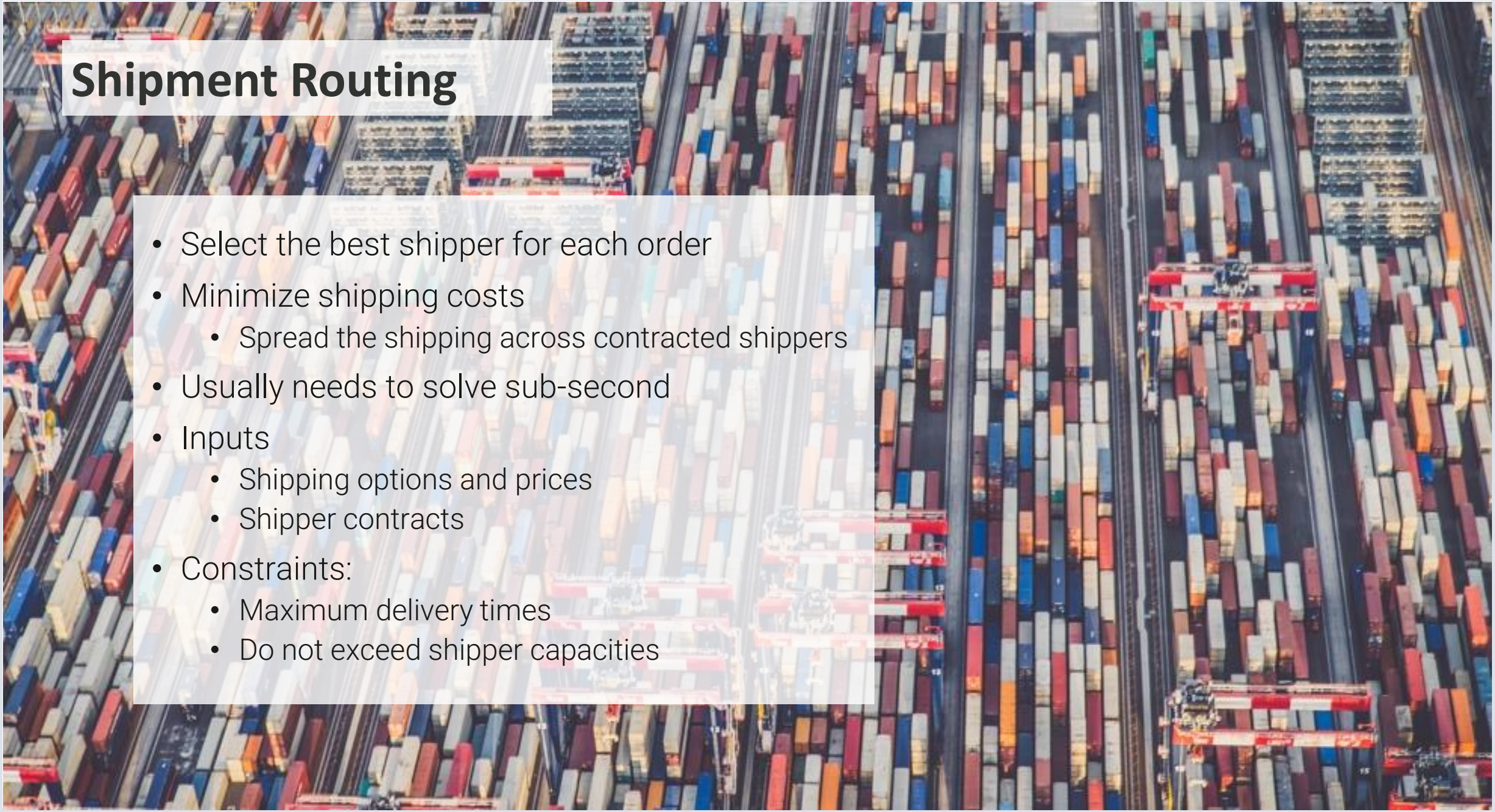
- https://demos.gurobi.com/workforce

Resource Allocation / Utilization



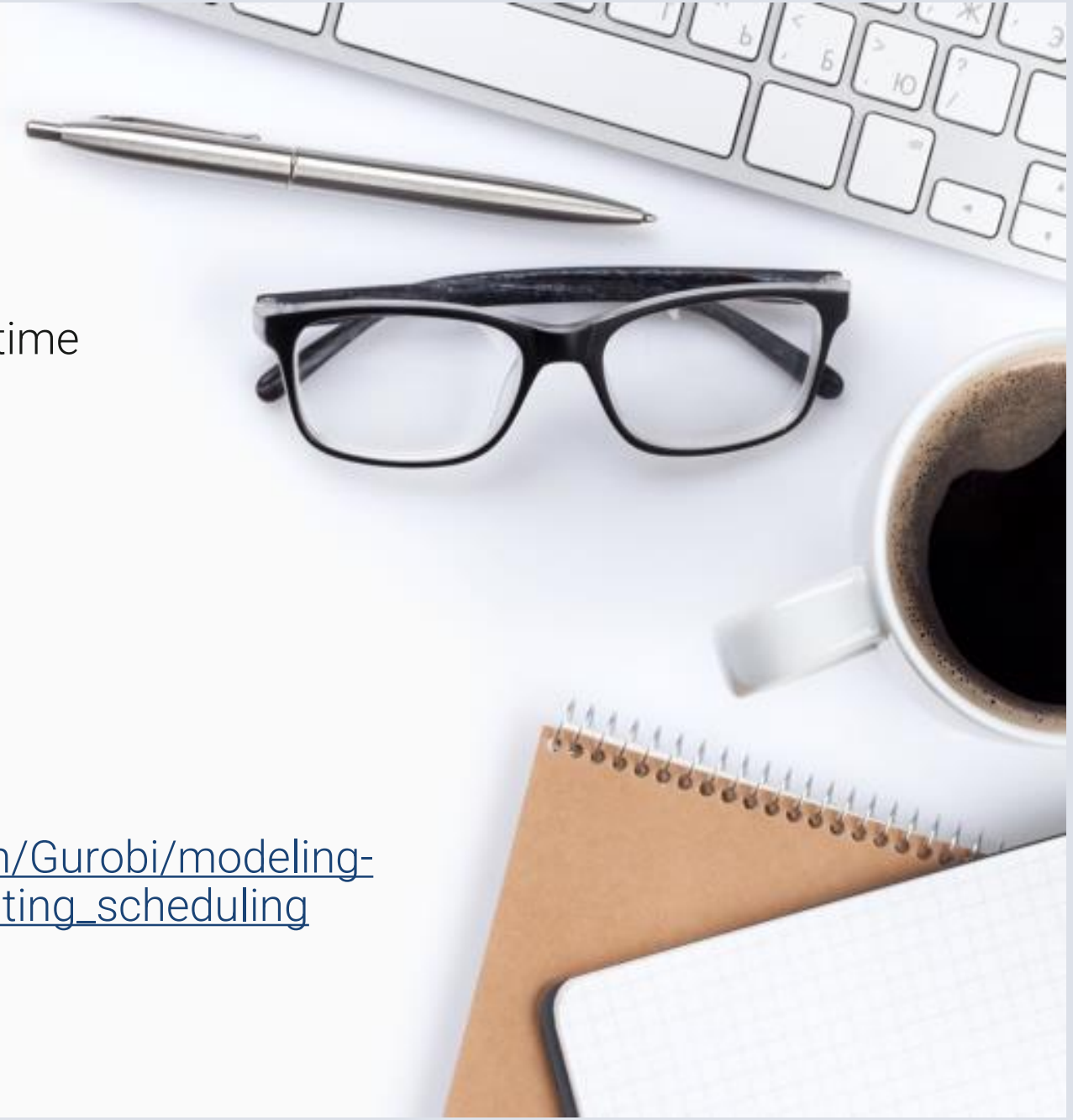
- Allocate a limited resource to achieve maximum benefit
  - Minimize illnesses or deaths, maximize profit, revenue, or customer satisfaction
  - Constraints
    - Limit resource usage to what is available
    - Meet rules or regulations
    - Meet rules on delivery times
- Examples:
  - COVID-19 Allocation Model
    - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10865525/

Shipment Routing



- Select the best shipper for each order
- Minimize shipping costs
  - Spread the shipping across contracted shippers
- Usually needs to solve sub-second
- Inputs
  - Shipping options and prices
  - Shipper contracts
- Constraints:
  - Maximum delivery times
  - Do not exceed shipper capacities

Real-Time Dispatching



- Decide how to deliver an order in real-time
  - Example: Pizza chain
- Minimize delivery times or costs
- Inputs
  - Maximum delivery time
  - Orders

- Technician routing: https://github.com/Gurobi/modeling-examples/tree/master/technician_routing_scheduling

Cutting Stock Problem

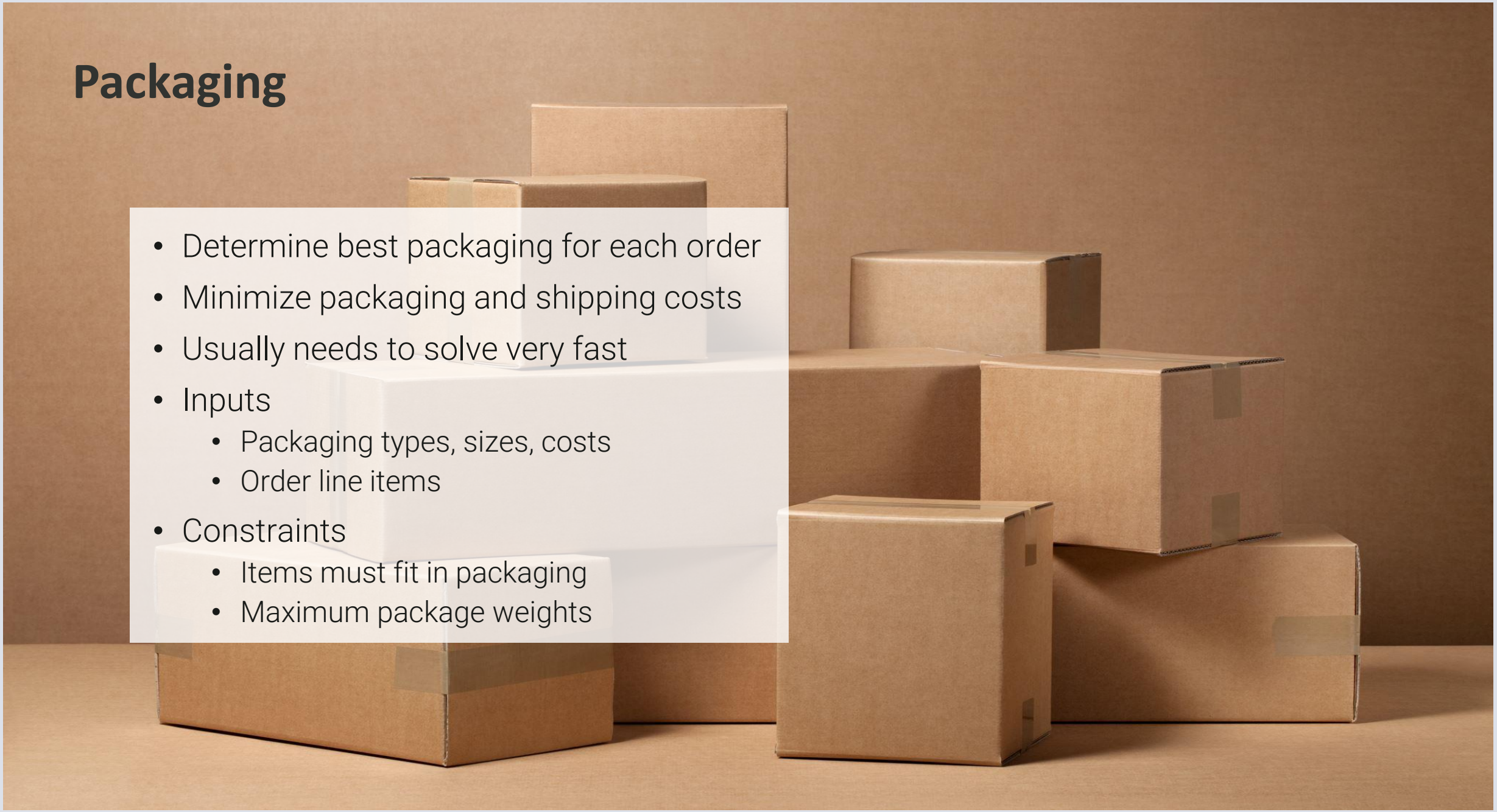
- https://demos.gurobi.com/cutstock

Blending

- Calculate best mix of ingredients to make a product
- Minimize cost
- Constraints
  - Required characteristics of final product
  - Available supplies – cost and all pertinent characteristics
  - Demand

- https://github.com/Gurobi/modeling-examples/tree/master/food_manufacturing

Packaging



- Determine best packaging for each order
- Minimize packaging and shipping costs
- Usually needs to solve very fast
- Inputs
  - Packaging types, sizes, costs
  - Order line items
- Constraints
  - Items must fit in packaging
  - Maximum package weights

Questions & Answers