Introduction to Optimization

Large Language Model for Optimization

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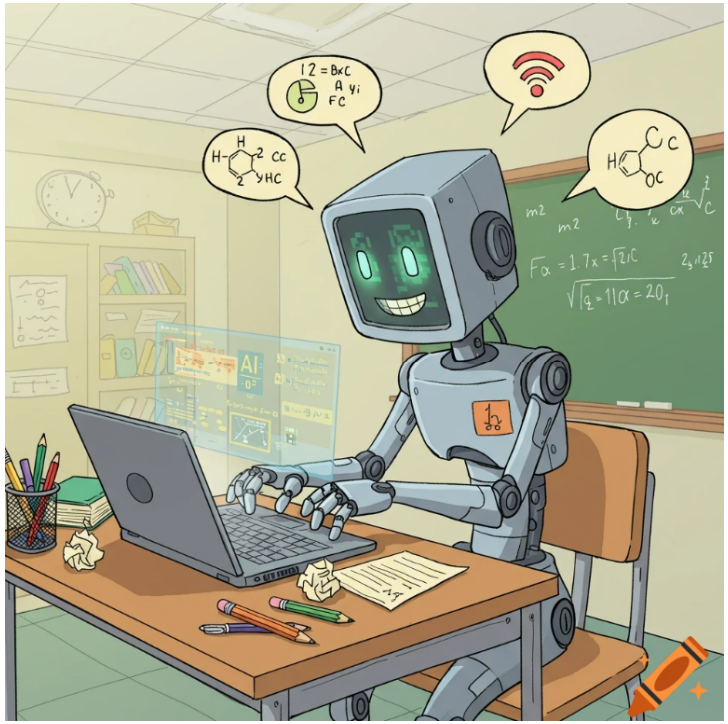
2025/09/02

What if I told you...

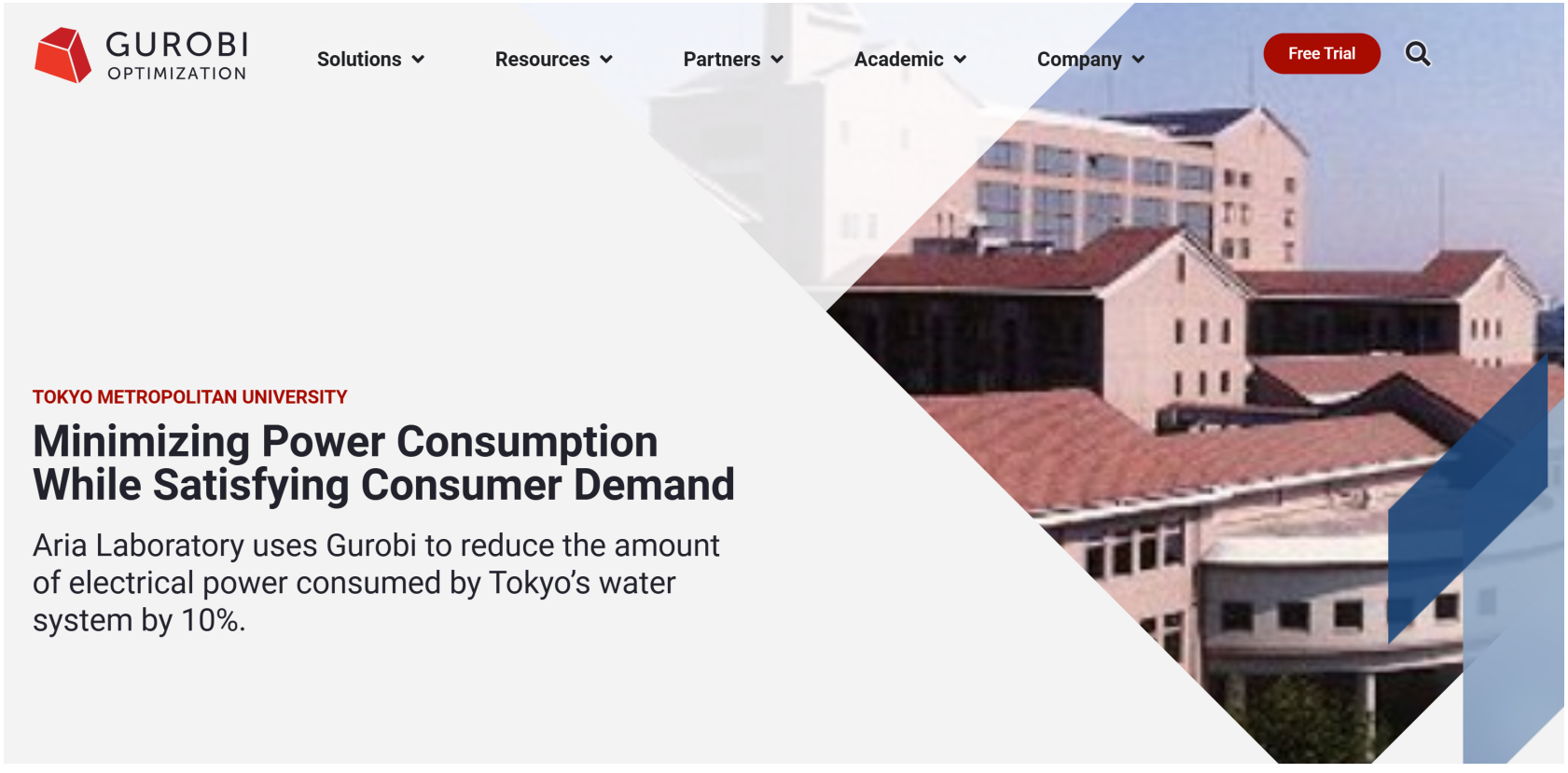


- You are using optimization every day
- Phone uses it to save battery
- Meituan use it to plan routes
- Netflix uses it to recommend movies
- **Today:** Discover the math behind better decisions

Today's Journey

- Operations Research in Action
- Cool Examples & Applications
- Why This Matters to You
- Wrap-up

Optimization is Everywhere!

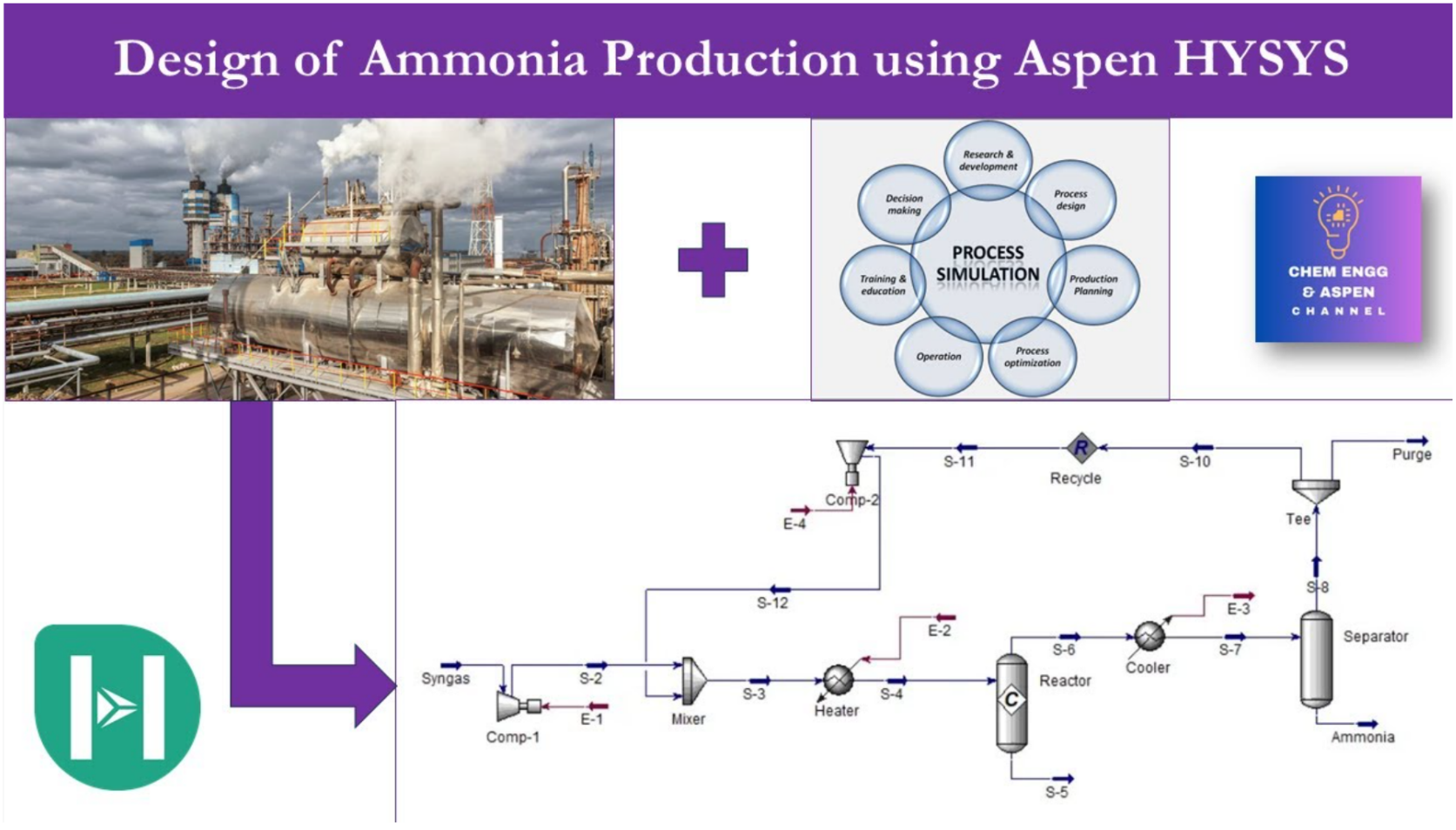


Optimization is Everywhere!

NASA, SpaceX watching weather in downrange abort zones for crew launch

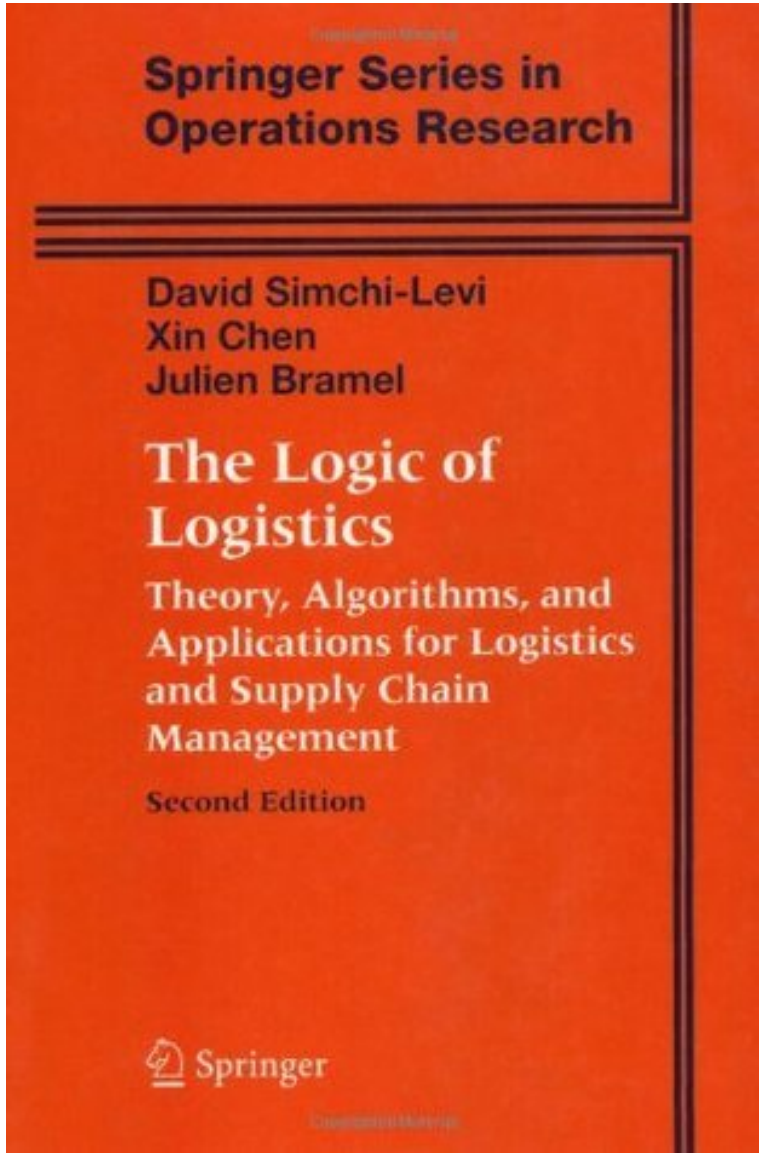
April 20, 2021 Stephen Clark

Optimization is Everywhere!



Aspen HYSYS Tutorial: Ammonia Production Process Design Explained! 观看 ›

Optimization is Everywhere!



Optimization is Everywhere!

The Mathematical Recipe

Three ingredients for any optimization problem:

1. **Decision Variables**

   What we can control (x, y, etc.)

2. **Objective Function**

   What we want to maximize/minimize

3. **Constraints**

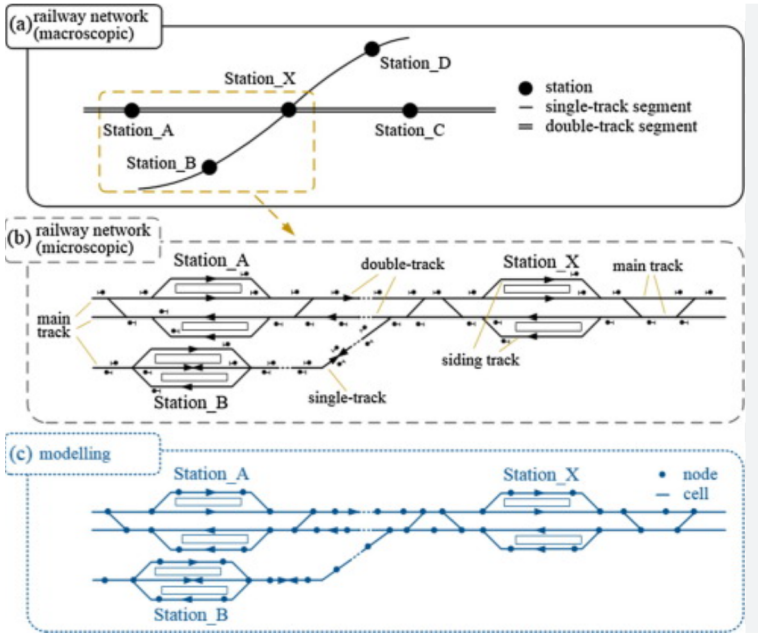
   Limits on what we can do

Example: Pizza Party Optimization

Problem: You can buy a cheese pizza for \$10 and get a happiness degree 8, and a pepperoni pizza for \$15 and get a happiness degree 10. Maximize pizza happiness with \$30 budget.

- **Decision:**
- **Objective:**
- **Constraint:**

The Challenge: ztM03 Railway Scheduling Problem



- One of the largest Linear Programming problems ever solved
- Railway scheduling optimization problem
- Represents real-world planning challenges in transportation

Problem Dimensions: Massive Scale

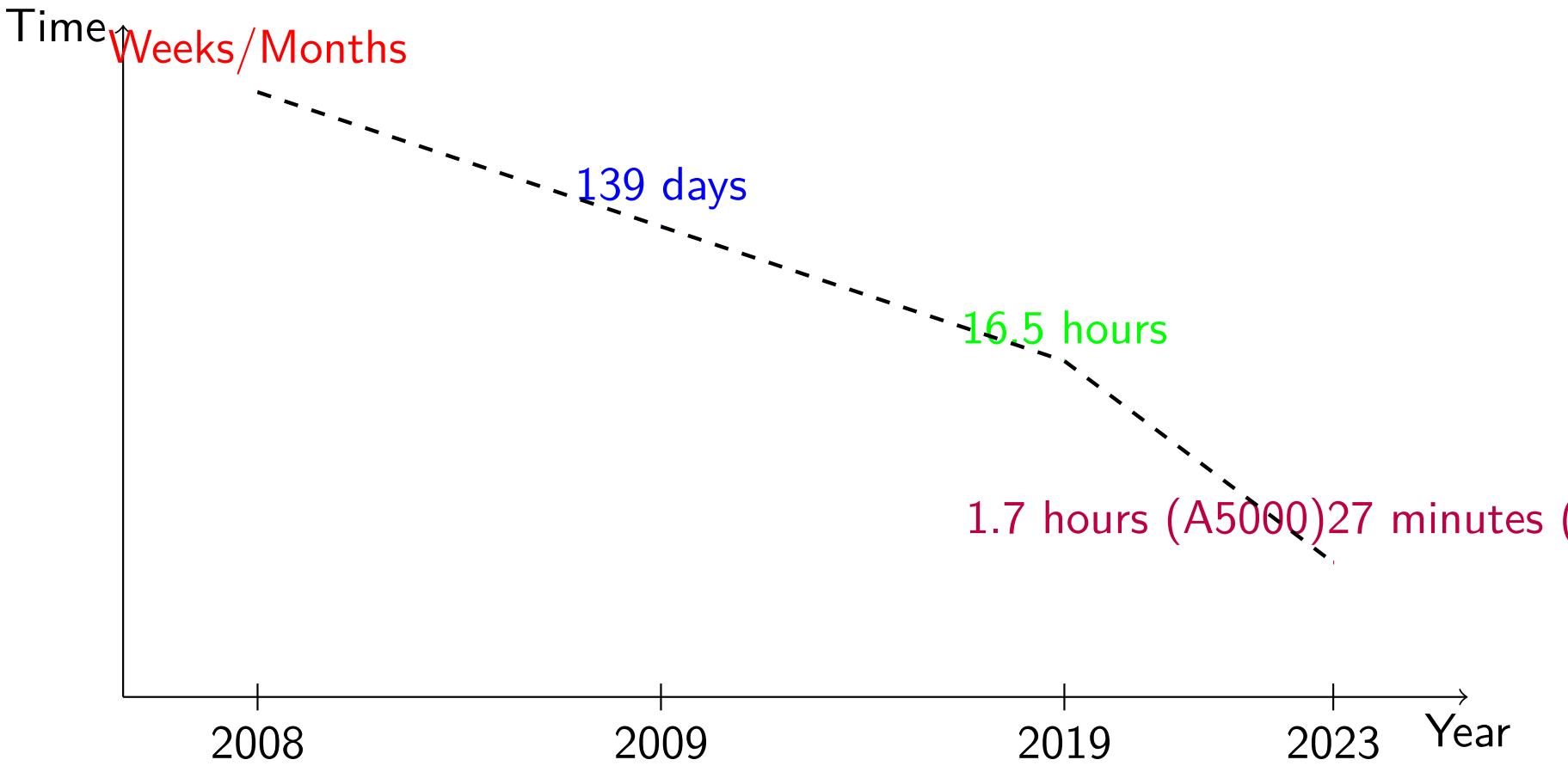
Parameter	Value
Variables (Columns)	29,128,799
Constraints (Rows)	19,731,970
Non-zero elements	104,422,573

- Could not be solved with simpler algorithms
- Barrier methods required at least 250 GB of memory
- Represented a significant computational challenge

2008: The First Solution

- **Solver**: CPLEX (out-of-core mode)
- **Hardware**: 8 threads, 4 ET-SS80v4 CPUs @ 2.3GHz
- **Performance**:
  - 12,000 crossover iterations
  - 56 hours per iteration
  - Total solution time: Significant (weeks/months)
- **Limitations**: Required specialized hardware and extensive runtime

Computational Progress Over Time



Algorithmic Evolution

Year	Method	Key Innovation
2008	CPLEX Barrier	First feasible solution
2009	Improved Barrier	Better memory management
2019	Advanced Barrier	Algorithmic optimizations
2023	cuPDLP-C	GPU acceleration

- Transition from CPU to GPU computing
- Improved numerical methods and precision
- Better memory management techniques
- Parallel processing advancements

Implications for Operations Research

- **Scale**: Problems once considered intractable are now solvable
- **Applications**:
  - Railway and transportation scheduling
  - Supply chain optimization
  - Energy grid management
  - Financial portfolio optimization
- **Accessibility**: High-performance optimization becoming more accessible
- **Future**: Real-time optimization for complex systems

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What is Operations Research?

OPERATIONS RESEARCH

- The term Operations Research was coined in WWII
- Scientists and mathematicians optimized radar, convoy routes, and logistics
- Success in the militar spread to business, healthcare, and finance today

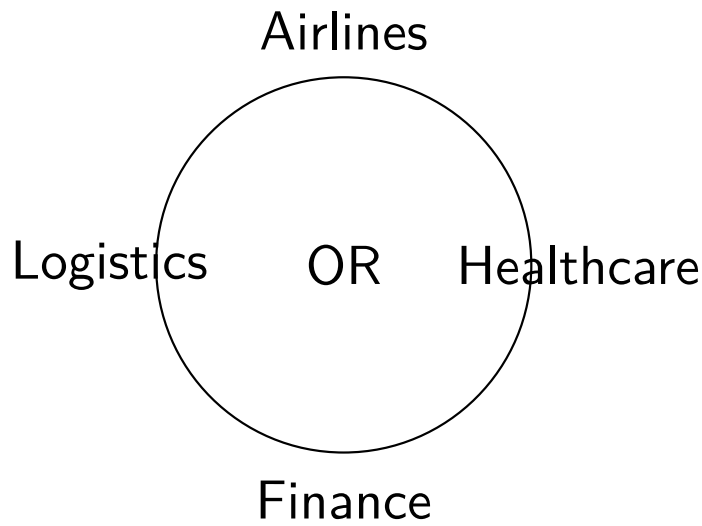
What is Operations Research?

The science of better decision making

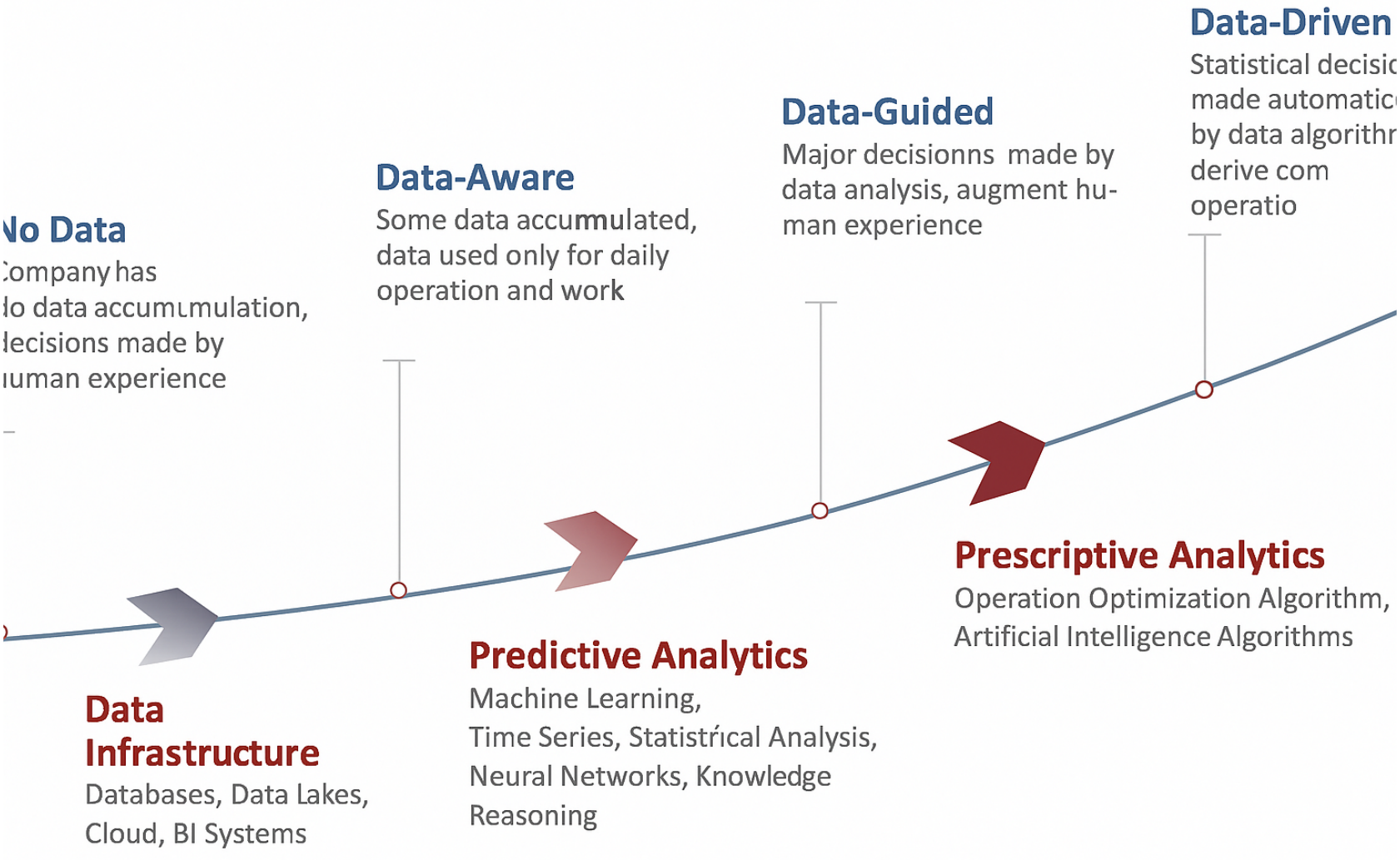
"Using math to solve real-world problems"

Where it's used:

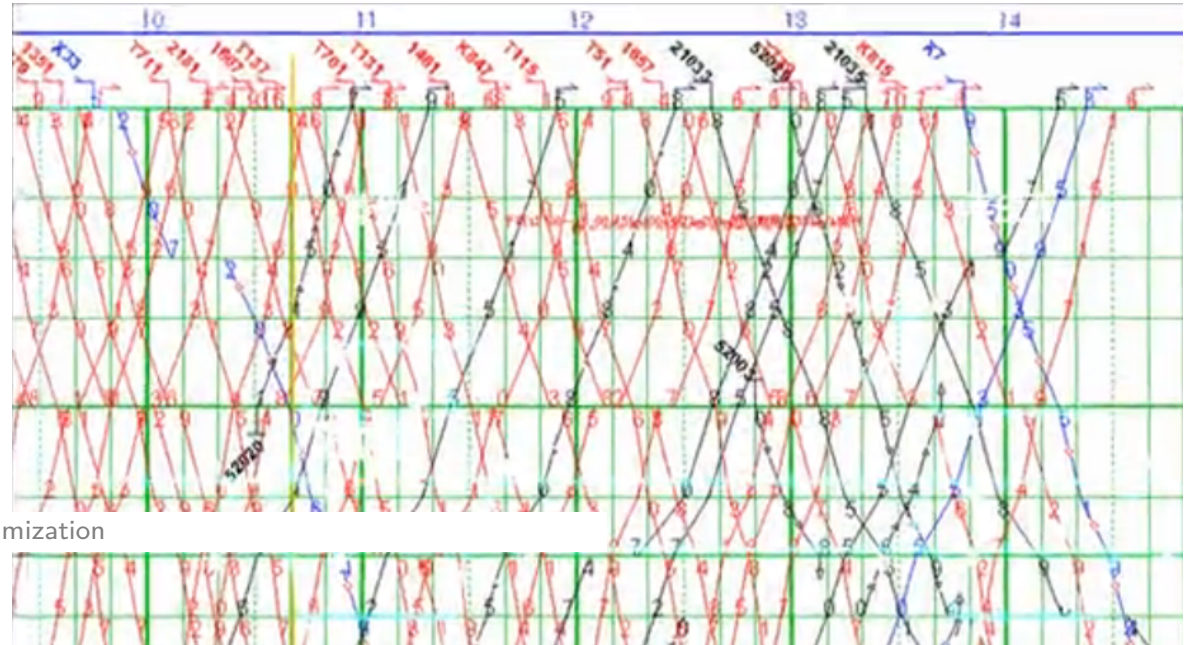
- Airlines (scheduling)
- Hospitals (staffing)
- Factories (production)
- Finance (investing)



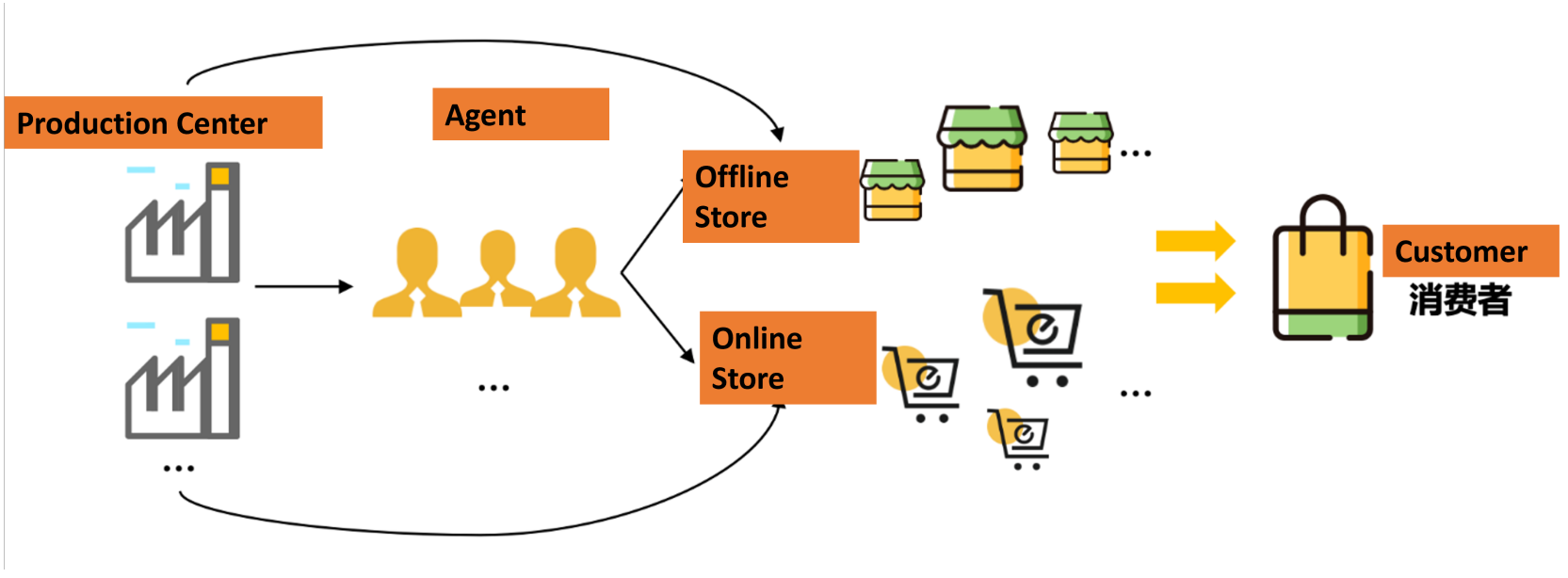
OR in Business Operations



OR Success Stories: Highspeed Train Scheduling Optimization



OR Success Stories: Inventory



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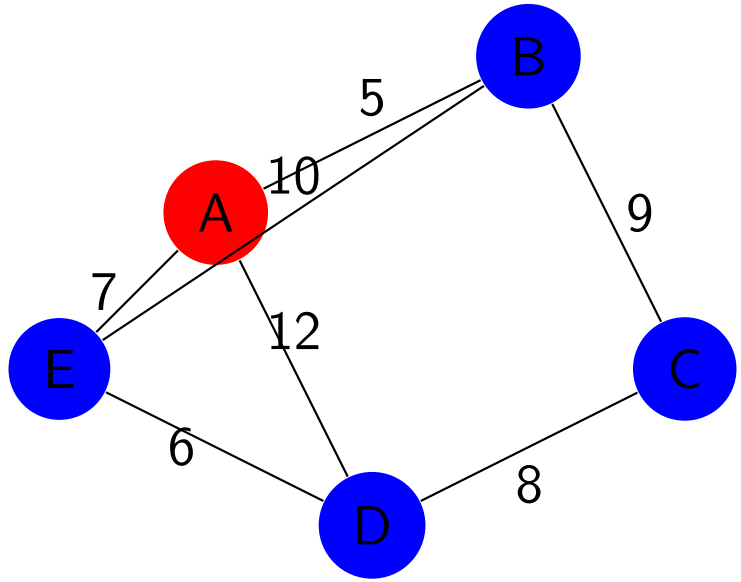
The Traveling Salesperson Problem

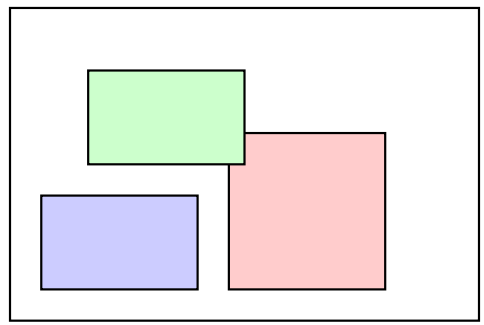
Question: What's the shortest route to visit all cities exactly once?



- Seems simple? Try 20 cities: 2,432,902,008,176,640,000 possible routes!
- Used in: delivery routes, circuit design, DNA sequencing

The Knapsack Problem

Question: What items should you pack to maximize value without exceeding weight limit?



Maximize value within weight limit

- Used in: resource allocation, investment portfolio selection
- Your backpack for school is a knapsack problem!

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OR & Optimization in Your Life

Today:

- Google Maps routes
- Netflix recommendations
- Amazon delivery
- Social media feeds

Tomorrow:

- Self-driving cars
- Smart cities
- Personalized medicine
- Climate change solutions

You'll help build this future!

Career Opportunities

Industry	Role
Technology	Data Scientist
Finance	Quantitative Analyst
Healthcare	Operations Analyst
Logistics	Supply Chain Manager
Consulting	Operations Research Analyst
Energy	Resource Planner

"The demand for operations research analysts is projected to grow 25% from 2020 to 2030"

— *U.S. Bureau of Labor Statistics*

What You'll Learn

Mathematical Tools:

- Linear Programming
- Integer Programming
- Network Optimization
- Decision Analysis
- Simulation

Skills You'll Gain:

- Problem-solving
- Mathematical modeling
- Data analysis
- Computational thinking
- Decision-making

Contents

Key Takeaways

- Optimization is about making the **best** choices given constraints
- Operations Research uses math to solve **real-world problems**
- These techniques power modern technology and business
- You'll encounter optimization problems in **your daily life**
- This field offers exciting career opportunities

Your First Optimization Challenge

Your daily schedule:

- 8 hours of classes
- 2 hours of studying per class hour
- 8 hours of sleep
- Some time for fun/socializing
- Only 24 hours in a day!

How will you optimize your time?

Thank You!

Questions?