

BDC5101

Deterministic Operations Research Models

Zhenyu Hu

Semester II, 2018/2019



Course Information

- **Lecture hours:** Monday 2 – 5 pm / 6:30 – 9:30 pm
- **Classroom:** BIZ 2 5-9
- **Instructor:** Zhenyu Hu
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- **Office:** BIZ1 8-62
- **Office hour:** by appointment
- **TA:** Hailong Sun
- **Email:** hailong.sun@u.nus.edu
- **Office hour:** by appointment
- **Website:** IVLE

Textbook and Reference

- **Text:**
 - **Introduction to Operations Research, Hillier and Lieberman (2015)**
 - **Applied Mathematical Programming, Bradley, Hax and Magnanti (1977)**
 - **Introduction to Linear Optimization, Bertsimas and Tsitsiklis (1997)**
 - **Mostly, lecture notes**
- **Software:**
 - **Python (Anaconda) and Gurobi**
 - **Excel Solver**

Optimization Software

V · T · E	Mathematical optimization software	[hide]
Data formats	LP · MPS · nl · OptML · OSiL · sol · xMPS	
Modeling tools	AIMMS · AMPL · APMonitor · CMPL · CVX · CVXOPT · CVXPY · ECLIPSe-CLP · GEKKO · GAMS · GNU MathProg · JuMP · LINDO · OPL · MPL · OptimJ · PICOS · PuLP · Pyomo · ROML · TOMLAB · Xpress-Mosel · YALMIP · ZIMPL	
LP, MILP* solvers	ABACUS* · APOPT* · Artelys Knitro* · BCP* · BDMLP · BPMPD · BPOPT · CLP · CBC* · CPLEX* · CSDP · DSDP · FortMP* · GCG* · GIPALS32 · GLPK/GLPSOL* · Gurobi* · HOPDM · LINDO* · Lp_solve · LOQO · MINOS · MINTO* · MOSEK* · OOPS · OOQP · PCx · QSopt · SAS/OR* · SCIP* · SoPlex · SOPT-IP* · Sulum Optimization Tools* · SYMPHONY* · XA* · Xpress-Optimizer*	
QP, MIQP* solvers	APOPT* · Artelys Knitro* · BPMPD · BPOPT · BQPD · CBC* · CLP · CPLEX* · FortMP* · GloMIQO* · Gurobi* · IPOPT · LINDO* · LSSOL · LOQO · MINOS · MOSEK* · OOPS · OOQP · OSQP · QPOPT · QPSOL · SCIP* · XA Quadratic Solver · Xpress-Optimizer*	
QCP, MIQCP* solvers	APOPT* · Artelys Knitro* · BPMPD · BPOPT · CPLEX* · GloMIQO* · Gurobi* · IPOPT · LINDO* · LOQO · MINOS · MOSEK* · SCIP* · Xpress-Optimizer* · Xpress-SLP*	
SOCP, MISOCP* solvers	CPLEX* · DSDP · Gurobi* · LINDO* · LOQO · MOSEK* · SCIP* · SDPT3 · SeDuMi · Xpress-Optimizer*	
SDP, MISDP* solvers	CSDP · DSDP · MOSEK · PENBMI · PENSMP · SCIP-SDP* · SDPA · SDPT3 · SeDuMi	
NLP, MINLP* solvers	ALGENCAN · AlphaECP* · ANTIGONE* · AOA* · APOPT* · Artelys Knitro* · BARON* · Bonmin* · BPOPT · CONOPT · Couenne* · DICOPT* · FilMINT* · FilterSQP · Galahad library · ipfilter · IPOPT · LANCELOT · LINDO* · LOQO · LRAMBO · MIDACO* · MILANO* · MINLP BB* · MINOS · Minotaur* · MISQP* · NLPQLP · NPSOL · OQNLP* · PATHNLP · PENNON · SBB* · SCIP* · SNOPT* · SQPlab · WORHP · Xpress-SLP*	
GO solvers	BARON · Couenne* · LINDO · SCIP	
CP solvers	Artelys Kalis · Choco · Comet · CPLEX CP Optimizer · Gecode · Google CP Solver · JaCoP · OscaR	
Metaheuristic solvers	OptaPlanner · LocalSolver	

What You Should Expect

- **Mathematical Thinking**
 - Understand the basic logic behind algorithms
 - Understand the general principles in optimization
 - Judgement on the difficulty of a problem; be able to assess the quality of a solution
 - **Analytics Skills**
 - Building up models
 - Picking the right tools
 - Implementing in Software
-

What I Expect

- **Prerequisite**
 - Linear algebra
 - Basic probability theory
- **Assessment**

- Team Term Paper	30%
- Team Term Paper Presentation	5%
- Individual Assignments	30%
- In-Class Quizzes	30%
- Class Participation	5%

Term Paper

- **Apply the analytical techniques to a business problem of your choosing**
 - Motivation and statement of the problem
 - Methodology and processes of solving the problem
 - Analysis and interpretation of the results

Course Content

- Theory and application of linear programming*
- Integer programming and network flow*
- Dynamic programming*
- Heuristic design

Homework 0

- Download and install python (Anaconda distribution) and gurobi (academic license)
 - See the note and Gurobi optimizer quickstart guide
- Form a team of around 6 members

Operations Research in Practice

In a Nutshell

- **Maximize/Minimize ...**
- **Subject to ...**

Areas of Operations Research

- Manufacturing
- Transportation
- Airline, Hotel and Retail

Synonyms and overlaps: Management Science, Decision Science, Industrial Engineering, Operations Management.

Areas of Operations Research

Platinum Sponsors



Gold Sponsors



Individual Sponsors



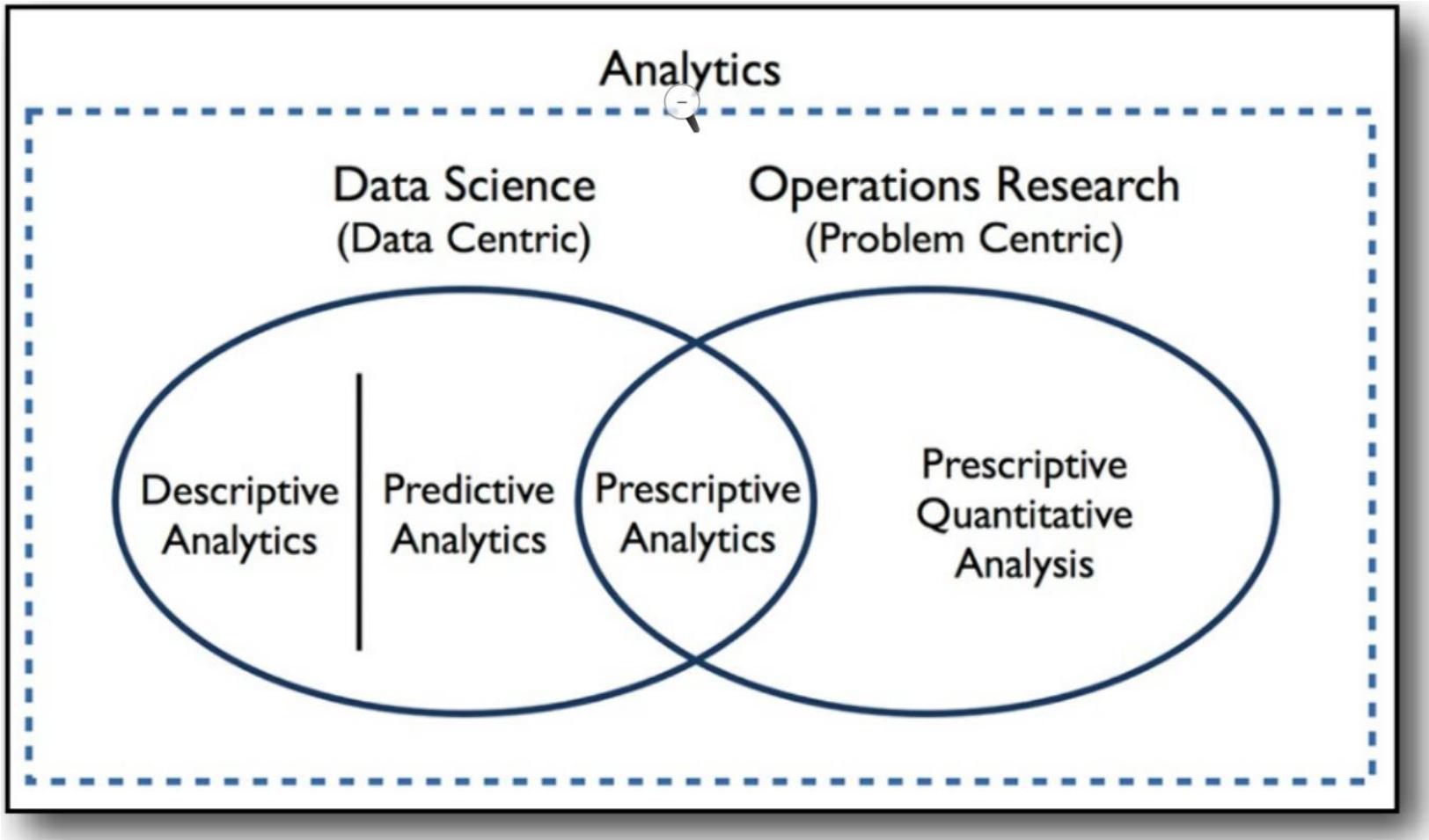
Industrial Engineering and Operations Research
Decision, Risk and Operations



Areas of Operations Research



Rise of Analytics



Source: Robert Rose, "Defining analytics: a conceptual framework", 2016, *OR/MS Today*, Vol. 43, No.3

MAR 17, 2011

FORD OPENS FLEXIBLE, GREEN MICHIGAN ASSEMBLY PLANT WITH PRODUCTION OF ALL-NEW FORD FOCUS

- Transformed Michigan Assembly Plant (MAP), which will produce the fuel-efficient new global Ford Focus for North American customers, **features flexible manufacturing**, environmentally friendly practices and a highly trained work force
- A \$550 million investment transformed the plant, creating new benchmarks for flexible manufacturing. Multiple models to run down the same production line, making Michigan Assembly the world's first plant to build gasoline-powered, battery electric, hybrid electric and plug-in hybrid electric vehicles on the same line
- MAP also features one of Michigan's largest solar-powered generation systems and electric vehicle charging stations

Ford Motor Company celebrated the launch of the 2012 Ford Focus with employees, dealers, suppliers, media and other invited guests at the Michigan Assembly Plant.

Click here to download related images.

Ford

**FIESTA****FOCUS****FUSION****MUSTANG****C-MAX****TAURUS**Starting MSRP \$14,090¹Starting MSRP \$17,225¹Starting MSRP \$22,120¹Starting MSRP \$24,645¹Starting MSRP \$24,170¹Starting MSRP \$27,110¹

United States - Chicago Assembly Plant



United States - Dearborn Truck Plant



United States - Kansas City Assembly Plant



United States - Kentucky Truck Plant



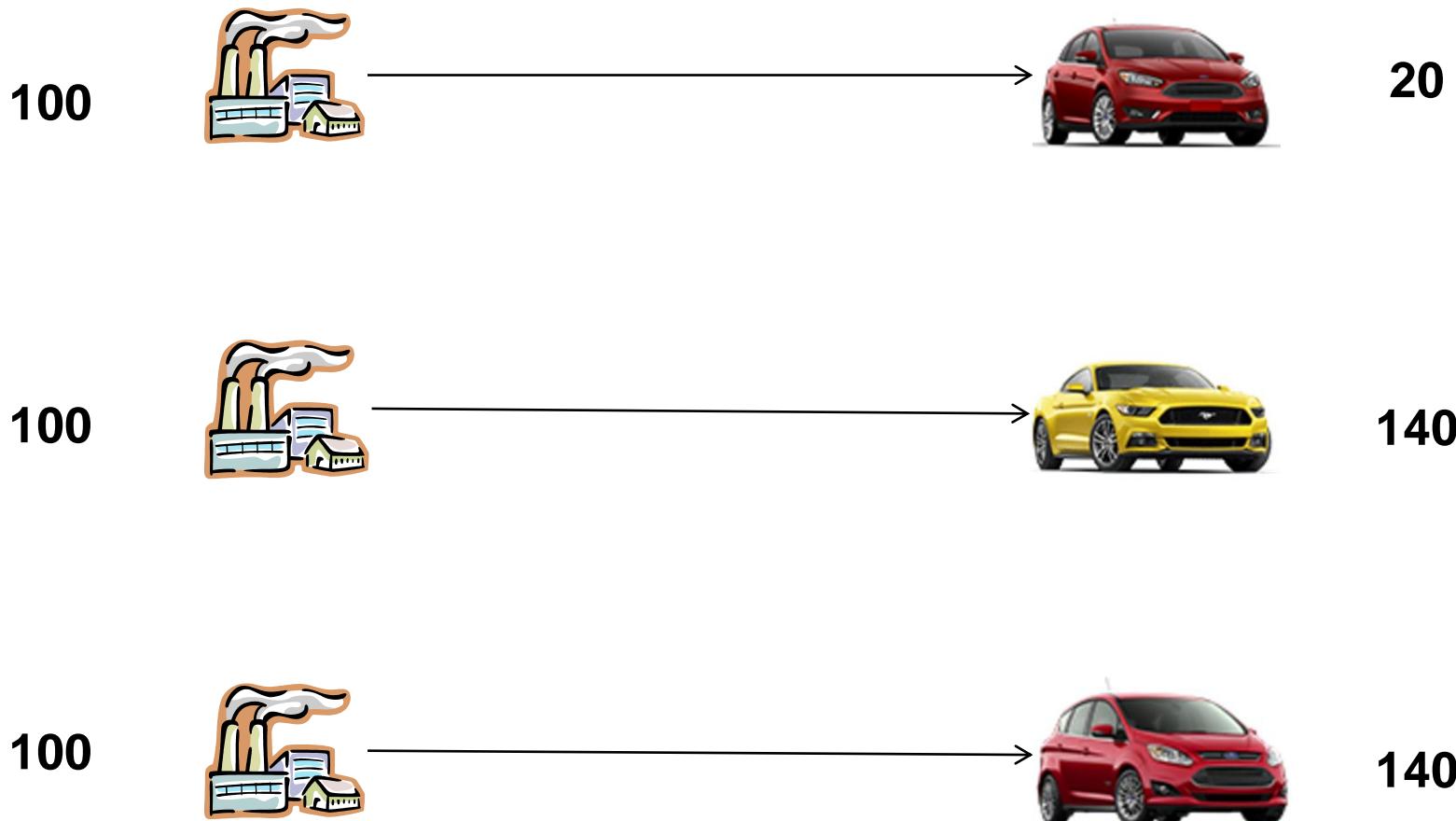
United States - Louisville Assembly Plant



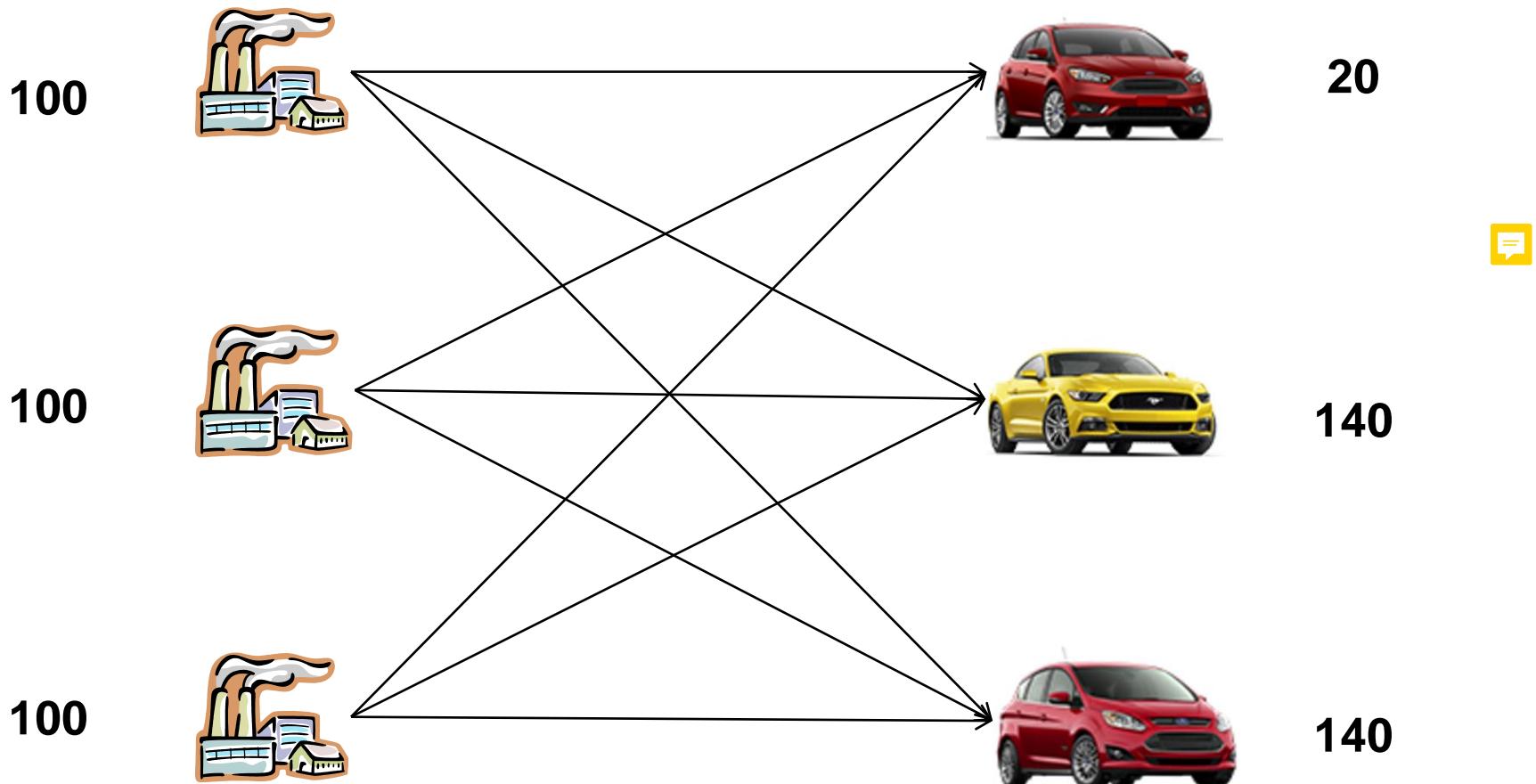
United States - Michigan Assembly Plant



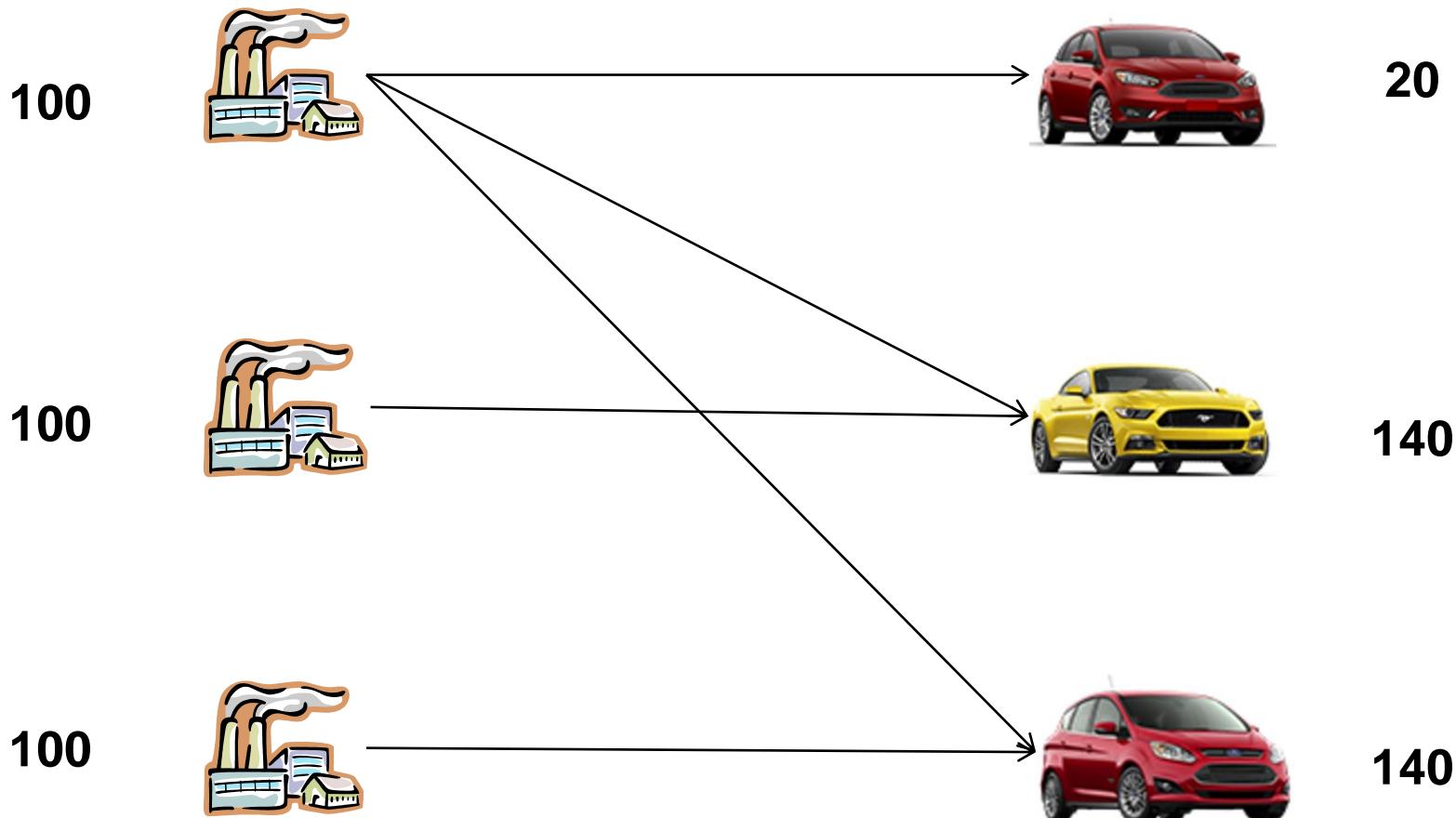
Traditional Dedicated System



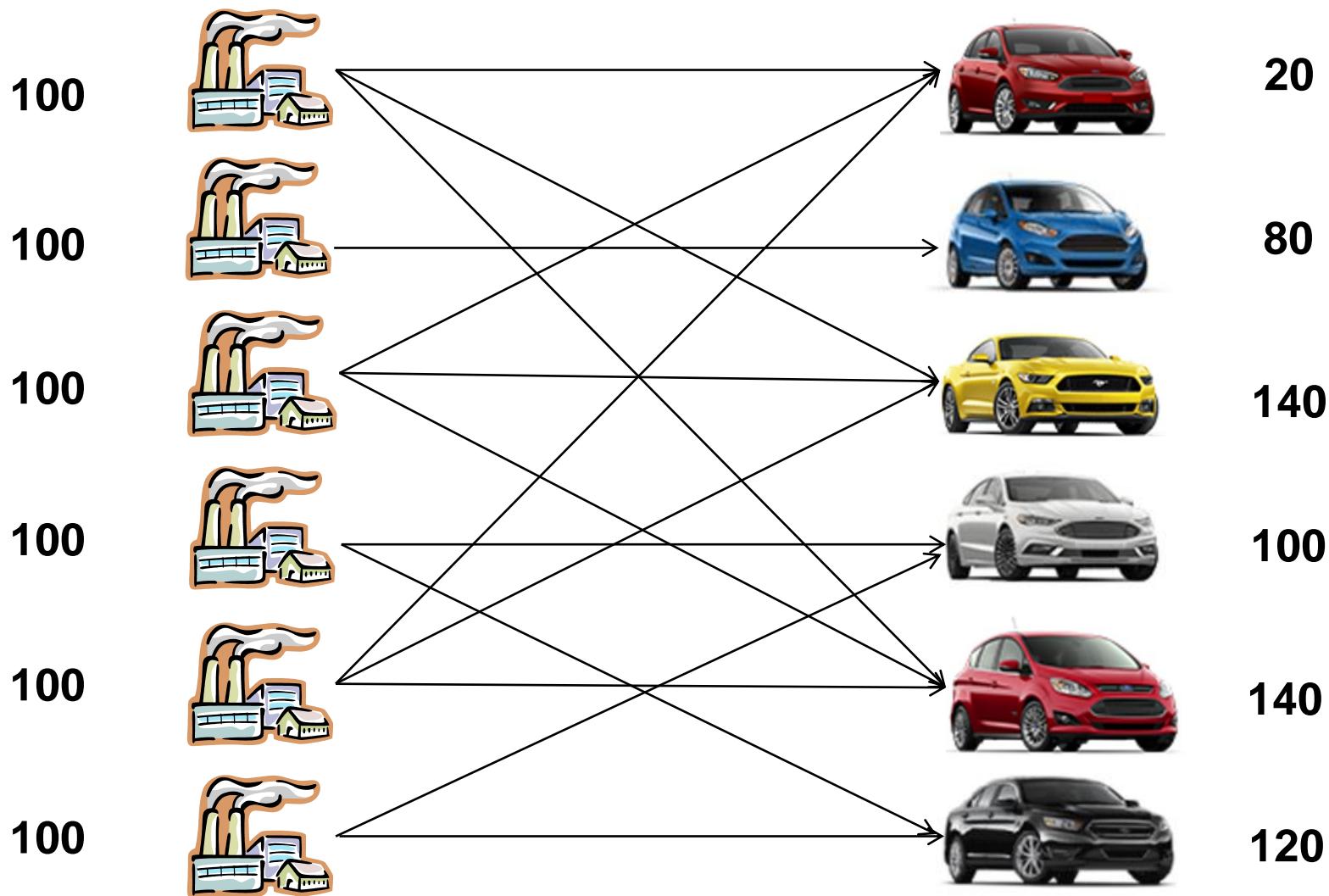
Full Flexible System



If we know demand...



How to Compute the Maximum Sales?

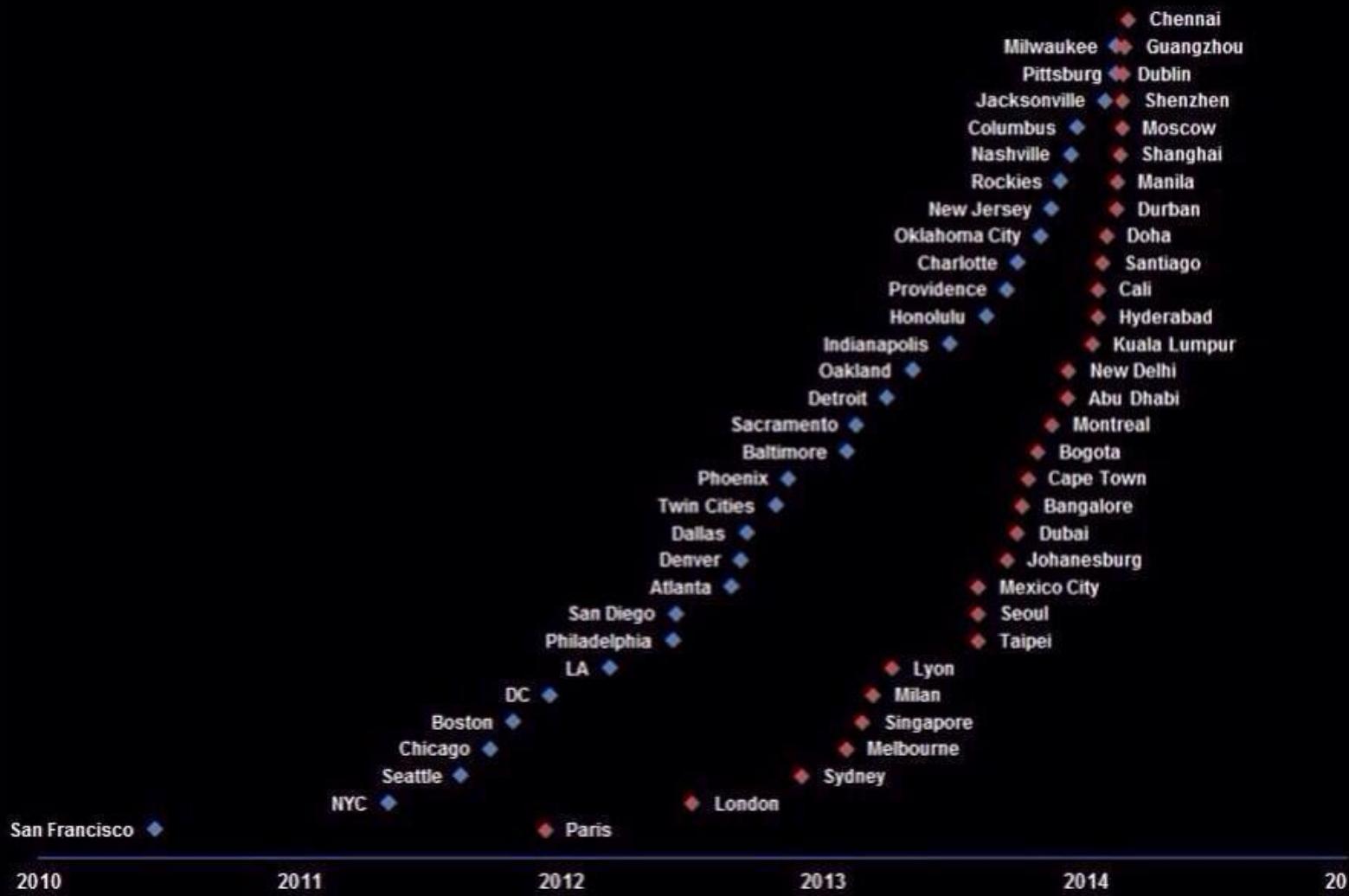


Operations Research Tools

- **Given a design, how do we evaluate its performance?**
 - Linear programming
 - Maximum flow
 - Simulation

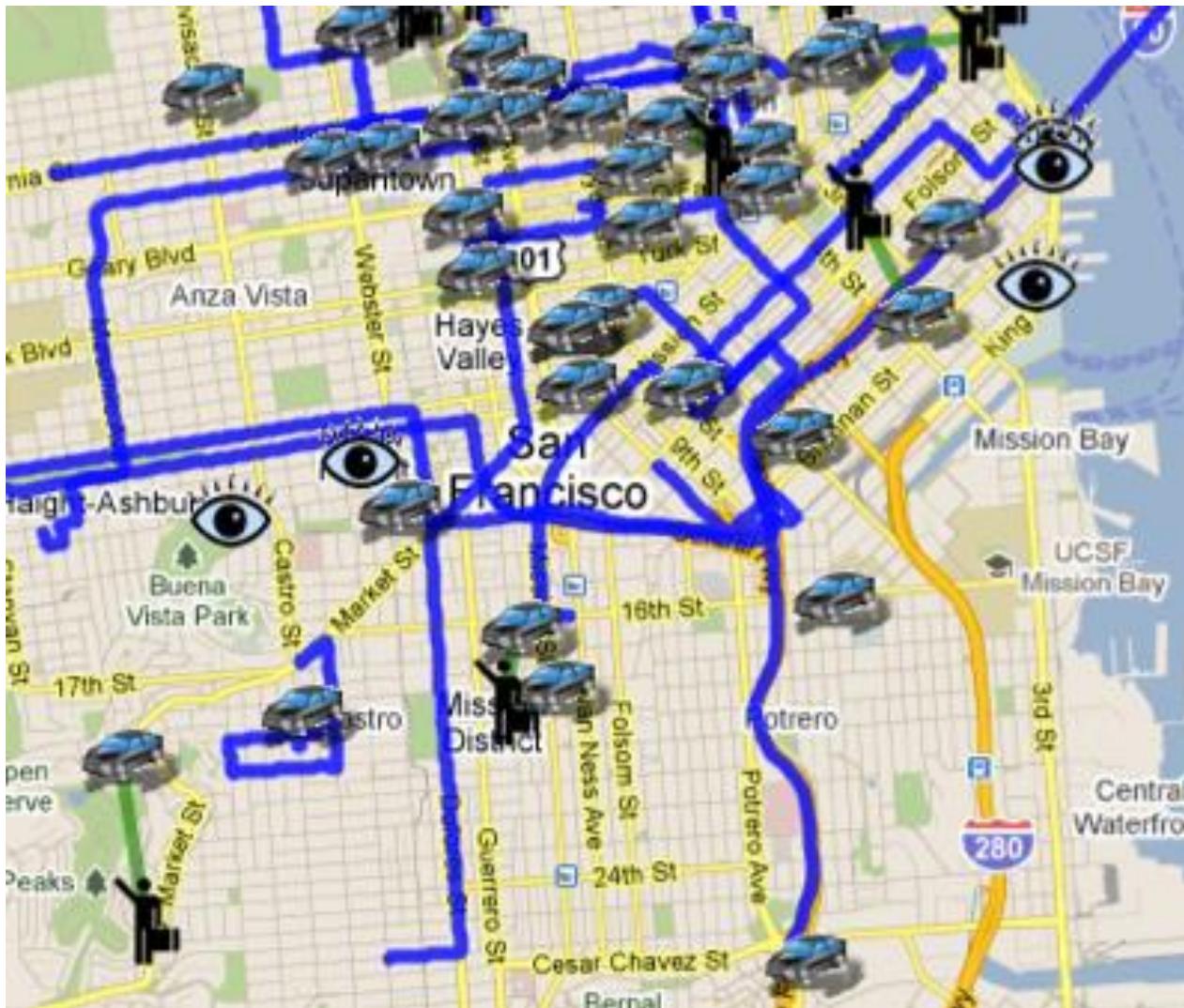
Uber

Uber Expansion



- **What does Uber offer?**
- **Matching Algorithms**
 - Dispatch system
 - Surge pricing
 - Uber POOL

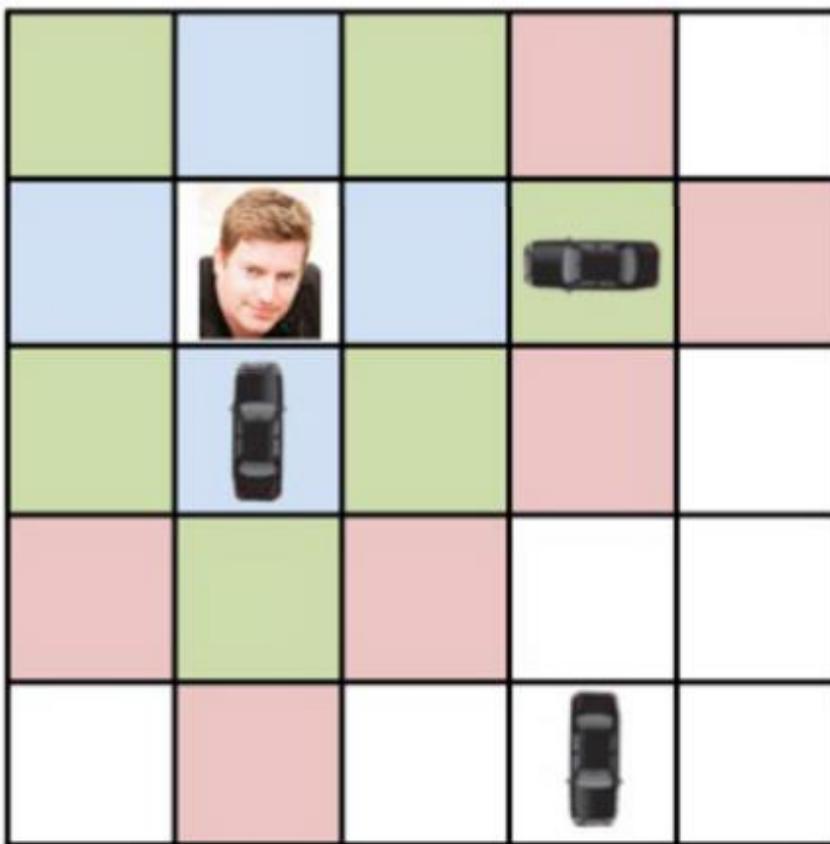
Dispatch System



Source: <http://www.wired.com/2011/04/app-stars-uber/>

Greedy Approach

Uberg



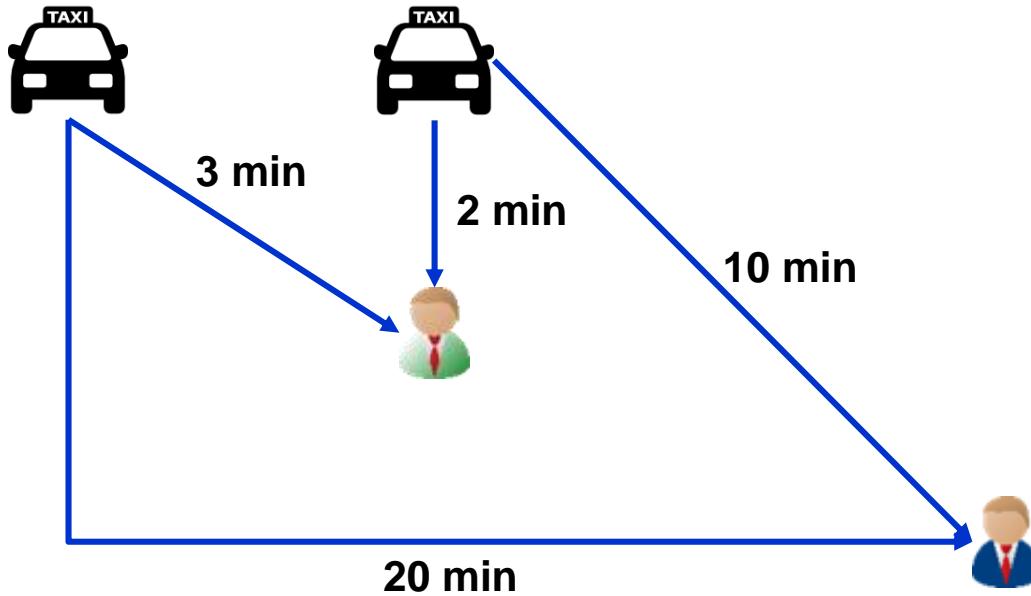
Dispatch Radius =

- 1
- 2
- 3

♪♪ we built this city on pyyy-thon cooooode ♪♪

Source: <https://newsroom.uber.com/semi-automated-science-using-an-ai-simulation-framework/>

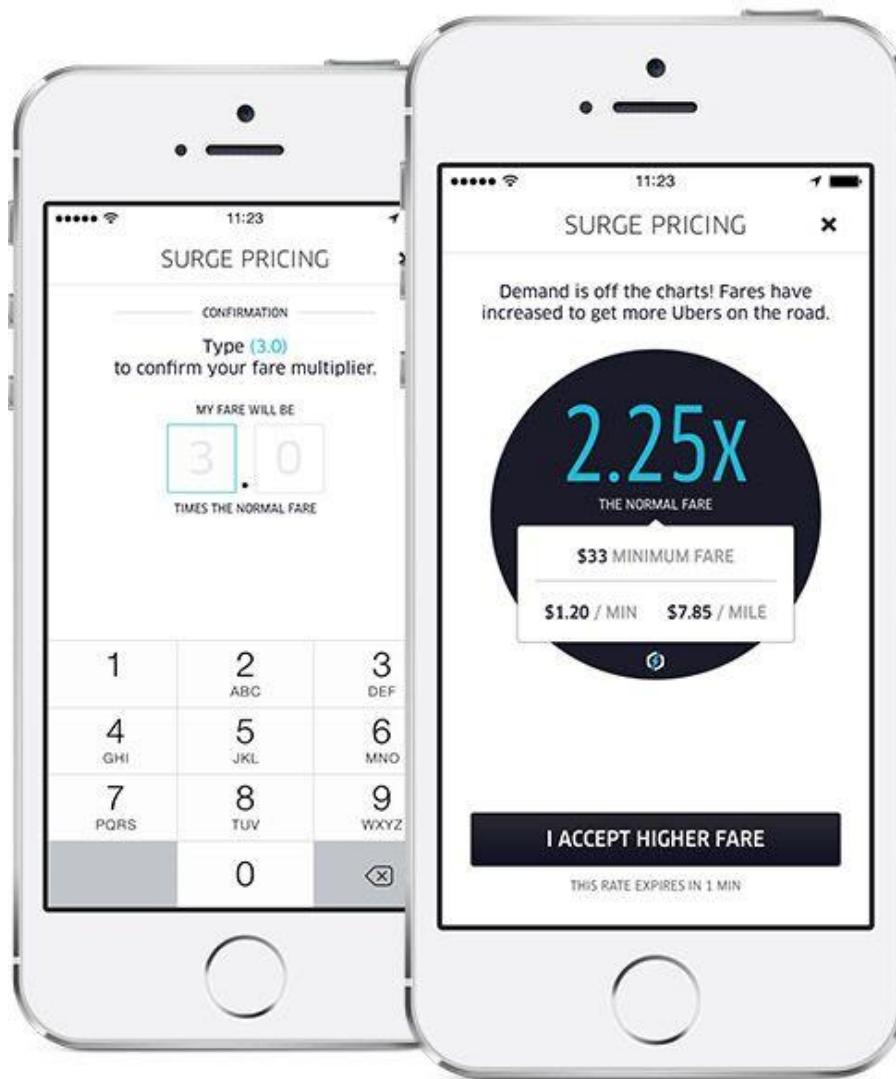
Is Greedy Good?



Operations Research Tools

- **Linear programming.**
- **Shortest Path.**
- **Assignment Problem.**

Surge Pricing

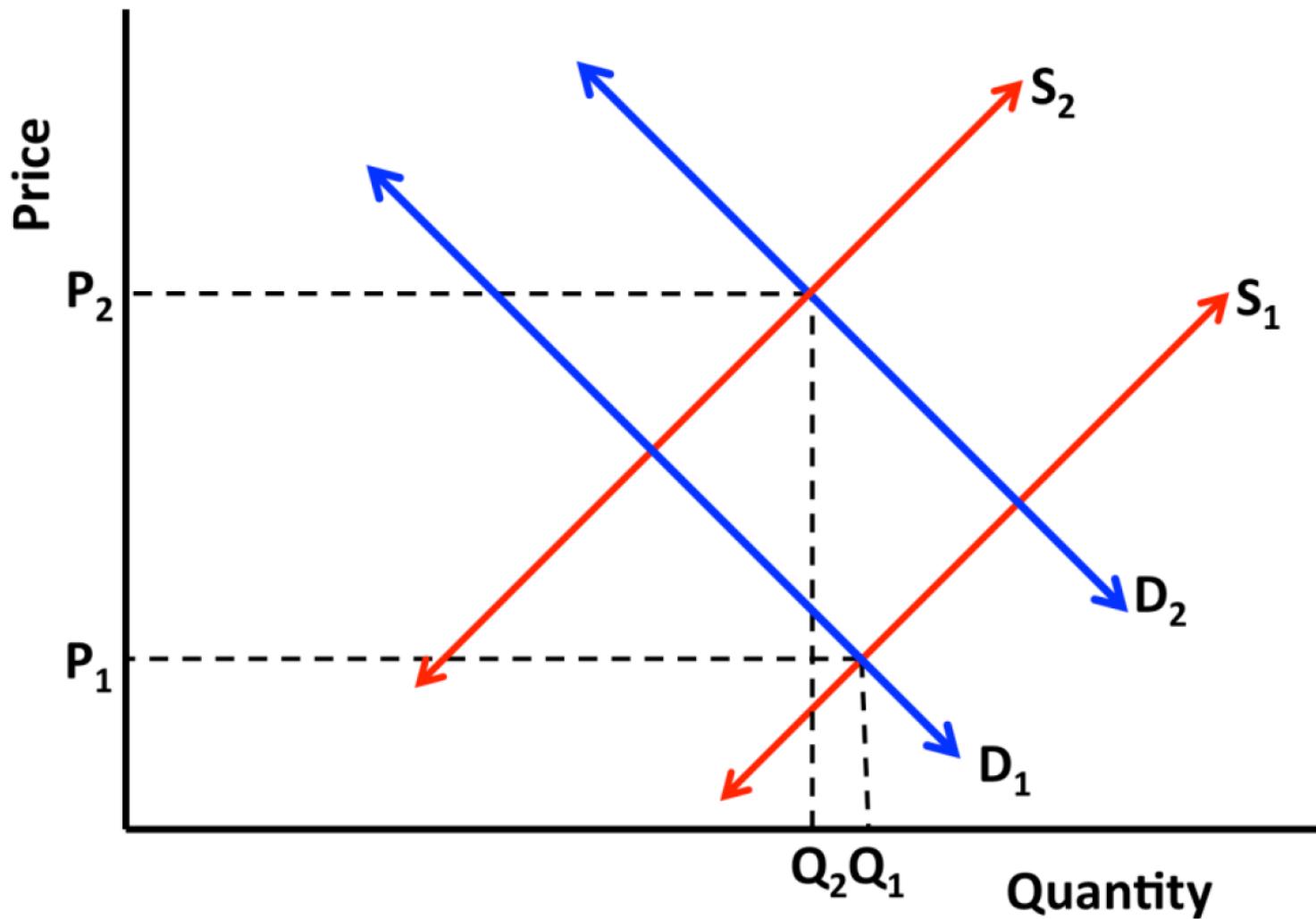


Source: <http://www.tnp.sg/news/singapore-news/she-pays-169-27-minute-uber-ride-beach-road-ayer-rajah>

Why?

- **Profit Maximization?**
 - Compare to airline industry

ECON 1001



Source: <https://newsroom.uber.com/guest-post-a-deeper-look-at-ubers-dynamic-pricing-model/>

A Model for Supply and Demand

- n locations.
- Demand at location i : $a_i - b_i p_i$
- Supply at location i :

$$c_i + d_i p_i - \sum_{j \neq i} \theta_{ij} p_j$$

Optimization Problem

- Non-profit
 - Linear programming (in fact, linear algebra)
- Profit
 - Nonlinear programming

UberPOOL

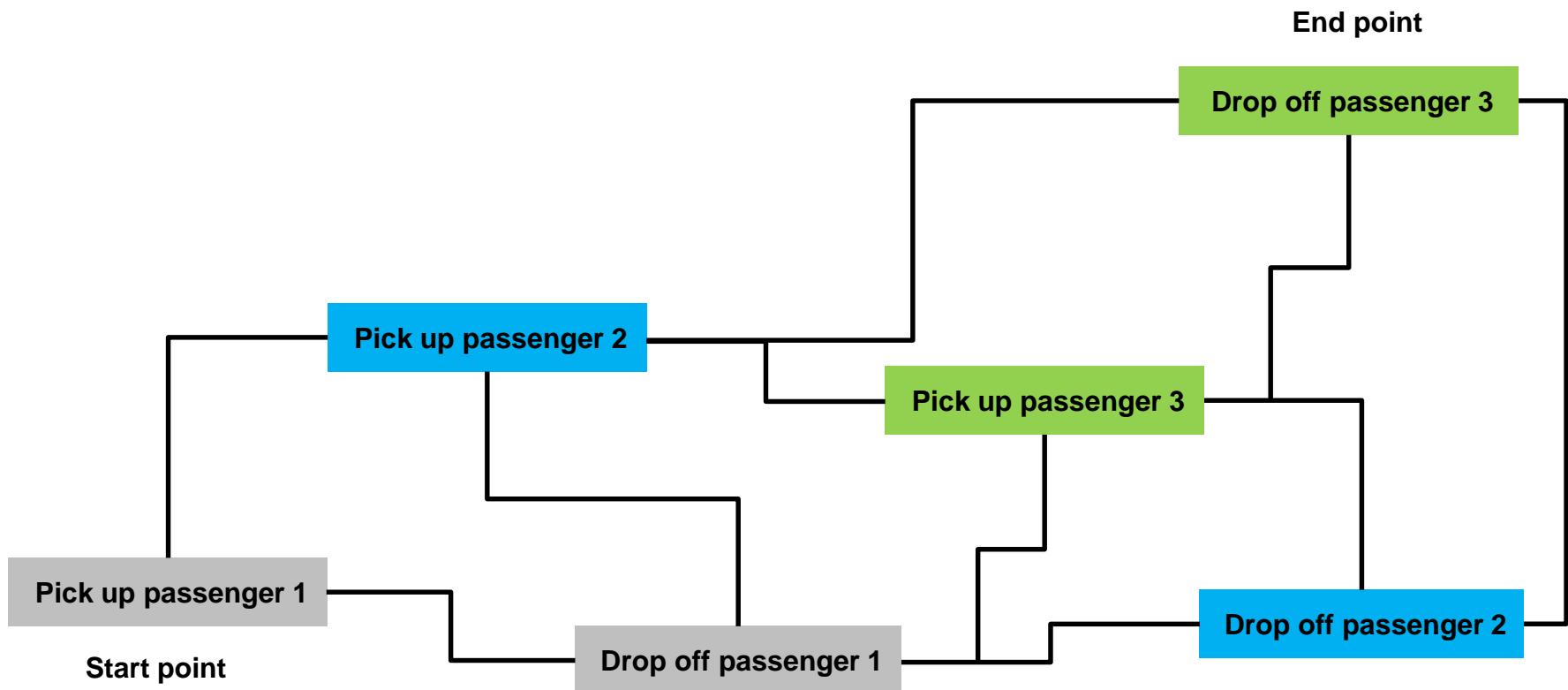
DLD

IMAGINE uberPOOL...



Source: <http://blog.under.com/uberPOOL-2015>

Traveling Salesman Problem



Solving TSP

- Linear programming.
- Integer programming.
- Heuristic design.

Rue La La



LAGOS ▶

Closing in 1 day, 07:01:02



First Look: Cool-Weather Style for Men ▶

Closing in 3 days, 07:01:02



Feel Brand New: Crisp Looks for Work ▶

Closing in 1 day, 07:01:02

Source: <https://www.ruelala.com/boutique/>

Rue La La



John Varvatos Star U.S.A. Linen Moto
Jacket

\$169.99 \$498.00

2 LEFT



Feldton Japanese Selvedge Jacket

\$199.99 \$398.00



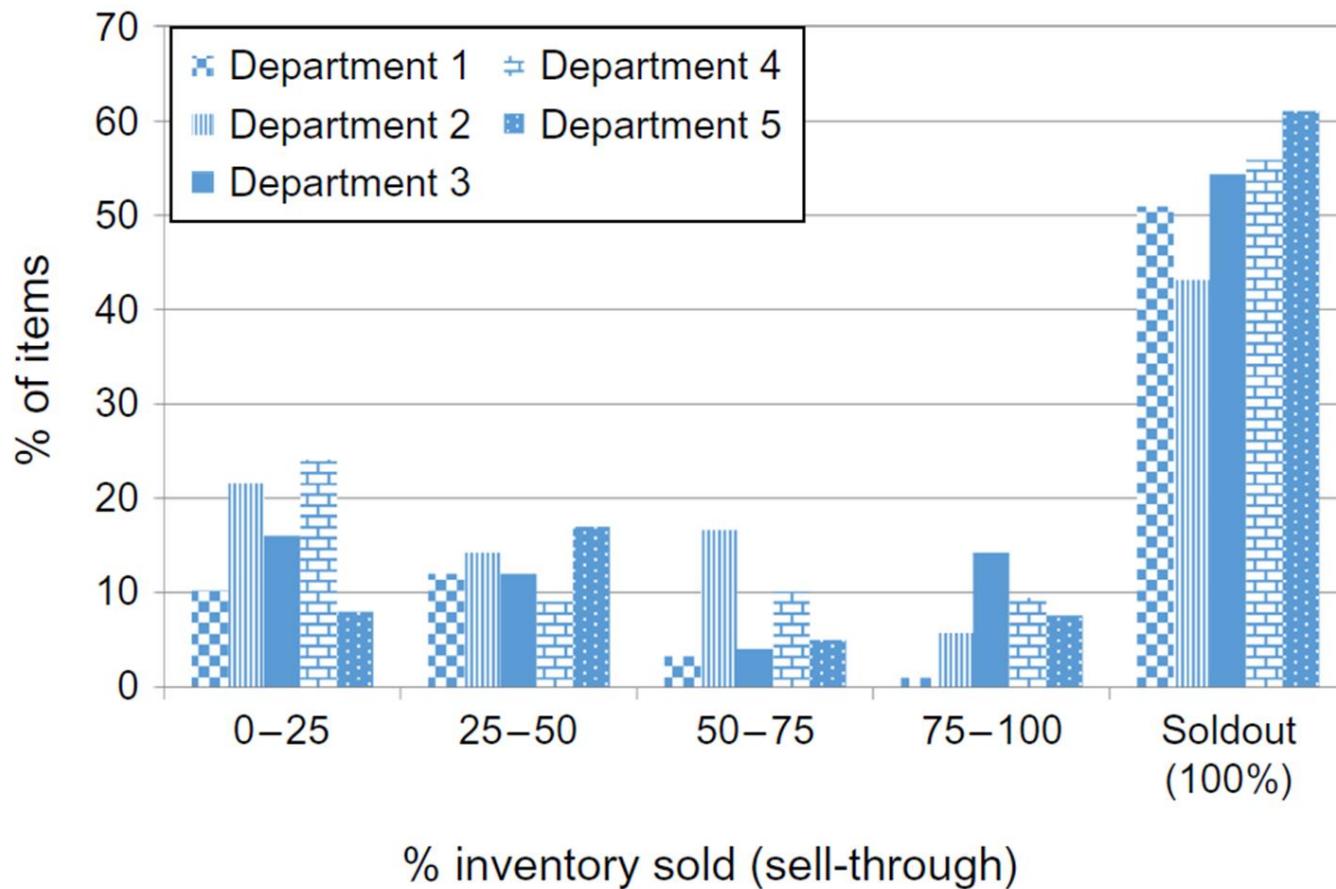
John Varvatos Star U.S.A. Linen-Blend
Hooded Pullover

\$84.99 \$248.00

Source: <https://www.ruelala.com/boutique/>

- Legacy pricing process
 - Percentage markup on cost
 - Competitor's price
 - Subjective judgement

Rue La La



Source: Ferreria, Lee, Simchi-Levi (2016), “Analytics for an Online Retailer: Demand Forecasting and Price Optimization”, 2016, *MSOM*, Vol. 18, No.1

Price Optimization

- **Methodology**
 - Integer programming/ linear programming
- **Experiment**

Category	Estimate of percent increase in revenue (%)	Estimate of 90% confidence interval (%)	Estimate of 95% confidence interval (%)
A	−3.4	[−11.5, 7.7]	[−13.5, 10.1]
B	11.4	[3.9, 19.2]	[1.1, 21.0]
C	12.5	[1.1, 23.4]	[−2.0, 26.6]
D	13.7	[3.4, 22.8]	[0.0, 25.2]
E	23.8	[5.4, 47.6]	[0.0, 56.7]
Overall	9.7	[2.3, 17.8]	[0.0, 20.2]

Source: Ferreria, Lee, Simchi-Levi (2016), “Analytics for an Online Retailer: Demand Forecasting and Price Optimization”, 2016, *MSOM*, Vol. 18, No.1

Other Ways of Improving Profit?

- **Markdown Management/Dynamic Pricing**
 - Inventory is determined before the selling season begins
 - Dynamically reduce price over the selling season to boost demand and increase revenue
- **When to decrease and by how much? Tradeoff?**

<http://retailer2.net/>

Dynamic Pricing

- **Linear programming.**
- **Dynamic programming.**