ORIE 4154 - Pricing and Market Design

Module 2: Network RM and Approximate DP
(Intro to Network RM and Approximate DP)

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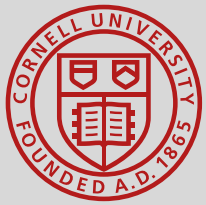


Cornell University

From single-resource to network RM

The models we studied till now were for allocating a single resource

- Eg Seats on a single flight, tickets for single event, rental cars

Network RM: Managing capacity of multiple interlinked resources.

- Seats on multiple connecting flights
- Hotel rooms for multi-day bookings
- Project requiring collection of experts (construction contractor, consulting teams, etc.)

Externality: cost or benefit from a sale to someone who is not part of that sale (i.e., not the buyer or seller)

- Positive: Subscribing to a newspaper, joining a social network
- Negative: Causing pollution, occupying resources

Good pricing should internalize externalities.

- Discount if positive externality, markup if negative externality

Some terminology

Resources

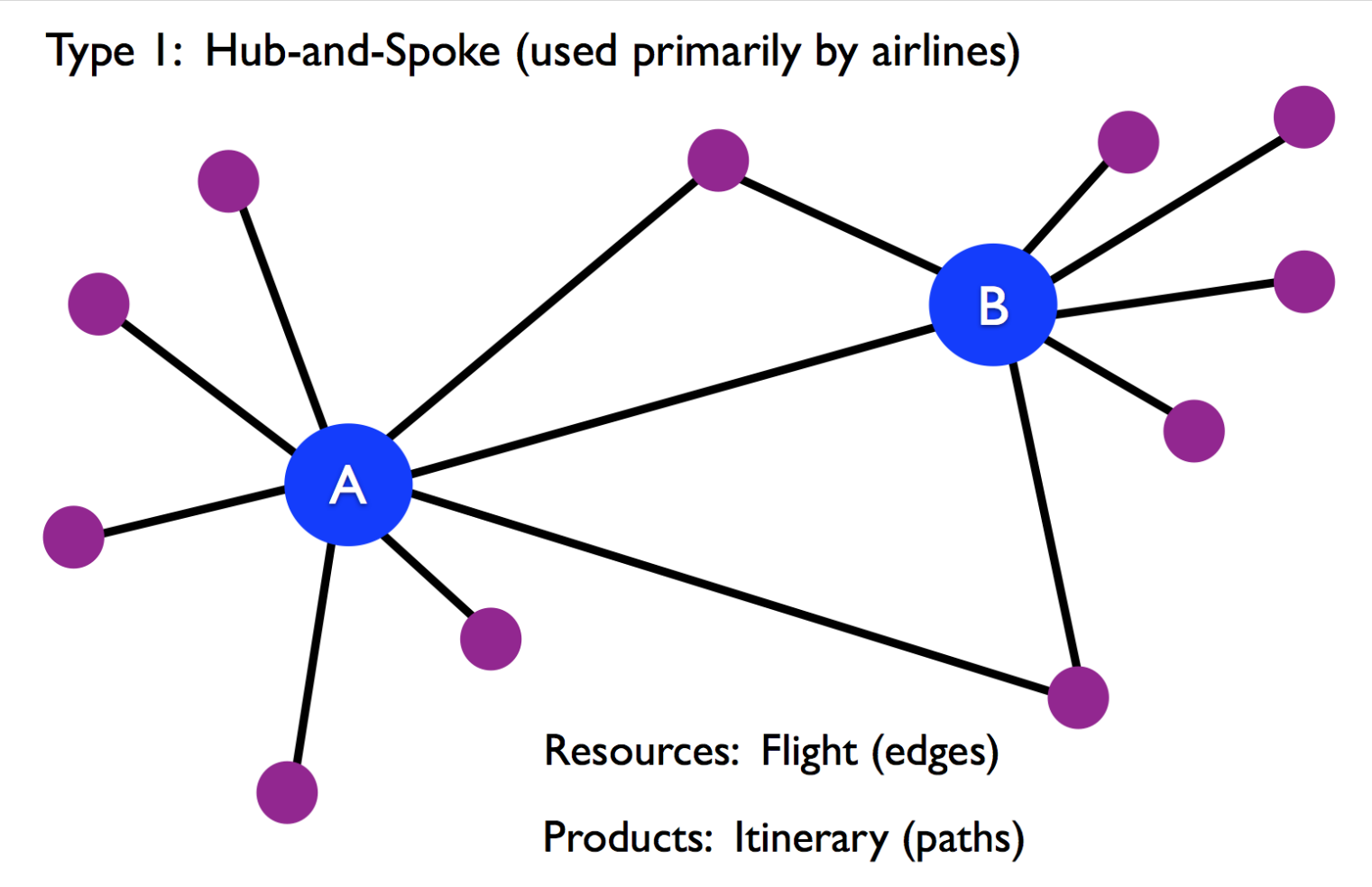
- Units of capacity managed by firm
  E.g. Seats on a flight, hotel room nights, employee hours
- Constrained (C_i units of resource i)
- Perishable (each resource expires at a certain time)

Product

- Set of resources a customer wants
  E.g. multi-leg flight, multiple days stay at hotel
- Each product needs a specified set of resources
- Each product has a different fare

Interactions between resources/products represented by constraint network

Types of constraint networks



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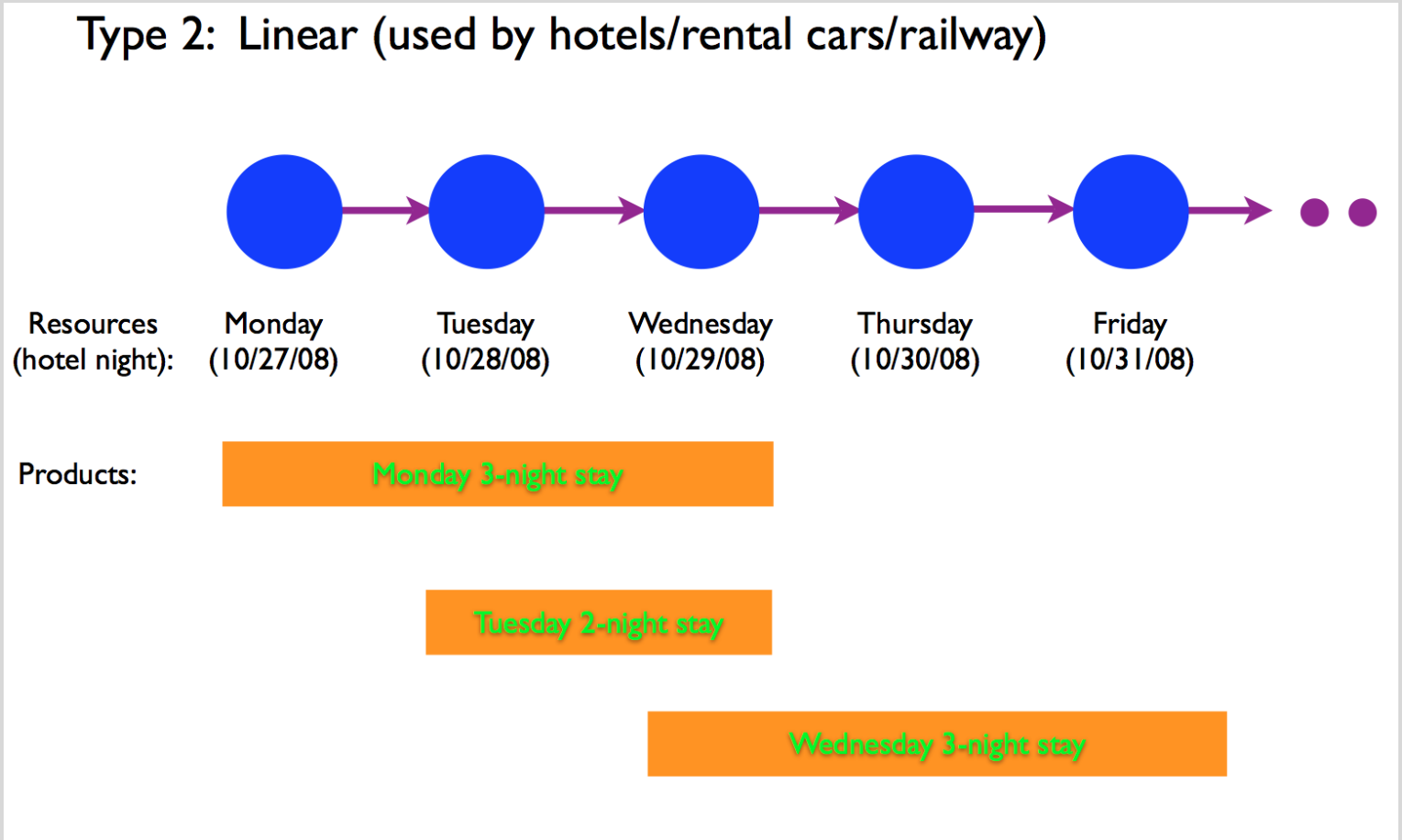
Types of constraint networks



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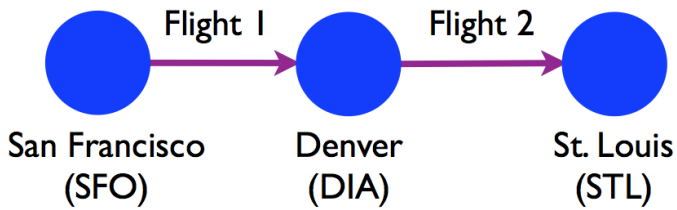
Why is network RM more difficult?



Fares		
SFO-DIA	DIA-STL	SFO-STL
$200	$160	$300

Scenario: Have only one seat left on each of the two flights. We have a customer who wants to fly from SFO to STL. What should we do? Tradeoffs?

Courtesy: Huseyin Topaloglu

Example 1: Selling flight seats

- Do we prefer connecting traffic or single-leg traffic for each leg?
- Idea: Let q_1 and q_2 denote probability of at least one future booking for flight 1 and 2
  - Accept booking iff $200q_1 + 160q_2 < 300$
- Problem: Answer depends on both forecasts q_1 and q_2
  - When lots of resources are constrained, need to optimize over the entire network; no clear ordering $\Rightarrow$ complicated

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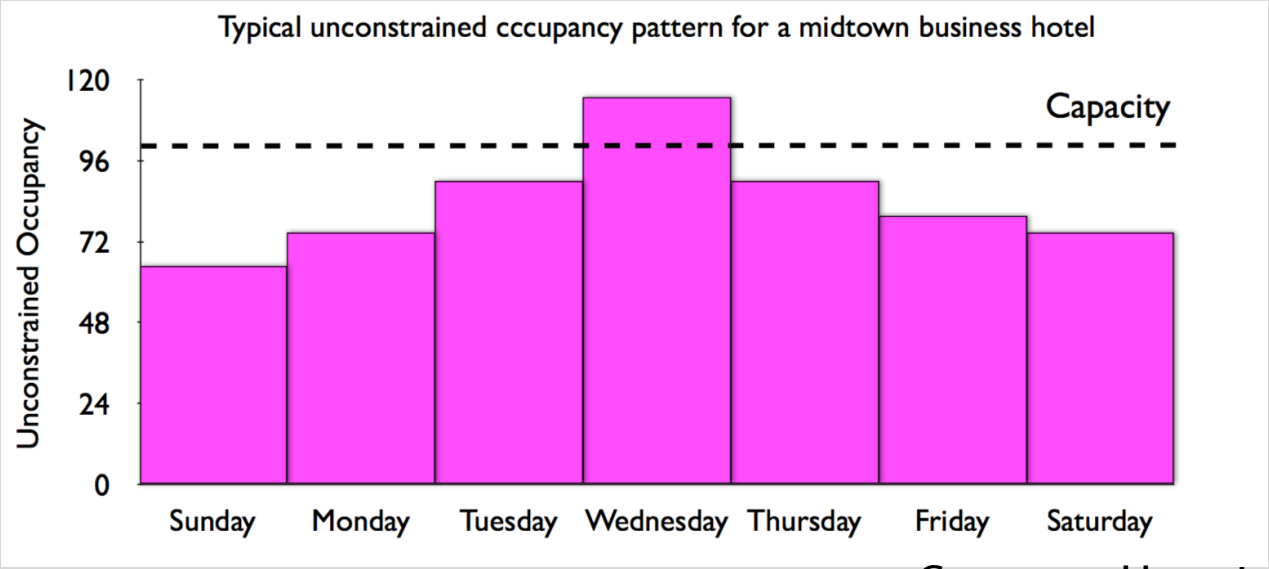

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Example 2: Selling hotel rooms

- Full fare and disconut fare per night room rate
- Each customer wants room for some # of nights
- Unconstrained demand: total # of room-nights that the hotel can sell if it accepts every booking request
- Needs to reject some bookings to avoid being oversold
  - Decision criteria: room rate and length of stay

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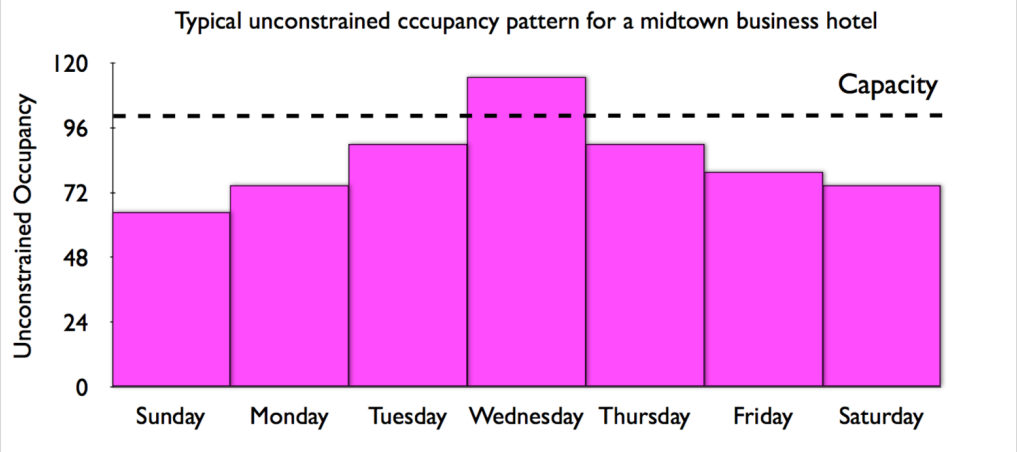

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- Full rate: \$200 per night; discount rate \$150 per night
- Idea 1 (Decoupling): Solve separate single-resource problem for the constrained resource (bottleneck).
  - In this example, we group together all discount rate and full rate customers who want to stay on Wednesday
  - Suboptimal: For example, if full rate customers all arrive on Wednesday for a 1-night stay, and discount-rate customers all arrive on Tuesday for a 3-night stay

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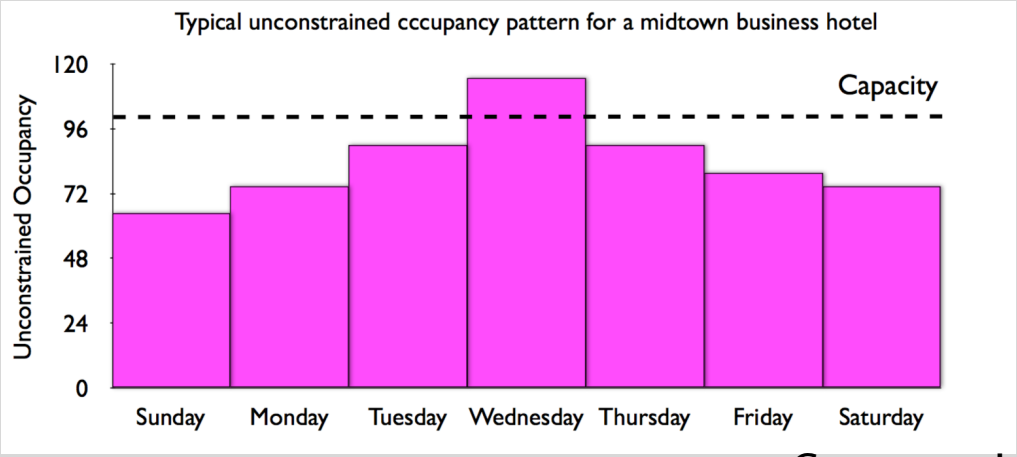

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- Full rate: $\$200$ per night; discount rate $\$150$ per night
- Idea 2 (Greedy): Sort all products that use constrained resource (bottleneck) by total rate
  - Sorting Wednesday stays in ascending order
    - (W) at discount rate $(\$150)$
    - (W) at full rate $(\$200)$
    - (W, Th) or (T, W) at discount rate $(\$300)$
    - (W, Th) or (T, W) at full rate $(\$400)$
    - ...

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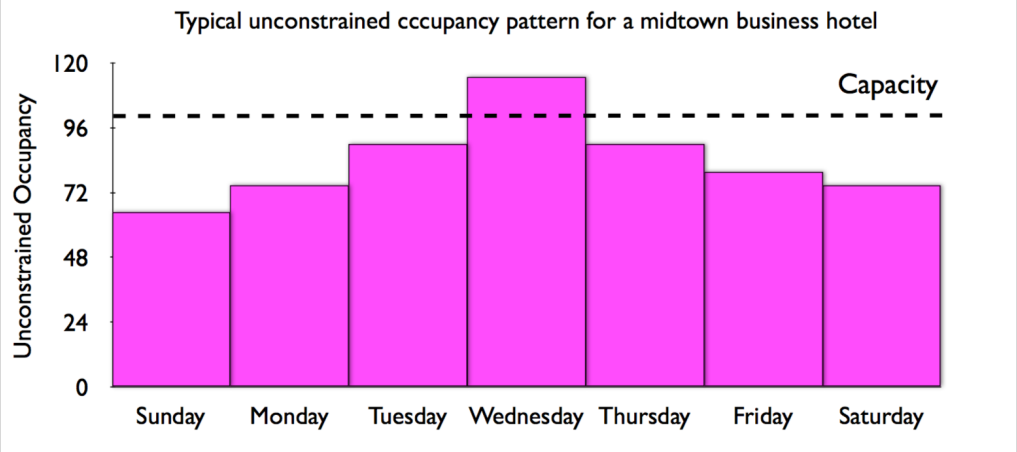

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- Idea 2 (Greedy): Sort all products that use constrained resource (bottleneck) by total rate
  - Optimal for single bottleneck
  - Suboptimal for multiple bottleneck: Suppose both W and Th were bottlenecks. Consider a (W, Th) discount-rate booking vs. two (W) plus two (Th) full-rate bookings
- Capturing all constraints $\Rightarrow$ very large set of states

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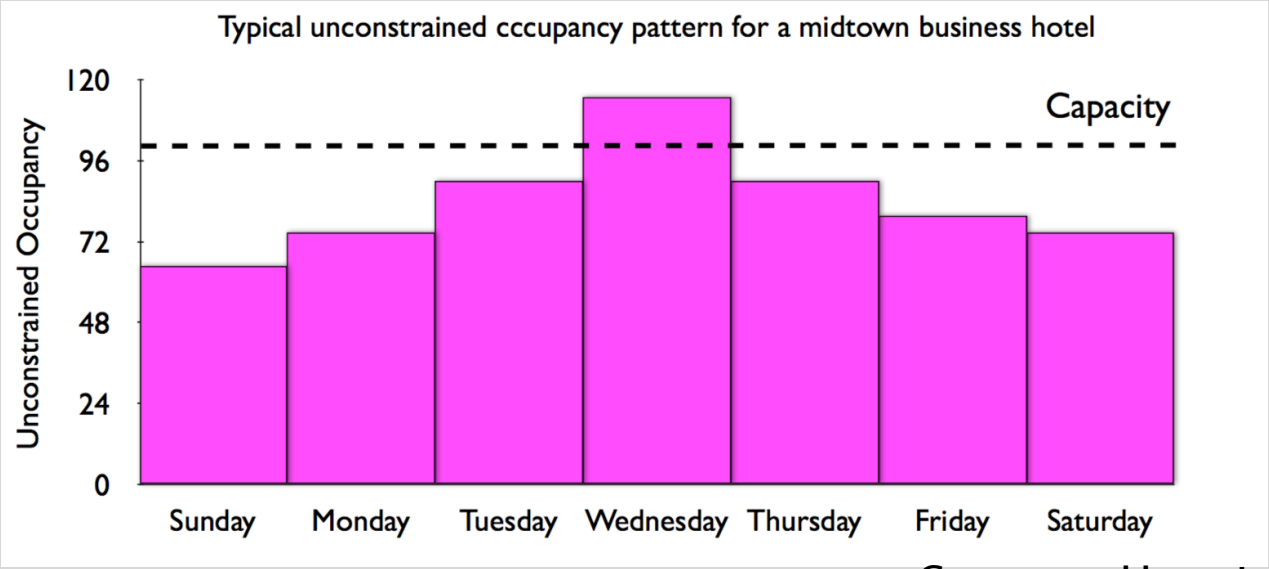

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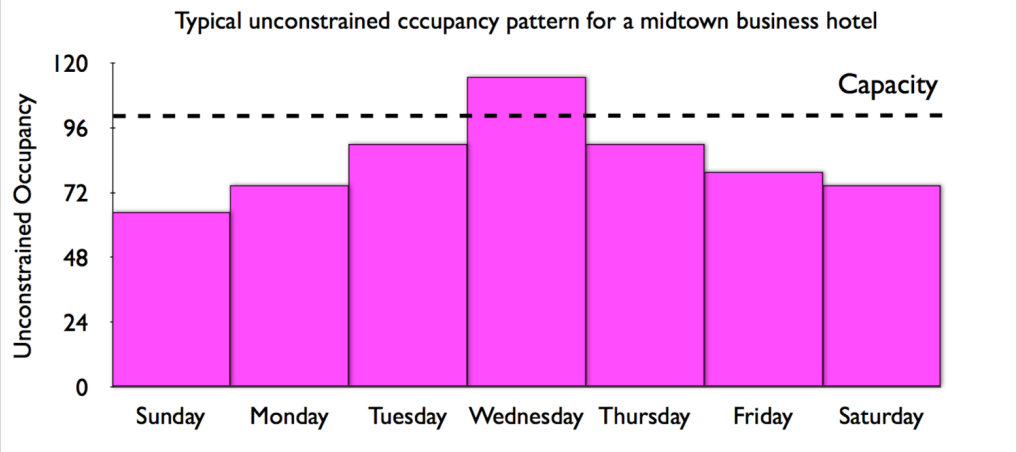

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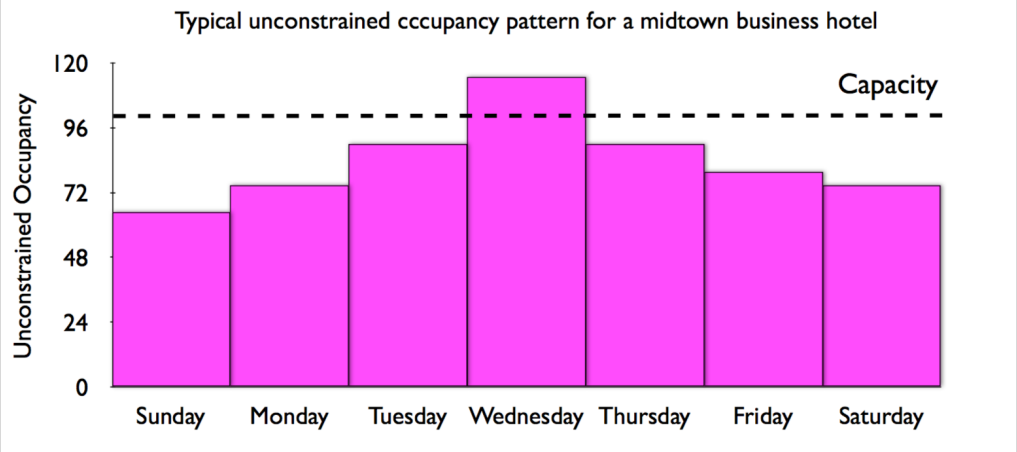

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Solving Network RM Problems

What we need

- Compact representation for resources/products/constraints (incidence matrix representation)
- Good approximations for solving the DP (bid-price heuristic (LP-based approximations))