

# Revenue Management under Reviews and Online Ratings<sup>1</sup>

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<sup>1</sup>This work is in collaboration with dr. D.M. Roijers

Home → [USA](#) → [New York State](#) → [New York City](#) → Search results  
 67,822 properties 2,416 properties 787 properties New York City, 1 adult, 2 nights (Jun 15 - Jun 17)

## Search

Destination/Hotel Name:

New York City, New York State, U...

☐ Work ☐ Leisure ?

Check-in

 June 15, 2016

Check-out

 June 17, 2016

2-night stay

Rooms

1

Adults

1

Children

0

Search

Filter by:

### Set Your Budget Per Night

☐ € 200 + 15

### Star Rating

☐ 2 stars 11

☐ 3 stars 9

☒ 4 stars

☐ 5 stars 4

### Front Desk

☐ Front desk open 24/7 16

☐ Check-in Until Midnight 1

### Reservation Policy

☐ Free cancellation 15



New York City is a top choice on our site with travelers for your selected dates (58% reserved).  
 Tip: Prices might be higher than usual for the dates you've selected. Why not try again with these alternatives?

Jun 14 — Jun 16

Jun 16 — Jun 18

Jun 13 — Jun 15

## New York City: 19 properties found

3 Reasons to Visit: Central Park, Times Square & The Statue of Liberty

Order by:

Our Top Picks First

Lowest Price First

Stars

More

Tip: [Open the map](#) to find your perfect place to stay!



TODAY  
22%  
OFF

### Residence Inn by Marriott New York Downtown Manhattan/World Trade Center Area ★★★★★

Neighborhood: [Wall Street - Financial District, New York City](#) – Subway Access

14 people are looking right now

Booked 12 times today

👤 Studio – In high demand – only 5 rooms left on our site!

Wonderful 9.0

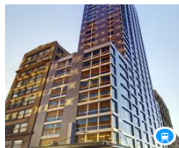
1,123 reviews

Price for 2 nights

-22% € 954 € 742

Breakfast Included

Select your room >



### Fairfield Inn by Marriott New York Manhattan/Financial District ★★★★★

Neighborhood: [Wall Street - Financial District, New York City](#) – Subway Access

10 people are looking right now

Booked 15 times today

👤 Double Room – In high demand – only 5 rooms left on our site!

Very good 8.5

932 reviews

Price for 2 nights

€ 591

Breakfast Included

Select your room >

M

Mark

United Kingdom

1 property review

10

## “Excellent value for money in a great location”

Leisure trip

Couple

King Studio

Stayed 3 nights

– Lifts a little slow at times.

+ Great location, right next to subway and downtown sights. Staff helpful and friendly. Room the usual small NY standard, but well appointed and laid out. Felt modern and clean. Bed very comfortable. Breakfast was as expected and always well stocked. Gym was small and more for running / cross training etc (a few dumbbells) but perfectly adequate.

Helpful

C

Chris

United Kingdom

20 property reviews

2 destination reviews

1 helpful vote

9.2

## “Very clean and modern hotel. Friendly. Near WTC”

Leisure trip

Solo traveler

King Studio

Stayed 2 nights

– Nothing really. Financial district not really where I want to stay but very near subway. I stayed during memorial weekend and was woken by noise in the corridor (just a group getting back) at 5am. Once they were in their rooms (I think they had two rooms next to each other), I couldn't hear a thing but it all woke me with a start. When there is room (and the rooms here nice and large), I don't know why designers don't put in an internal hall, creating an inner hallway. Hotels that do this are great and it blocks off all the noise from the hallway, people coming in/out, discussing what time for breakfast, knocking on friends doors etc. Anyway not the hotel's fault I stayed during memorial w/e or that I happened to stay next to two rooms who went out partying :-)

# Trade-off: Revenue vs Rating

- Customers are highly influenced by (negative) information
- (Negative) reviews influence customers purchasing products
- (Negative) price/quality perception influences customers writing reviews

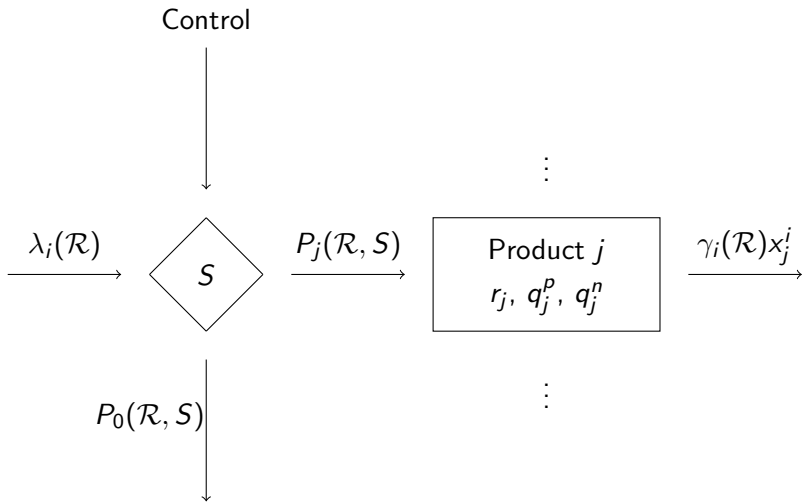
# Trade-off: Revenue vs Rating



Goal: Maximize long-term revenue

- Optimizing revenue might lead to worse ratings and suboptimal revenue

- Clients consider the hotel, depending on the reviews  $\mathcal{R}$  ( $\lambda_i(\mathcal{R})$ )
- Depending on the products  $S$  that are offered, clients make a purchase ( $P_j(\mathcal{R}, S)$ )
- A purchase leads to:
  - revenue  $r_j$
  - positive review probability  $q_j^p$
  - negative review probability  $q_j^n$
- purchased products can be cancelled





# Modelling demand and cancellations as a function of reviews

- $Q_i^p = \#$  positive reviews from day  $i$
- $Q_i^n = \#$  negative reviews from day  $i$
- $\alpha \in (0, 1)$  discounting parameters
- $M = \#$  past arrival days
- Adjusted reviews:

$$\tilde{Q}_k^p := \sum_{i=k-M}^{k-1} \alpha^{k-i-1} Q_i^p, \quad \tilde{Q}_k^n := \sum_{i=k-M}^{k-1} \alpha^{k-i-1} Q_i^n.$$

- Rating:

$$\rho := \frac{\tilde{Q}_k^p}{\tilde{Q}_k^p + \tilde{Q}_k^n}.$$

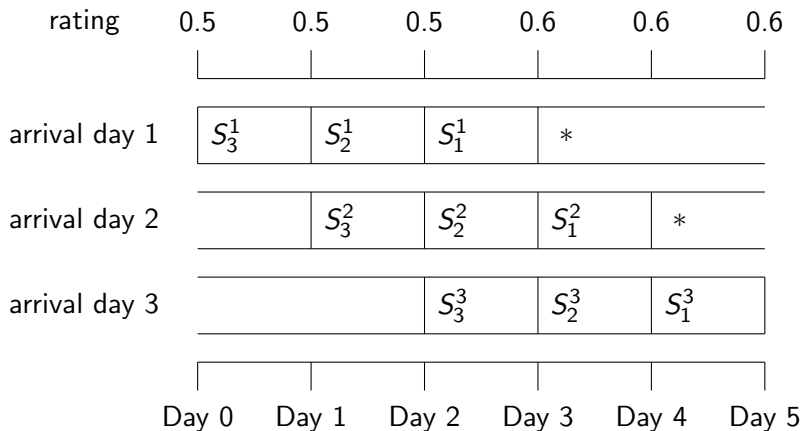
# Modelling demand and cancellations as a function of reviews

- Demand and cancellation parameters:

$$\lambda_i(\mathcal{R}) := \bar{\lambda}_i \exp(\beta_p^\lambda \rho + \beta_n^\lambda (1 - \rho)),$$

$$\gamma_i(\mathcal{R}) := \bar{\gamma}_i \exp(\beta_p^\gamma \rho + \beta_n^\gamma (1 - \rho)).$$

# Multiple arrival day example



# Multiple arrival day dynamics

- $R^i(S^1, \dots, S^i)$  revenue from arrival day  $i$
- $S^i = \{S_T, \dots, S_1\}$  strategy for arrival day  $i$
- Objectives:

$$\phi^I(S) = \sum_{i=1}^I R^i(S^1, \dots, S^i),$$

$$\phi^\infty(S) = \sum_{i=1}^{\infty} a^{i-1} R^i(S^1, \dots, S^i).$$

## Problem

- State space size:  $N^I$
- Action space size:  $N^T$
- Intractable due to curse of dimensionality

## Solution: Equilibrium Solutions

- Keep expected rating constant, equal to a **target rating**  $\rho^*$
- Now  $R^i$  depends solely on  $S^i$
- Each arrival day can be solved separately

# One arrival day Bellman equation

$$V_{i,t}^{\pi}(x) = \sum_{S \subseteq N} \pi(x, t, S) \left\{ \lambda \sum_{j \in S} P_j(S) [r_j^i - \Delta H_j^i(t) + V_{i,t-1}^{\pi}(x+1)] \right. \\ \left. + \gamma x V_{i,t-1}^{\pi}(x-1) \right. \\ \left. + \left( 1 - \lambda \sum_{j \in S} P_j(S) - \gamma x \right) V_{i,t-1}^{\pi}(x) \right\}.$$

Three objectives:

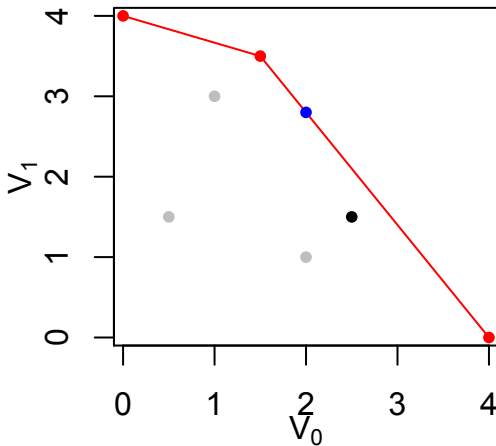
$$\mathbf{V}^{\pi} = (V_1^{\pi}, V_2^{\pi}, V_3^{\pi})$$

Scalarization:

$$V_{\mathbf{w}}^{\pi} = f(\mathbf{V}^{\pi}, \mathbf{w}) = w_1 V_1^{\pi} + w_2 V_2^{\pi} + w_3 V_3^{\pi}$$

# Convex Coverage Set (CCS)

Every weight  $w$  has a corresponding optimal policy  $\pi$  and value function  $V^\pi$



# Finding equilibrium solution

- Policy  $\pi \in \text{CCS}$  corresponds to value vector  $V^\pi$
- Hyperplane where rating =  $\rho$ :

$$\mathcal{H} = \left\{ x \in \mathbb{R}^3 \mid \frac{x_2}{x_2 - x_3} = \rho \right\} = \{ x \in \mathbb{R}^3 \mid x_2(\rho - 1) - \rho x_3 = 0 \}.$$

- Target-rating policy:

$$\pi(\rho) = \arg \max_{\pi \in \text{CCS}} \{ V_1^\pi \mid \mathbf{V}^\pi \in \text{CCS}' \cap \mathcal{H} \}$$

- Optimal target-rating and corresponding policy:

$$\pi(\rho^*) = \arg \max_{\pi(\rho)} V_1^{\pi(\rho)}$$



# One instance: policy analysis

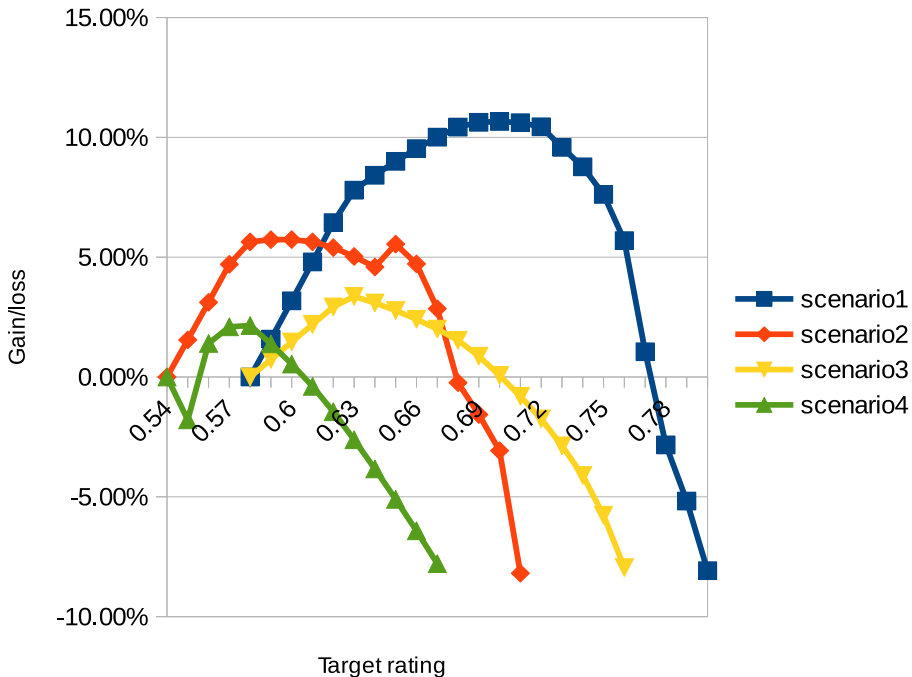
Revenue	Positive reviews	Negative reviews	Rating $\rho$
0	0	0	-
7493.76	33.01	3.75	0.90
12513.99	42.88	9.28	0.82
12595.63	41.42	6.30	0.87
14252.80	42.48	9.77	0.81
15137.33	41.09	7.57	0.84
16021.48	41.67	10.38	0.80
17983.01	40.40	11.16	0.78
18693.24	39.78	10.61	0.79
19985.47	38.61	9.99	0.79
21719.66	36.79	11.74	0.76
23528.79	33.55	12.81	0.72
24686.86	26.26	12.34	0.68
25194.50	29.93	13.87	0.68
26943.83	25.33	15.07	0.63
27098.09	21.11	15.62	0.57

## Observations

- ➊ By sacrificing revenue the rating can be increased
- ➋ Sacrificing revenue not always increases rating
- ➌ When revenue increases, positive reviews increase and negative reviews decrease
- ➍ However, increases are not strict due to the trade-off

## Scenarios

- ① Large effects of demand and review probabilities
- ② Large effect of demand, small effect of review probabilities
- ③ Small effect of demand, large effect of review probabilities
- ④ small effects of demand and review probabilities



## Observations

- ① All scenarios show structural increase in revenue, of up to 11%
- ② 11.1% increase in rating leads to 5.7% increase in revenue (similar to Ye et alii (2011))

## Implications

- Tractable solution methods
- Improving hotel facilities
- Multiple night stay