Dynamic Pricing and Revenue Management

IEOR 4601 Spring 2013

Professor Guillermo Gallego
Class: Monday and Wednesday 11:40-12:55pm
Office Hours: Wednesdays 3:30-4:30pm
Office Location: 820 CEPSR
E-mail: gmg2@columbia.edu
Why Study Dynamic Pricing and Revenue Management?

- Revenue Management had its origins in the airline industry and is one of the most successful applications of Operations Research to decision making.
- Pricing and capacity allocation decisions directly impact the bottom line.
- Pricing transparency and competition make pricing and capacity allocation decisions more difficult and more important.
Applications of Dynamic Pricing and Revenue Management

- Capacity allocation of limited, perishable, resources to different fare classes
  - Airlines, hotels, car rentals, cruises, travel packages, tickets for events
- Design and pricing of products
  - Fare restrictions and pricing
  - Consumption and fulfillment options
  - Upgrades, downgrades and upsells
- Pricing under competition
  - Electronic-commerce
Objectives of this course

- Understand the critical tradeoffs and decisions in Revenue Management

- Learn how to
  - Monitor and control product availability for single and multiple resources
  - Overbook limited resources when customers shows are random
  - Use upgrades, upsells and real options to improve revenues
  - Price under competition
  - Improve on the current practice of Revenue Management

“Physics should be explained as simply as possible, but no simpler.”
Albert Einstein
Professor Gallego’s experience and background on subject

- Author of seminal papers on dynamic pricing and revenue management
- Winner of several prizes from academia and industry related to work on Revenue Management
- Consultant for airlines and RM solution providers
- Consultant for other users of Revenue Management
Readings

- **Class Notes**
  - *I will provide with notes of the different topic we cover in class*

- **Textbook**

- **References**
  - Assigned papers
Prerequisites and Grading

- **Prerequisites**
  - Probability and Statistics at the level of IEOR 4150
  - Deterministic Models at the level of IEOR 4003

- **Corequisites**: Stochastic Models IEOR 4106

- **Grading**
  - Assignments 20%
  - Midterm 35%
  - Final 45%
Introduction to Revenue Management

- Revenue Management refers to the strategy and tactics used by perishable capacity providers to allocate capacity to different fare classes or market segments to maximize expected revenues. (See Chapter 6 in Phillips.)

- RM is often practice when
  - Sellers have fixed stock of perishable capacity
  - Customers book capacity prior to usage
  - Seller offers a sets of fare classes
  - Seller can change the availability of fare classes
History of Revenue Management

- Prior to 1978 the Airline Industry was heavily regulated
- In the early 80’s the industry was deregulated to encourage new entrants
- Low-cost carriers such as People Express started encroaching into key markets of large carriers
- American Airline dilemma:
  - Match fares and lose money
  - Keep fares and lose customers
AA’s Response to People Express

- Ultimate Super Saver Discount Fare
  - Same fare as People Express
  - Passenger must buy at least two weeks prior to departure
  - Stay at his destination over a Saturday night

- AA restricted the number of discount seats sold on each flight to save seats for full-fare passengers
Rational and Impact of Strategy

○ Product Design
  ● Imposing restrictions that appealed to the leisure segment without cannibalizing the business segment

○ Capacity Allocation
  ● Carefully control capacity to maximize revenues

○ Strategy started in January 85
  ● PE was struggling by March
  ● PE was at the verge of bankruptcy by August
Post-mortem

- People Express was bought by Texas Air for 10% of the market value it had enjoyed a year before.
- “We had great people, tremendous value, terrific growth. We did a lot of things right. But we didn’t get our hands around the yield management and automation issues.” Donald Burr CEO of PE
RM: The System Context

- AA was based on a computerized reservation system (CRS) called Sabre developed in 1963. This system:
  - Replaced index cards to manage reservations
  - Sabre is also a GDS (global distribution system) that allowed AA to distribute its products and fares globally

- Other GDSs: Amadeus, Galileo, Worldspan.
RM Constraints Imposed by Systems

- AA’s used Sabre’s Computerized Reservation System as the backbone to Revenue Management
  - The reservation system served as a repository of all the bookings that have been accepted for future flights
  - The CRS also contains the controls that specify how many bookings from different fare classes the airline will accept on future flights
- Remember: RM systems were developed in the context of existing CRSs.
Levels of Revenue Management

- **Strategic:**
  - Market segmentation (leisure vs business)
  - Product design (restrictions, fares, options)
  - Pricing (Static vs. Dynamic)

- **Tactical:**
  - Calculate and updated booking limits

- **Booking Control:**
  - Determine which booking to accept and which to reject based on booking limits
Strategic Revenue Management

- Design low fares to increase sales without cannibalizing full fare demand
  - Time of Purchase Restrictions
    - Advance purchase requirements
  - Traveling Restrictions
    - Saturday night stays
  - High cancellation and change penalties

- Other opportunities
  - Contingent options on capacity
  - Flexible and callable products
Tactical Revenue Management

- **Resources**
  - Units of capacity
    - Seats on a flight
    - Hotel capacity for a specific night

- **Products**
  - What consumers seek to purchase
    - May involve one or more resources

- **Fares**
  - A combination of a price and a set of restrictions
Tactical Definition of RM

- A supplier controls a set of resources with fixed and perishable capacity, a portfolio of products consisting of combinations of one or more of the resources, and a set of fare classes associated with each of the products. The tactical revenue management problem is to choose which fare classes should be open and which closed for sale at each moment to maximize total revenue.
Components of Tactical RM

- **Capacity Allocation**
  - How many customers from different fare classes should be allowed to book?

- **Network Management**
  - How should bookings be managed across a network of resources?

- **Overbooking**
  - How many total bookings should be accepted for a product when there are cancellations and show uncertainty?
Booking Controls

- Limits on bookings for different fare classes:
  - Example: An airline receives a B-class request for 3 seats departing in two weeks. The current B-class booking limit is two seats. As a result, the request is rejected.
Booking Limits

- Nesting Controls:
  - Label the fare classes so that 1 is the highest fare class and n is the lowest fare class. For any i let $b_i$ denote the nested booking limit for class i.
  
  $b_1 \geq b_2 \geq \cdots \geq b_n$

- Protection Levels:
  
  $y_i = b_1 - b_{i+1}, \quad i = 1, 2, \cdots n - 1$

- Updates: If x units are sold in a transaction
  
  $b_i \leftarrow \max(b_i - x, 0), \quad i = 1, 2, \cdots n - 1$
# Nested Booking Limits (Example)

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Is RM successful?

- By most measures (revenues relative to resources) it has been a success at most major airline, hotel, rental car companies.
  - Why have major airlines have been losing money?
    - Costs are 25-30% higher per mile, so even though larger carriers bring in about 25% more revenue per mile the cost disadvantage is overwhelming
  - What can be done?
    - Cost cuts
    - Improve RM systems
      - Big move from independent to dependent demand models
Price discrimination exists when sales of *identical* goods or services are transacted at different prices from the same provider.

- A feature of monopolistic or oligopolistic markets where market power can be exercised.
- Requires market segmentation and means to discourage discount customers becoming resellers.
  - This is achieved by fences to keep segments separate.
- Price discrimination is more common in services where resale is not possible.
- Price discrimination can also be seen when the requirement of *identical* goods is relaxed.
  - Premium products have price differential not explained by production costs.
Taxonomies of Price Discrimination

- First degree: requires selling at maximum willingness to pay
- Second degree: quantity discounts (sellers not able to differentiate consumer types)
- Third degree: Prices vary by attributes (e.g., senior discounts)
- Fourth degree: Prices are the same but costs are different (reverse discrimination)

Alternative taxonomy:
- Complete discrimination (like first degree)
- Direct discrimination: seller conditions price on some attribute (like third degree)
- Indirect discrimination: the seller relies on some proxy such as quantity discounts (like second degree)
RM and Price Discrimination

- Differentiating by time-of-purchase and imposing traveling restrictions like Saturday night stays is a form of second degree or indirect discrimination.

- Selling premium seats is another form of second degree or indirect discrimination.
  - Eg., uncomfortable second class seats on trains to entice wealthier people to purchase first class seats.
  - Advance seat selection, mileage accrual, use of lounge, and priority boarding may be forms of second and/or fourth degree discrimination.
Other Examples of Price Discrimination

- Retail price discrimination is in violation of the Robinson-Patman Act (1936)
- Coupons
- Segmentation by age group and student status
- Discounts for members of certain occupations
- Employee discounts
- Retail incentives (rebates, seasonal discounts, quantity discounts)
- Gender based examples
- College financial aid
- User-controlled price discrimination
- See http://en.wikipedia.org/wiki/Price_discrimination
Static and Dynamic Pricing

- Pricing is studied by people in Economics and Marketing.
- Economist look at equilibrium prices.
- Marketing focuses on demand estimation.
- We focus on more tactical aspects of pricing:
  - Customer arrival rates.
  - Capacity constraints.
  - And increasingly on choice models and competition.
Static Pricing

- $d(p)$ demand at $p$
- $z$ unit cost or dual of capacity constraint
- $r(p,z) = (p-z)d(p)$ profit function
- Find $p$ to maximize $r(p,z)$
- Is there a finite maximizer $p(z)$?
- Is $p(z)$ monotone?
- Is $r(z) = r(p(z),z)$ monotone? Convex?
- Multiple market segments with limited price menus
Dynamic Pricing

- Finite sales horizon
- Customers arrive stochastically over time
- State \((t,x)\)
  - \(t\) time-to-go
  - \(x\) remaining inventory
- What price \(p(t,x)\) should be charged at state \((t,x)\)?
- Are there simple and effective pricing heuristics?
- What about strategic customers?
- What about competition?
Topics to be Covered

- Single Resource RM
  - Independent Demands
    - Dynamic Programming, Bounds and Heuristics
  - Dependent Demands based on choice models

- Static and Dynamic Pricing

- Network RM
  - Independent Demands, Choice Models

- Overbooking

- Service Engineering
  - Design and pricing of service features
Useful Techniques you will Learn

- **Dynamic Programming (DP)**
  - Tool for sequential decision making
  - Optimal Control (continuous time DP)
- **Approximate Dynamic Programming**
  - Tool to approximate DPs
- **Bounds and Heuristics Techniques**
- **Choice Modeling**
- **Game Theory**