Things That Go Bump in the Flight

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Introduction

We develop a risk assessment model that allows an airline to specify certain parameters and receive recommendations for compensation policy for bumped passengers and for how much to overbook each flight. The basis is the potential cost of each bumped passenger compared to the potential revenue from booking an extra passenger. Our model allows an airline to compare quickly the likely results of different compensation and overbooking strategies.

To demonstrate how our model works, we apply it to Vanguard Airlines. Publicly available data provide all of the needed parameters for our model. Our software package reaches an overbooking policy by calculating and comparing the expected revenues for all possible situations and compensation policies.

Terms and Definitions

We set out terminology, taking much of it from Delta Airlines [2002].

- *Available seat miles* **(ASM)**: A measure of capacity which is calculated by multiplying the total number of seats available for transporting passengers by the total number of miles flown during a reporting period.
- *Revenue passenger mile* **(RPM)**: One revenue-paying passenger transported one mile. RPM is calculated by multiplying the number of revenue passengers by the number of miles they are flown for the reporting period.
- *Load factor* **(LF)**:A measure of aircraft utilization for a reporting period, calculated by dividing RPM by ASM.

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- *Cost per available seat mile* **(CASM)**: Operating cost per available seat mile during a reporting period; also referred to as *unit cost*.
- *Revenue per available seat mile* **(RASM)**: Total revenue for a reporting period divided by available seat miles; also referred to as *unit revenue*.
- *"No-show"*: A person who purchased a ticket but does not attempt to board the intended flight.
- *Bumping*: The practice of denying boarding to a ticket holder due to lack of sufficient seating on the flight.
- *Voluntary bumping*: When passengers who purchased ticket for a flight give up their seats for some compensation offered by the airline.
- *Involuntary bumping*: When not enough passengers voluntarily give up their seats, the airline chooses whom to bump against their will.
- *Revenue*: Money gained by the airline from a flight minus penalties paid to bumped passengers. **This is *not* the standard definition of revenue** ("inflow of assets as result of sales of goods and/or services" [Porter 2001, 146]). We use this different definition to highlight the effect of bumping practices.)
- *Flight leg*: A direct flight from one airport to another with no stops.

Assumptions

- **Passenger airline traffic is returning to normal, so yearly industry statistics can be used.** Airline traffic trends are returning to the levels before the terrorist attacks on September 11 [Airline Transport Association 2001], so statistics from before that date are still valid.
- **We model U.S. flights only.** International flights have different policies.
- **The "no-show" rate is about 10%.** ["More airline passengers . . . " 1999].
- **Ticket prices may be represented by calculated averages.**
- **The number of passengers on the plane does not affect the cost of the flight to the airline.** The most significant part of the operating costs for a flight are fixed costs that are not be affected by the number of passengers.
- **The flight schedule is static.** The schedule of flights is outside of the scope of our problem statement. Thus, we make recommendations only about the overbooking strategy, not about changes to the schedule.
- **Airlines must follow the DOT "Fly-Rights" regulations.** These regulations outline the minimal compensation required to passengers when bumping occurs [U.S. Department of Transportation 1994].

- **Compounded overbooking takes care of itself (i.e., goes away naturally).** Consistent industry-wide statistics establish a 60% to 80% load factor [Airline Transport Association 2002], resulting in naturally combating the waterfall effect of one overbooked flight causing another to be even more overbooked.
- **There is sufficient demand for at least some flights to warrant overbooking.**
- **No-shows do not generate revenue.** No-shows are given a refund or (if original ticket was nonrefundable) a ticket voucher.
- **Taxes paid by a passenger are nonrefundable.**

Statement of Purpose

- Our first priority is to maximize revenue for the airline.
- Our second priority is to maximize customer service in the form of providing as much compensation to bumped passengers as is financially feasible.

Naive Model

The naive approach is to assume that since not all ticket buyers show up for the flight, we simply overbook the flight so that on average the plane fills to capacity. If on average 90% show up, we book to $100/90$ capacity.

However, the 90% is only an average; for some flights, more than 90% will show up, resulting in bumped passengers and a penalty for the airline paid to bumped passengers. Since the penalty is often more than the potential revenue for one more passenger, the airline could pay more in penalties than the extra revenue received. We need a way to factor the risk of penalties into our model.

Risk Assessment Model

We maximize revenue on each individual flight leg, which we regard as independent of other flight legs. Thus, optimizing the revenue of one flight does not adversely affect potential revenue from other flights.

Since an airline incurs an increased penalty the longer that a bumped passenger is delayed, an airline minimizes the penalty by transporting the passenger to their destination as quickly as possible. Therefore, bumped passengers are usually booked on the next flight or series of flights to their destination.

Expected Revenue of a Flight

Let a flight have capacity of c and we book b passengers. Let r be the potential revenue from a passenger and p the potential penalty cost of a passenger bumped . Finally, let x be the percentage of ticket holders who show up for the flight. The revenue generated by the flight is

$$\text{revenue}(x, b) = \begin{cases} xbr, & \text{if } xb \leq c; \\ cr - (xb - c)p, & \text{if } xb > c. \end{cases}$$

The percentage x of passengers who show up follows some probability distribution with density function $f(x)$ and an appropriate mean (in our case, 0.9). We find the value of b that maximizes the expected revenue for b passengers:

$$\text{expected\_revenue}(b) = \int_0^1 f(x) \cdot \text{revenue}(x, b)\, dx$$

Repeat this process for all flights and you have a complete recommendation for an overbooking policy.

Examining Compensation Policies

We can adjust our model even further by examining the effects of different compensation policies. Airlines have several forms of compensation at their disposal, from food to hotel stays to vouchers. The cost of the compensation policy is the penalty paid to a bumped passenger (p in our formulas above). By rerunning our expected revenue calculations for each compensation policy, we can see how each policy affects the maximum expected revenue of a flight.

Key Overbooking Flights

An airline can determine from historical data the "key" overbooking flights, the ones most likely to require overbooking. It can then use a compensation policy that concentrates on maximizing expected revenue for those flights.

From Theory to Reality: Vanguard Airlines

We illustrate our ideas by a case study of Vanguard Airlines, using publicly available information below [Vanguard Airlines 2001]. We assume that the January 2001 through September 2001 statistics provide an accurate picture of the airline:

- RASM = $ 0.073/seat-mile.
- RPM = 817,330 passenger-miles.

- ASM = 1,225,942 seat-miles.
- Operating expenses per ASM = $ 0.090/seat-mile.
- A full flight (Boeing 737-200 or MD-80 aircraft) holds $c = 130$ passengers.
- 95% of bumped passengers are volunteers [U.S. Department of Transportation 2001].

Applying the Model

We created a software package parameterized for adaptation to any airline.

Vanguard's web site [2002] gives a list of flight legs, along with source cities, destination cities, departure times, and arrival times. All flight legs are flown daily, except for four; to keep our example simple, we ignore these exceptions and treat all flights as daily.

The potential revenue r per passenger is the average ticket price for the flight leg; we calculate it as flight-leg distance times revenue earned per passenger mile. The latter is total revenue (RASM $\times$ ASM) divided by passenger-miles flown (RPM). So we have

$$r = \frac{(\text{distance})(\text{RASM})(\text{ASM})}{\text{RPM}}.$$

We could not locate good data on the distribution of how many ticket buyers show up for the flight. In lieu of a real distribution, we use a truncated normal distribution with mean 0.9 and appropriately small standard deviation (0.05):

$$f(x) = \frac{1.023}{0.05\sqrt{2\pi}}\, e^{200(x-0.9)^2}.$$

Penalty costs depend on how long the passenger is delayed, so we search the flight schedule for the quickest alternative route for each flight leg. We require at least 30 min between connecting flights.

Compensation Policies

There are three main forms of compensating bumped passengers:

- **Cash Payment vs. Ticket Voucher**
  - Bumped passengers who arrive at their destination within one hour of their originally scheduled arrival receive no compensation.
  - Those who arrive between one and two hours after their originally scheduled arrival are eligible for compensation in the amount of their full ticket cost up to $200.

  - A passenger who arrives two or more hours late is eligible for compensation in the amount of double their ticket cost up to $400.

  Compensation is required only for passengers involuntarily bumped, but common practice is to offer similar amounts to attract volunteers for bumping. We assume that 95% of all "bumped" passengers are voluntary and we offer them vouchers in place of cash. We calculate that a $1.00 voucher costs the airline $0.82. Incorporating that 5% of bumped passengers receive cash, this plan costs (voucher_value) $\times$ 0.831 per bumped passenger.

- **Meal Compensation** In our software, a passenger sitting in an airport through particular intervals gets compensation for a meal: 6 A.M. to 9 A.M., breakfast ($10); 11 A.M. to 1 P.M., lunch ($10); 5 P.M. to 8 P.M., dinner ($15). This compensation is not mandated, so it serves only as customer service.

- **Providing Board** A quick survey of airport motels in Kansas City (the hub for Vanguard) showed that $50 is reasonable to cover a motel room along with transportation to and from the motel. Our plan offers overnight accommodation to a passenger stranded in an airport for at least 6 hrs including midnight who has a flight leaving after 4 A.M. This compensation is not mandated, so it serves only as customer service.

Choosing a Compensation Policy

We compare the impacts of the following policies:

- Meal compensation, hotel compensation, and cash
- Hotel compensation and cash
- Meal compensation, hotel compensation, and voucher
- Hotel compensation and voucher
- Meal compensation and cash
- Meal compensation and voucher

We tabulate penalties for each flight leg and each compensation policy and calculate an optimal number of passengers to book on each flight leg depending on the compensation policy. To ensure that bumping is no more likely than not needing to bump, we impose a maximum booking level of 10/9. We then calculate the expected revenue for each flight leg at the optimal booking level for each policy and rank the policies for each flight leg by expected revenue. [EDITOR'S NOTE: We omit the authors' extensive tables giving results for specific flights.]

An important consideration in choosing a compensation package is customer service. While there is little short-term impact on revenue from good or bad customer service, there can be significant long-term impact. We should give some preference to policies that offer greater customer satisfaction. When o two or more policies produce the same revenue, our model chooses one that maximizes customer service.

The Best Compensation Policy for Vanguard

To determine its best compensation policy, Vanguard would need to examine historical data to determine flights most likely to require overbooking.

Responding to the Current Situation

We turn to issues currently facing the airline industry. Here we demonstrate how our model deals with unexpected circumstances.

Fewer Flights

The airline sets its schedule; our model adapts to it. In any case, flight traffic is increasing back to the level before September 11 (**Figure 1**).

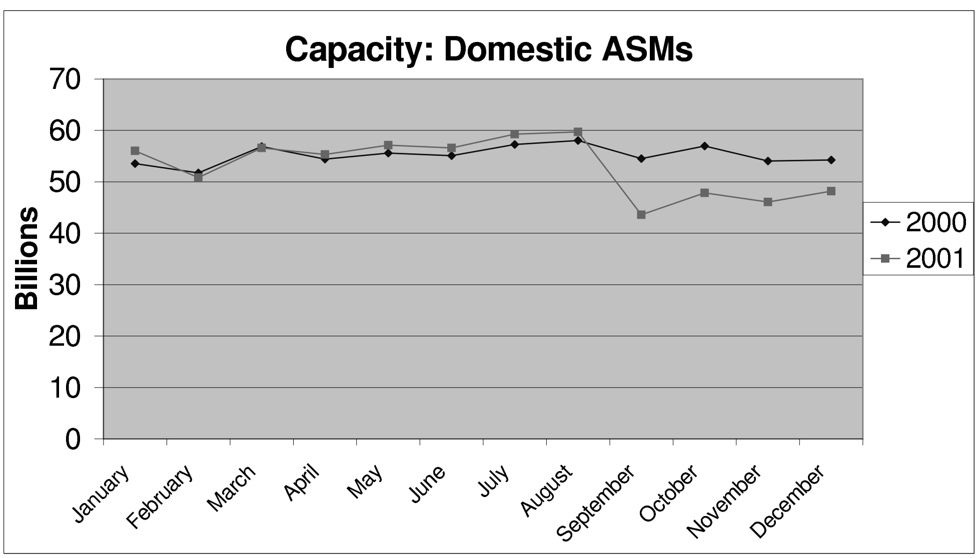

Figure 1. Domestic available seat miles (ASM) by month [Airline Transport Association 2002].

Heightened Security

Since the change in security policies at airports nationwide, both the checking in for a flight and layover gate changes could slow down passengers. Our model adjusts for that by factoring in 30 min for a layover.

Passengers' Fear

Passengers' fear could reduce no-shows (because those who purchase tickets are more serious about needing to fly) or increase them; there are no statistics to verify either effect. In either case, any effect of passengers' fear of flying seems to be declining [Airline Transport Association 2002].

Airlines' Losses

Revenue losses will likely make airlines cautious about taking on too much risk yet anxious to maximize revenue. Our model takes both goals into account, including enhancing revenue by dropping some customer service aspects.

Revenue loss also could cause an airline to schedule fewer flights to reduce costs. Our model gives an optimal recommendation adapted to the schedule.

Other Recommendations

- If two compensation packages have the same revenue benefits, choose the package that benefits the customer the most.
- Use vouchers instead of cash for compensation, because it costs less yet carries comparable perceived value for the customer.
- Give gate attendants some power to negotiate with angry customers, possibly including additional food vouchers.
- Upgrade bumped passengers to first class on their next flight when possible. This has no added cost in the case of an empty first class seat, yet has high value to the customer.
- Whenever possible, bump volunteers first, followed by passengers flying only one flight leg. This reduces the risk of further complicating a passenger's schedule.
- Ensure that the compensation policy is comparable to other airlines'.

Analysis of our Model

Strengths

The fundamental strengths of our model are its robustness and flexibility. All of the data is fully parameterized, so the model can be be applied to any airline. An airline can easily create probability distributions that accurately reflect not only average no-show percentages but also historical or per-flight trends. Although the industry may face constantly changing situations, our model adjusts to give the best recommendation possible.

Opportunities for Further Development

- The Vanguard implementation of our model ignores exceptions in flight schedules, assuming that all flights are daily. The incorporation of flight schedule exceptions into our implementation would be straightforward.
- Proprietary data would improve the accuracy of our Vanguard example, including the probability distribution of no-shows, average ticket prices, the current cost of various forms of compensation, and which flights are high-demand flights.

References

Airline Rules and Policies. 2002. `http://www.onetravel.com/advisor/AR_rules_Menu.cfm` . Accessed 9 February 2002.

Airline Transport Association. 2002. `http://www.airlines.org/public/industry/` .

Delta Airlines. 2000. Glossary of Terms. `http://www.delta.com/inside/investors/annual_reports/2000b_annual/06_glossary.html`. Accessed 9 February 2002.

More airline passengers get "bumped". 2000. *USA Today* (6 October 2000). `http://www.usatoday.com/life/travel/business/1999/bt002.htm` .

Porter, Gary A., and Curtis L. Norton. 2001. *Financial Accounting*. New York: Harcourt College Publishers.

U.S. Department of Transportation. 1994. Fly-Rights Regulations. `http://www.dot.gov/airconsumer/flyrights.htm#overbooking` . September 1994. Accessed 9 February 2002.

________. 2001. Air Travel Consumer Report. `http://www.dot.gov/airconsumer/0112atcr.doc` . December 2001. Accessed 11 February 2002.

Vanguard Airlines. 2001. Vanguard Airlines 10-Q Filing. Securities and Exchange Commission. `http://www.sec.gov/Archives/edgar/data/1000578/000100057801500016/r10q111401.htm`. Filed 11 November 2001. Accessed 11 February 2002.

________. 2002. `http://www.flyvanguard.com` .

WebFlyer MileMarker. 2002. Air Distance Calculator. `http://www.webflyer.com/milemarker/getmileage.cgi` . Accessed 9 February 2002.

M e m o r a n d u m

February 11, 2002

To: Scott Dickson,

Chairman, CEO and President of Vanguard Airlines

From: Team 229

Airline Yield Management Research

Subject: **Policy Changes for Optimal Overbooking and Compensation**

After careful analysis of our company's current flight schedule, revenue per additional passenger, overbooking strategy, and several different compensation schemes for bumped passengers, we have the following recommendations to maximize revenue on high demand flights.

1) Since our historical records indicate that flights101b, 251a, 325b, 451a, 552a and 902a are the flights in highest demand, we recommend that our airline adopt a compensation package consisting of the following policies
   a) Provision of overnight accommodations for those stranded during applicable times
   b) Ticket vouchers for all sufficiently delayed passengers who will accept them in lieu of cash.
   c) In addition, we are recommending against the use of meal compensation.

   This policy ensures the least cost to the airline in the case of an overbooked passenger while maintaining the highest possible level of customer satisfaction at that cost.
2) While using this compensation package, we also advise you to overbook flights using the following numbers of allowable bookings for each high demand flight. A complete reference of allowable flight booking levels is available.

Flight	Allowable Bookings
101b	142
207a	140
325b	142
451a	142
552a	142
902a	142