Optimization II
Project 2- Overbooking Flight Strategy
Group 2

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Introduction

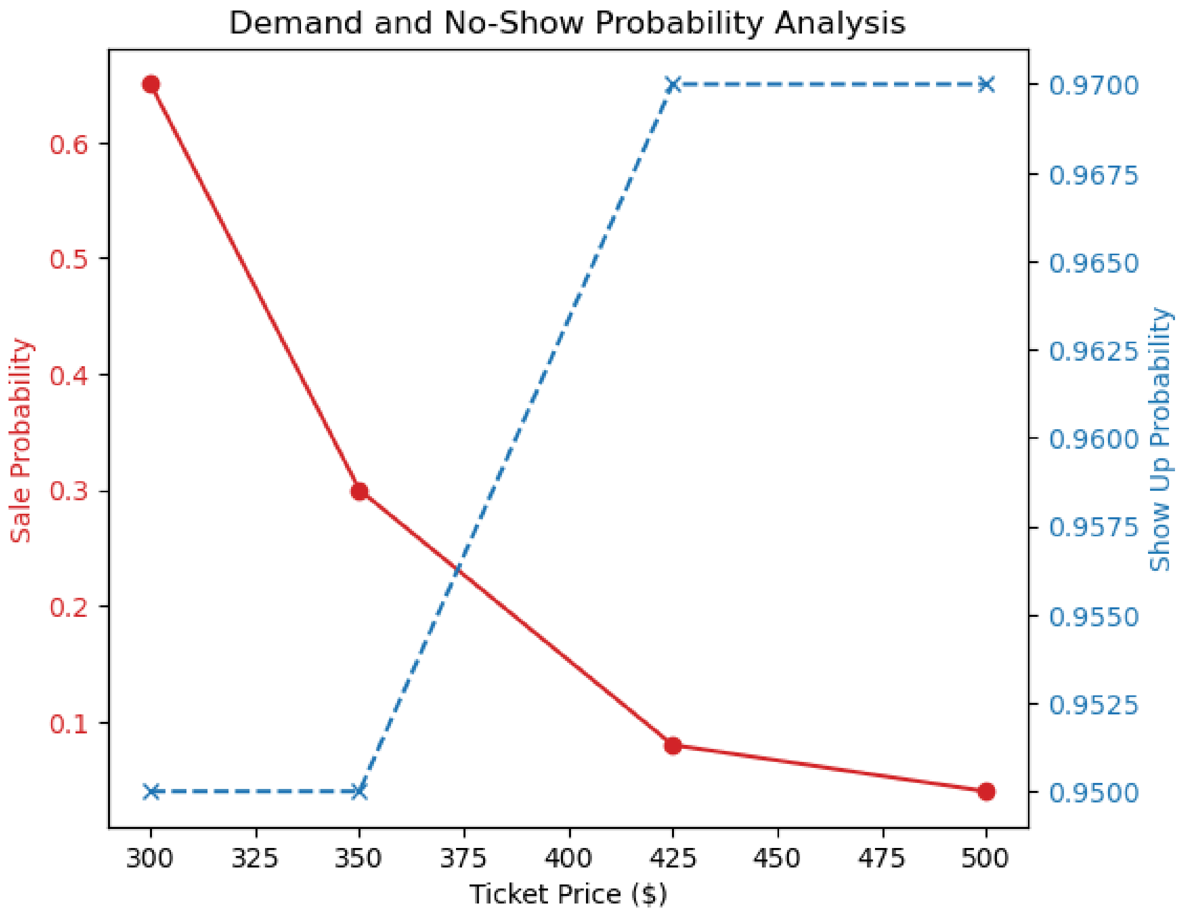
In the competitive landscape of the airline industry, maximizing the utilization of each flight's seating capacity is crucial for optimizing revenue. However, airlines face the challenge of dealing with passenger no-shows, which can lead to flights departing with empty seats, despite high demand. To mitigate this issue and enhance revenue opportunities, airlines often employ an overbooking strategy. This report delves into the analysis of overbooking as a strategic approach for an Airline, aiming to determine the optimal balance between increased revenue from selling more tickets than available seats and the potential costs associated with accommodating passengers when a flight is overbooked.

Overbooking, while financially beneficial, carries inherent risks, primarily the possibility of having more passengers show up for a flight than the aircraft can accommodate. This situation necessitates the bumping of passengers, either to later flights or, in certain cases, upgrading them to higher service classes, if available. These actions, while necessary from an operational standpoint, can lead to passenger dissatisfaction and potential damage to the airline's reputation if not managed carefully.

The core of our analysis focuses on:

- **Quantifying the Benefits of Overbooking:** By carefully modeling demand, pricing strategies, and passenger show-up probabilities, we aim to quantify the potential increase in revenue through overbooking.
- **Understanding the Risks and Costs:** Identifying the direct costs associated with overbookings, such as compensations for bumped passengers, and indirect costs like potential harm to customer satisfaction and brand reputation.
- **Finding the Optimal Overbooking Limit:** Through dynamic programming and simulation models, we explore various overbooking limits to identify the policy that maximizes expected discounted profits for the airline, considering both the financial benefits and associated risks.
- **Evaluating Overbooking Policies:** We compare traditional overbooking strategies with a flexible approach that allows for day-to-day adjustments in ticket sales, providing insights into the potential benefits and drawbacks of each.

The effectiveness of an overbooking strategy is contingent upon accurately predicting passenger no-show rates and understanding the demand elasticity for different flight routes and times. Airline's approach to overbooking needs to be nuanced and data-driven, leveraging historical data and advanced analytics to inform policy decisions.



The accompanying graph illustrates two critical aspects of our ticket pricing and passenger behavior:

- **Sale Probability:** There is a negative correlation between ticket price and the probability of a sale. The sale probability for coach tickets priced at $300 is notably higher than for tickets priced at $350, indicating a strong price sensitivity in this segment. This sensitivity diminishes as we transition into the first-class ticket segment, where the difference in sale probability between $425 and $500 tickets is less pronounced. This suggests that first-class passengers may be less price-sensitive, a consideration that could influence our overbooking strategy for different classes.
- **Show-Up Probability:** The graph also shows a subtle increase in show-up probability as ticket prices rise. For coach tickets, the probability of a passenger showing up is already high at 95%, but this increases slightly for first-class passengers, peaking at 97% for the $500 ticket price point. This difference underlines the higher reliability of first-class passengers showing up for their flights, which may be attributable to the higher stakes associated with the cost of their tickets.

The insights drawn from this analysis inform our overbooking models, allowing us to tailor strategies that align with the behaviors observed in different ticket classes. For instance, the high show-up probability in first-class reinforces our policy against overbooking this segment, while the greater price sensitivity in coach suggests a more flexible approach to pricing and overbooking could yield better revenue without significantly impacting passenger show-up rates.

As we proceed, this report will detail the methodology used in our analysis, present the findings, and discuss the implications of adopting different overbooking policies. Our goal is to offer a comprehensive overview that will aid in making informed decisions regarding the implementation of overbooking strategies, ensuring that revenue optimization does not come at the expense of customer satisfaction and brand integrity.

Methodology

To assess the viability and effectiveness of overbooking strategies for Airlines, our analysis employed a combination of dynamic programming and simulation techniques. These methodologies allowed us to model complex interactions between ticket pricing, passenger demand, show-up probabilities, and the costs associated with overbooking. This section outlines the analytical framework and assumptions that underpin our evaluation of overbooking policies.

Dynamic Programming Model for Optimal Pricing and Overbooking

Airlines face the challenge of optimizing revenue while managing the risk of passenger no-shows. Dynamic programming offers a structured approach to determine the most profitable overbooking and pricing policy by balancing additional revenue against the costs associated with overbooking.

The airline can overbook the coach class by up to 15 seats beyond its 100-seat capacity and must decide on a daily pricing strategy to maximize expected profits, considering the probability of passenger show-ups and the associated costs of overbooking.

Model Framework

The dynamic programming model is developed as follows:

- Objective: Maximise the expected discounted profit over a year by selling tickets and managing overbooking costs.
- State Variables: Number of days until departure (365), tickets sold in coach and first-class, and overbooking level in coach.
- Decision Variables: Daily ticket prices for coach ($300 or $350) and first-class ($425 or $500), and the level of overbooking in coach (5 to 15 seats).
- Transitions: Each day, a decision is made to sell at a certain price point, which affects the probability of a ticket sale and, consequently, the state variables.
- Constraints: No overbooking is allowed for first-class. Coach can be overbooked within the specified range.
- Probabilities:
    - Coach show-up rate: 95%
    - First-class show-up rate: 97%
    - Sale probabilities vary with price and first-class availability.

Discounted Profit Calculation
We calculate the expected discounted profit using the following formula:

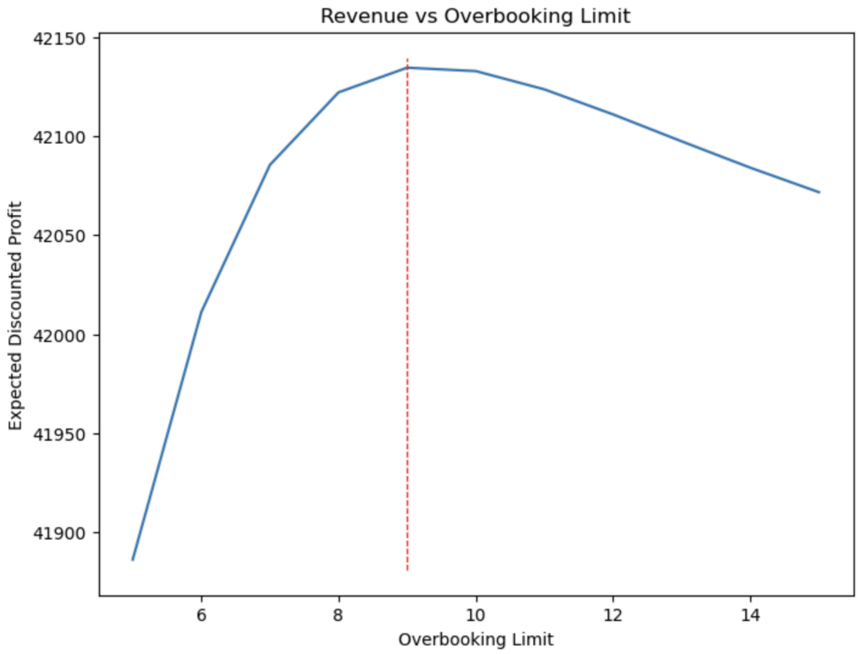
Expected Discounted Profit = ∑(Ticket Revenue − Overbooking Costs) × Discount Factor ^ (365−d)

where d represents the day in the selling period.

Costs
- Bumping a coach passenger to the first class: $50.
- Bumping a coach passenger off the plane: $425.
- Discount rate: 17% per year, with a daily discount factor of 1 / (1 + 0.17 / 365).

Computational Approach
A binomial distribution is used to calculate the expected cost on the day of departure, where a trial is the number of tickets sold and a success is a passenger showing up.

Results
Upon executing the dynamic programming model, we obtained a detailed projection of expected discounted profits across varying overbooking limits. The data unfolds a narrative that is instrumental in guiding the airline's overbooking strategy.



Here are the pivotal findings:
- **Profit Increase with Overbooking**: As the overbooking limit is incrementally raised from 5 to 9 seats beyond the plane's capacity, there is a consistent increase in expected profit. This trend aligns with the initial hypothesis that overbooking can serve as a lever to heighten revenue due to the likelihood of no-shows.

- **Optimal Overbooking Limit**: The analysis pinpoints an overbooking limit of 9 seats as the optimum, with the peak expected profit reaching $42,134.62. It suggests that at this juncture, the balance between additional ticket revenue and the incremental costs of accommodating overbooked passengers is most favorable.
- **Profit Decline Beyond Optimum**: As we extend the overbooking limit past 9 seats, a gradual decline in profit is observed. Although incremental revenue is still generated from selling extra tickets, the costs associated with bumping passengers—to either a later flight or upgrading to first class—begin to eclipse the revenue gains. The decrease in profit underscores the diminishing returns of overbooking and highlights the need for a restrained approach to avoid escalating costs and potential customer dissatisfaction.
- **Cost Implications**: It is noteworthy that the profit erosion beyond the optimal overbooking limit is relatively moderate, suggesting that the cost per bumped passenger ($50 to first-class, $425 off the plane) does not drastically outweigh the revenue from additional ticket sales up to the 15-seat overbooking limit. However, this cost balance must also factor in the intangible impacts on customer satisfaction and brand image, which are not directly accounted for in the profit calculations.

The findings from this analysis offer a compelling case for the airline to implement an overbooking limit of 9 seats in the coach. This strategy promises the highest expected discounted profit while maintaining a prudent buffer against the risks associated with passenger displacement due to overbooking. The decision is substantiated by quantitative data and can be visually represented in the provided graph, which clearly illustrates the profit maximization at an overbooking limit of 9 seats, with a pronounced peak in the profit curve.

This optimization analysis is crucial for decision-making, as it balances the numerical insights with operational realities, paving the way for a strategy that is not only profitable but also operationally viable and customer-centric.

Alternate Approach: Flexible No-Sale Policy for Coach Tickets

In a departure from the traditional overbooking model, we consider a new policy that introduces an additional level of flexibility in ticket sales. This policy allows the airline to choose not to sell any coach tickets on a given day, effectively making the demand zero. The addition of a 'no sale' option to the existing high and low pricing decisions offers a more dynamic approach to managing overbooking and revenue.

Adjustments to the Dynamic Programming Model

The dynamic programming model has been adjusted to account for this additional decision variable. Each day, the airline now faces three choices for coach:

- Sell at a high price ($350)
- Sell at a low price ($300)
- Opt for no sale

First-class tickets continue to be sold at either a high price ($500) or a low price ($425), with no option for a no-sale decision.

Model Constraints and Assumptions
With the implementation of the no-sale policy, we maintain a ceiling of 120 seats for coach ticket sales. The model strategically selects no-sale days based on two factors:

- The current level of overbooking
- The number of days remaining until departure

These decisions aim to fine-tune the balance between potential revenue and the risk of incurring overbooking costs as the departure date draws nearer.

Comparative Analysis of Overbooking Strategies

In this section, we evaluate two distinct overbooking strategies: the traditional policy with a hard cap on the number of coach seats sold and the revised strategy which includes a 'no-sale' option for coach seats each day.

Traditional Policy with Hard Cap on Seats Sold
The traditional policy imposes a strict overbooking limit, allowing the airline to sell a fixed number of seats beyond the plane's capacity. This approach simplifies operational planning and provides a predictable revenue stream based on historical no-show rates and demand patterns. The hard cap policy ensures a ceiling on the potential costs incurred from overbooking, as it restricts the number of extra tickets sold.

Pros:
- Predictability: Fixed overbooking limits offer stable expectations regarding revenue and potential compensation costs.
- Simplicity: The operational processes are straightforward, as the rules are set and require less real-time decision-making.

Cons:
- Inflexibility: This strategy cannot adjust to daily changes in demand or passenger show-up rates.
- Potential Revenue Loss: The inability to tailor the overbooking limit closer to the departure date may result in lost opportunities for additional sales on days with lower no-show probabilities.

Flexible Strategy with No-Sale Option
The flexible strategy introduces a third choice in daily pricing decisions, allowing the airline not to sell coach tickets on a given day. This innovative approach provides a lever to fine-tune overbooking risks dynamically, based on real-time data and remaining days until departure.

Pros:
- Adaptability: The strategy adapts to daily market conditions and can mitigate overbooking risk by halting sales when necessary.
- Maximized Revenue: By optimizing the number of seats sold each day, the airline can potentially capture more revenue when the risk of no-shows is accurately predicted to be low.

Cons:

- Complexity: Requires sophisticated demand forecasting and decision-making frameworks to determine when to stop sales.
- Operational Demands: This may increase the burden on staff and systems to monitor and implement the no-sale decision daily.

Performance Comparison

When compared to the traditional policy, the flexible strategy with the no-sale option yielded a slightly higher expected discounted profit of $42,139.89, compared to the peak profit of $42,134.62 under the hard cap strategy. This marginal increase suggests that the no-sale option can provide a financially beneficial alternative to the traditional method.

However, it's important to note that the small difference in profit must be weighed against the potential operational costs and complexity introduced by the flexible strategy. The value of this approach also hinges on the airline's ability to accurately forecast demand and make informed day-to-day sales decisions.

Conclusion

The analysis suggests that the flexible strategy with the no-sale option has the potential to slightly outperform the traditional hard cap policy in terms of expected profit. However, the airline must consider the increased operational demands and the quality of demand forecasts when deciding whether to implement this more nuanced approach. The decision should ultimately align with the airline's capability to manage dynamic pricing effectively and its overarching business objectives.

Forward Simulation Analysis of Overbooking Policies

With the optimal overbooking policy identified through dynamic programming, the next step involves a forward simulation to evaluate the policy's practical implications over multiple iterations. This simulation projects the real-world scenarios of overbooking and assesses key performance metrics under both the hard cap and flexible no-sale policies.

Simulation Objectives

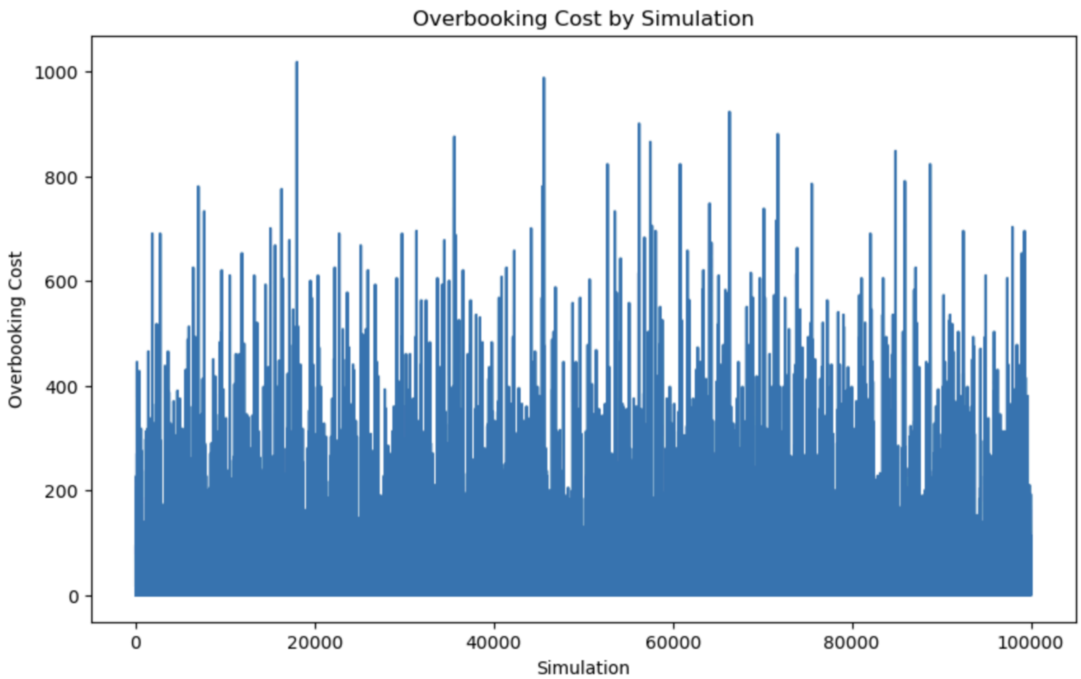
The forward simulation aims to answer the following questions:

- Overbooking Incidence: How frequently does the situation occur where a coach is overbooked under each policy?
- Passenger Impact: What proportion of flights result in passengers being denied boarding, and how does this compare between the policies?
- Cost Analysis: What is the average cost incurred from overbooking, and how does this translate into the net revenue impact for the airline?
- Profit Volatility: How does the volatility of discounted profits differ between the policies, and what are the implications for financial planning?
- Additional Metrics: Are there other relevant metrics, such as customer satisfaction scores or the rate of first-class upgrades due to overbooking, that can inform the airline's strategy?

Simulation Methodology
To conduct the forward simulation, we will use the optimal overbooking limit of 9 seats and the flexible no-sale option policy, executing the following steps:

- Simulate daily ticket sales based on the probability distributions defined for each pricing strategy.
- Track the number of tickets sold and compare it to the actual plane capacity to identify instances of overbooking.
- Apply the show-up rates to determine the actual number of passengers presenting for the flight and calculate overbooking costs accordingly.
- Repeat the simulation for a significant number of trials to gather robust data on overbooking frequencies and costs.
- Analyze the variance in profits across simulations to understand the risk profile of each policy.

Findings from the Simulation Data



- Variability in Overbooking Costs: There is a considerable variation in overbooking costs across different simulations. The spikes represent scenarios where the overbooking costs are significantly higher, likely corresponding to instances where a greater number of passengers were denied boarding.
- Frequency of High-Cost Occurrences: While many of the simulations result in moderate overbooking costs, there is a notable frequency of simulations resulting in high overbooking costs. This suggests that while the chosen policy is generally effective, there are outlier scenarios that could lead to substantial financial impact.
- Average Overbooking Cost: Although the graph does not explicitly provide an average value, the visual data suggests that the average overbooking cost per simulation might lie within the denser region of the lower half of the cost distribution. An exact numerical average would be beneficial for a complete analysis.

- Outlier Analysis: The presence of outliers indicates extreme cases that could be due to days with unexpectedly high sales or higher-than-average show-up rates. These outliers could skew the average and median overbooking costs and should be analyzed separately to understand their causes.

Key Metrics from the Simulation

- Overbooking Frequency: The frequency of overbooking situations is quite high, with approximately 70.83% of simulations resulting in more tickets sold than seats available in coach. This signifies a proactive approach to maximizing ticket sales, assuming the associated risk of potential costs due to overbooking.
- Average Overbooking Cost: The average cost incurred due to overbooking per flight is $-868.57. This figure is an essential indicator of the financial impact of the overbooking strategy and needs to be compared against the incremental revenue from additional ticket sales to evaluate the overall benefit.
- Volatility of Discounted Profits: A significant level of volatility has been observed in the discounted profits, amounting to $496.28. Such a high degree of fluctuation indicates that the revenue from the overbooking strategy can vary greatly, which may require careful financial planning and risk mitigation strategies.

Implications for Airline Revenue Management

- Risk Management: The airline must consider both the frequency and average cost of overbooking in its risk management strategy. While the overbooking strategy is likely profitable given the 70.83% overbooking frequency, the airline must also account for the potential negative impact on customer satisfaction and operational stress during high-cost events.
- Profit Volatility: The considerable volatility in discounted profits requires the airline to maintain financial flexibility to handle the fluctuating cash flows. This might involve setting aside a reserve or hedging against the risk of high overbooking costs in certain scenarios.
- Policy Optimization: Considering the average overbooking cost and the substantial volatility, there is an opportunity to fine-tune the overbooking policy. Reducing the overbooking frequency could lower the average cost and profit volatility, potentially leading to a more stable and predictable revenue stream.

Conclusion and Strategic Recommendations

The forward simulation has provided critical insights into the implications of the airline's overbooking policy. The high frequency of overbooking, along with the observed average costs and profit volatility, suggest that while the current policy may be profitable, there is room for optimization. The airline should consider measures to reduce the overbooking frequency, possibly by leveraging the flexible no-sale option more effectively, to strike an optimal balance between revenue maximization and risk management. Additionally, a focus on enhancing the prediction accuracy of demand and show-up rates could further refine the overbooking strategy.