Airline yield management

Introduction

You are in charge of managing the price of an airline company (yield management). Each seat of a flight can be sold at different fares, offering different services and with a different revenue for the company. The same seat can be sold with a fare one day and a different one the next day. The passengers are classified in several segments based on the services that they prefer. Your goal is to optimize the company's revenue.

The decisions that you have to make are:

- The booking intervals in which the fares are available, i.e. from which day to which day a fare is offered.
- The booking limit for each fare, i.e. maximum number of seats available for this fare.

The aim of the "Simulation Project" is to develop a discrete event simulation that represents the system and to evaluate the performance of two solutions for the fare availability.

During the "Optimization Project", the discrete event simulation is expanded, and the optimal solution in terms of revenue and fare availability is identified by an optimization algorithm.

Develop the discrete event simulation with a modular structure. It should be possible to modify the various components, such as the customer arrival rate, booking intervals and limits, during the "Optimization Project".

Project description

We consider a single flight scheduled from Geneva to Washington, DC for a given departure day and departure time. The planning horizon for the sale of the seat inventory is 180 days and ends on the day of departure. Time is discretized in days and indexed by t, with smaller values of t designating later point in time. In this respect, $t = 179$ represents the first day of sales and $t = 0$ represents the last day of sales, which is the day of departure.

Table 1 describes the set $S = \{A, \dots, I\}$ of fare products offered by the company. Each product has an associated revenue. On each day t, the company chooses a subset of fare products to offer. When the subset S' is offered, the probability that a customer will choose product $i \in S'$ is denoted by $P_i(S')$ and we assume that $P_i(S') = 0$ if $i \notin S'$. Moreover, the probabilities are only a function of S' and do not depend on t. Products D and H are not offered after $t = 21$.

Table 1: Description of fare products

Fare products	Priority boarding	21-day adv.	Seat selection	One free bag	Two free bags	Revenue (CHF)
A	Yes	No	Yes	No	Yes	1000
B	Yes	No	Yes	Yes	No	900

C	Yes	No	No	Yes	No	850
D	Yes	Yes	Yes	Yes	No	750
E	No	No	Yes	No	Yes	700
F	No	No	Yes	Yes	No	650
G	No	No	No	Yes	No	600
H	No	Yes	No	No	No	500
I	No	No	No	No	No	350

The company classifies passengers into three segments: Business, Leisure and Economy. Passengers from each segment have similar behavior. We represent the behavior of each segment by a preference weight. Table 2 reports the preference weights of the customers for each fare.

Table 1: Passenger segment/fare product preference weights

Passenger Segment /Fare Product	A	B	C	D	E	F	G	H	I	No Purchase (NP)
Business	11	15	18	20	19	15	12	11	13	8
Leisure	8	9	11	12	14	15	16	18	20	8
Economy	1	5	8	10	11	12	13	15	20	8

Customers purchase the tickets following a probability associated to the preference weight. For example, if products A, B and C are offered and the customer belongs to the segment Business, the probabilities of purchasing the fare products are: $P_A = 11/(11 + 15 + 18 + 8)$, $P_B = 15/(11 + 15 + 18 + 8)$, and $P_C = 18/(11 + 15 + 18 + 8)$. Finally, the probability of making no purchase is $P_{NP} = 8/(11 + 15 + 18 + 8)$.

The customer arrival rates vary in the period, and they are different for the three passenger segments. The arrival rates are the following [customers/day]:

1. Business: $\lambda(t) = 1.2 \sin(t)$, where the argument of sin is in degrees
2. Leisure: $\lambda(t) = 0.6\, t/179$
3. Economy: $\gamma = 0.8\,(1 + \sin(t + 180))$, where the argument of sin is in degrees

The airline controls its inventory by two decisions: (1) the booking intervals in which products are available, and (2) the booking limit for each product, which represents the maximum number of seats available for this product. It is only the number of seats that is important, and not the actual seat positions. The plane has a capacity of 180 seats and overbooking is not allowed. When an offered product reaches its booking limit, it is no longer available. Every seat can be sold at any fare.

Simulation

For the simulation project, you are requested to:

- Develop a discrete event simulation to represent the described project.
- Define the metrics used to quantify the quality of the service
    - Remember that extreme cases are important; evaluate other metrics in addition to the mean. Moreover, the booking limits for different fare product types could have different impact on how your service is perceived.

  - Report the mean square error of your estimation using bootstrapping when necessary.
  - Use variance reduction techniques to reduce the computational time.
- Evaluate the airline company's revenue for the following two cases:
  - All fare products are available from the beginning ($t = 179$) and each product has a booking limit of 20 seats.
  - The company offers only one product at a time. First it offers product I and as soon as it reaches its limit the company offers product H, and so on. This course of action continues until all fare products are sold out or the plane departs for Washington, DC. All fare products have a booking limit of 20 seats.
- Make any necessary assumptions.

Optimization

For the optimization project, you are requested to:

- Identify the decision variables of the airline yield management problem
- Define the objective function.
- Design an optimization algorithm and apply it to solve the problem. The value of the objective function is evaluated by discrete event simulation.
- Like in the simulation project, the objective function can reflect various policies of the decision maker: whether they want to optimize over the average, best, worst, or certain percentile of the objective function distribution. Decide what your position is and justify it, or present results for several alternatives.
- Use your creativity and define a new policy to offer seats to the customers that can improve the revenue.