Train service

Introduction

The train line between Geneva and Zurich needs to be planned. You are in charge of defining the train timetable and the train composition. The composition of a train indicates the number of carriages and the type, namely first or second class carriage. Given the demand of passengers among all cities, you should define the best possible service.

The decisions that you have to make are:

- The timetable to accommodate the demand.
- The composition of the trains, number and type of carriages.

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 of train timetable and composition.

During the "Optimization Project", the discrete event simulation is expanded, and the optimal solution in term of timetable and composition 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 passenger demand, train scheduling and type of trains, during the "Optimization Project".

Project description

The train line between Geneva and Zurich is composed of the following stations: Geneva (G), Lausanne (L), Bern (B) and Zurich (Z). Trains travel only in one directions from Geneva to Zurich. All trains start from Geneva, stop at every station and end the trip in Zurich.

Trains are composed of several carriages. There are two types of carriages: first and second class carriages. Second class carriages have a maximum capacity of 500 passengers/carriage, and first class carriages of 300 passengers/carriage.

Independently from the type of trains or the number of passenger embarking the train, the travel time between stops is constant. Trains never have delay. The travel time is as follows:

- G->L 40 minutes
- L->B 1 hour and 10 minutes
- B->Z 1 hour

Each passenger has an origin and a destination. The origin is the station where the passenger is generated, and the destination is the station that the passenger wants to reach. The demand, i.e. the number of passengers that want to travel, is represented by a demand matrix specifying origins and destinations. The demand is constant during the day, except for two peak periods. The morning peak period is between 7:00

and 9:00, and the evening peak period is between 16:00 and 18:00. Passengers arrive at the origin station following fixed constant rates. The arrival is independent from the train schedule. The arrival rates are:

Demand during peak periods [1000 passengers/h]:

	G	L	B	Z
G	-	1.5	2.2	1.3
L	-	-	2.4	1.1
B	-	-	-	3.3
Z	-	-	-	-

Demand off-peak periods [1000 passengers/h]:

	G	L	B	Z
G	-	0.4	0.3	0.5
L	-	-	0.5	0.3
B	-	-	-	0.5
Z	-	-	-	-

Passengers are divided into two groups: first class passengers and second class passengers. For each destination, there are different proportions of first and second class passengers. These vary between peak and off-peak period too. Second class passengers travel only in second class carriages, and first class passengers travel only in first class carriages. The proportions of first class passengers over the total number of passengers are as follows.

Proportion of first class passengers during peak periods:

	G	L	B	Z
G	-	0.13	0.15	0.17
L	-	-	0.21	0.18
B	-	-	-	0.32
Z	-	-	-	-

Proportion of first class passengers during off-peak periods:

	G	L	B	Z
G	-	0.21	0.18	0.23
L	-	-	0.24	0.23
B	-	-	-	0.19
Z	-	-	-	-

There are some costs and prices associated with trains and tickets. The price of tickets is calculated per number of stations. This means that a passenger going from Lausanne to Bern needs to buy a ticket for one station, i.e. Bern, and a passenger going from Lausanne to Zurich needs to buy a ticket for two stations, i.e. Bern and Zurich. The prices are as follows:

- First class 40 CHF per station/passenger
- Second class 20 CHF per station/passenger

The train operator has quantified the cost associated to a passenger that misses a train. This cost increases for every train that a passenger misses. For example, if a passenger needs to wait for 3 trains before boarding, the cost is multiplied by 2, i.e. number of trains that she missed. The costs of missing a train are as follows:

- First class passenger 30 CHF per passenger per train
- Second class 10 CHF per passenger per train

The train operator has also quantified the cost associated to empty seats. This accounts for the opportunity costs of using this seat (or carriage) on another train line. The costs are calculated per number of stations, as for the tickets. The costs of an empty seat are:

- First class seat 20 CHF per seat per station
- Second class seat 10 CHF per seat per station

Simulation

For the simulation project, you are requested to:

- Develop a discrete event simulation to represent the described project.
- Define the indexes used to quantify the quality of the service
    - Remember that extreme cases are important; evaluate other indexes in addition to the mean. Moreover, the waiting time is an important factor for 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 quality of the train service during 24 hours with two different configurations. :
    - For the entire day, the frequency of the trains is a train every 20 minutes. All trains are composed of 1 first class carriage and 3 second class carriages.
    - The frequency varies between peak and off-peak periods. During peak periods the frequency is a train every 15 minutes. During off-peak periods the frequency is a train every 30 minutes. All trains have the same composition, and it is identical to the one of the first scenario.
- Make any necessary assumptions.

Optimization

The service can be improved by accurately choosing the train time schedule and the train compositions. However, there is a limit on the maximum number of different train compositions. You cannot have more than 3 different configurations of trains per day, i.e. carriages compositions.

For the optimization project, you are requested to:

- Identify the decision variables of the problem.
- Define the objective function.
- Design an optimization algorithm and apply it to solve the problem. The value of the objective function is evaluated using 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 design a new train service, e.g. direct trains, that leads to better performance.