Case Study 4 - Open-ended Simulation Problem

Due the week of Monday, May 2. For this case study, you will form a group of 2 or 3 people to work on an open-ended problem involving a computer simulation. You can choose one of the problems listed after this page. Since these are open-ended problems, feel free to get creative with your simulations! When you have formed a group, please send me an email letting me know who is in your group and which problem you have chosen to work on. If you are looking for one or two other people to form a group with, send me an email, and I will make sure you have a group to work with.

Together, your group should turn in a *single* writeup (with all of your names on it), with reflections from each student at the end. Your group will also present your work during the final week of class. You should have a powerpoint (or similar format) detailing all of your work. Your presentation should be roughly 15 minutes long and include a synopsis of your problem, justification for all of the assumptions and decisions you made for your project, a demonstration of your simulation, and a discussion of your results.

Timeline: I will randomly choose which groups present on Monday, Wednesday, and Friday. Final reports are due from all groups on **Friday, May 6** by 5pm.

Grading: The grading structure is a bit different for this case study, to account for the presentation. Your grade will be determined out of 50 points, with the following breakdown:

15 Points: Mathematical Content

15 Points: Effective Communication

10 Points: Presentation

5 Points: Participation

5 Points: Reflection

To get your full participation points, I expect you to be present in class everyday and contributing significantly to your group. You must also be actively engaged in the presentations of other groups; this means being respectful and paying attention during presentations and asking questions.

Reflection: Conclude your report with one final reflection. Some possible prompts include: What did you think of math modeling? How can you envision yourself utilizing this skill set in your future career? What components of this class were most helpful to you in terms of learning the material?

Submit the report in the Moodle assignment "Case Study 4 Report" by Friday, 5/6 at 5pm.

Project #1: Airplane Seating

Airlines are free to seat passengers waiting to board an aircraft in any order whatsoever. Typically they start with passengers who need extra time, followed by first-class passengers (who sit at the front of the plane). Then one possible option is to seat coach and business-class passengers by groups of rows, beginning with the row at the back of the plane and proceeding forward.

Apart from consideration of the passengers' wait time, from the airline's point of view time is money, and it is best to minimize boarding time. The plane makes money for the airline only when it is in motion, and long boarding times limit the number of trips that a plane can make in a day. The development of larger planes, such as the Airbus A380 (800 passengers), reflects efforts to minimize boarding (and deboarding) time.

Devise and compare procedures for boarding and deboarding planes with varying numbers of passengers: small (85–210), midsize (210–330), and large (330–800). As part of your project, build a simulation to compare the efficacy of the proposed procedures, in comparison with other possible boarding options. Prepare an executive report in which you explain your conclusions to an group of airline executives, gate agents, and flight crews.

Project #2: Traffic Circle Design

Many cities and communities have traffic circles—from large ones with many lanes in the circle (such as at the Arc de Triomphe in Paris and the Victory Monument in Bangkok) to small ones with one or two lanes in the circle (like Easton). Some of these traffic circles position a stop sign or a yield sign on every incoming road that gives priority to traffic already in the circle; some position a yield sign in the circle at each incoming road to give priority to incoming traffic; and some position a traffic light on each incoming road (with no right turn allowed on a red light). Other designs may also be possible.

The goal of this problem is to determine how best to control traffic flow in, around, and out of a circle. State clearly the objective(s) you use in your model for making the optimal choice as well as the factors that affect this choice. Prepare a technical summary that explains to a traffic engineer how to use your model to help choose the appropriate flow-control method for any specific traffic circle. That is, summarize the conditions under which each type of traffic-control method should be used. When traffic lights are recommended, explain a method for determining how many seconds each light should remain green (which may vary according to the time of day and other factors). Use computer simulations to compare and contrast how your methods work.

Project #3: Campsites on a River

There is a river of length 225 miles, where visitors can enjoy scenic views and exciting white water rapids. The river is inaccessible to hikers, so the only way to enjoy it is to take a river trip that requires several days of camping. River trips all start at First Launch and exit the river at Final Exit, 225 miles downstream. Passengers take either oar- powered rubber rafts, which travel on average 4 mph, or motorized boats, which travel on average 8 mph. The trips range from 6 to 18 nights of camping on the river, start to finish.

The government agency responsible for managing this river wants every trip to enjoy a wilderness experience, with minimal contact with other groups of boats on the river. Currently, X trips travel down the river each year during a six month period (the rest of the year it is too cold for river trips). There are Y camp sites on the river, distributed fairly uniformly throughout the river corridor. Given the rise in popularity of river rafting, the park managers have been asked to allow more trips to travel down the river. They want to determine how they might schedule an optimal mix of trips, of varying duration (measured in nights on the river) and propulsion (motor or oar) that will utilize the campsites in the best way possible. In other words, how many more boat trips could be added to the river's rafting season? The river managers have hired you to advise them on ways in which to develop the best schedule and on ways in which to determine the carrying capacity of the river, remembering that no two sets of campers can occupy the same site at the same time. Prepare a technical summary to the managers of the river describing your key findings and use computer simulations to support your conclusions.

Project #4: Bus Line

Consider a bus stop in Philadelphia during the morning hours, specifically from 7 am to 12 pm, where you can assume that 7-9am represents the rush hour period. You can think of the arrival of riders as a random event, and the goal of this project is to determine an optimal schedule for the buses to arrive at this stop. When considering this optimal schedule, you want to avoid crowding at the bus stop, which can occur if there are long periods of time between bus arrivals. The crowding could result in some of the customers not being able to fit on the bus. On the other hand, in order to minimize costs, you do not want to use more buses than are needed. You can use a different schedule during the rush hour period and non-rush hour period (with different assumptions about passengers during these periods), and your optimal schedule should depend on the number of riders using this bus stop and the frequency with which they arrive.

Write a report to the owners/managers of the bus company with your proposed schedule, using computer simulations to support your conclusions.

Project #5: QuickPasses for Parks

"'QuickPass" systems are increasingly appearing to reduce people's time waiting in line, whether it is at tollbooths, amusement parks, or elsewhere. Consider the design of a QuickPass system for an amusement park. The amusement park has experimented by offering QuickPasses for several popular rides as a test. The idea is that for certain popular rides, you can go to a kiosk near that ride and insert your daily park entrance ticket, and out will come a slip that states that you can return to that ride at a specific time later. For example, you insert your daily park entrance ticket at 1:15 p.m., and the QuickPass states that you can come back between 3:30 and 4:30 p.m. and use your slip to enter a second, and presumably much shorter, line that will get you to the ride faster. To prevent people from obtaining QuickPasses for several rides at once, the QuickPass machines allow you to have only one active QuickPass at a time.

You have been hired as one of several competing consultants to improve the operation of QuickPass. Customers have been complaining about some anomalies in the test system. For example, customers observed that in one instance, QuickPasses were being offered for a return time as long as 4 hours later. A short time later on the same ride, the QuickPasses were given for times only an hour or so later. In some instances, the lines for people with QuickPasses are nearly as long and slow as the regular lines.

The problem, then, is to propose and test schemes via a computer simulation for issuing QuickPasses in order to increase people's enjoyment of the amusement park. Part of the problem is to determine what criteria to use in evaluating alternative schemes. Prepare a technical summary for amusement park executives who must choose between alternatives from competing consultants.

Project #6: Hurricane Evacuation

Evacuating the coast of South Carolina ahead of the predicted landfall of Hurricane Floyd in 1999 led to a monumental traffic jam. Traffic slowed to a standstill on Interstate I-26, which is the principal route going inland from Charleston to the relatively safe haven of Columbia in the center of the state. What is normally an easy 2-hour drive took up to 18 hours to complete. Many cars simply ran out of gas along the way. Fortunately, Floyd turned north and spared the state this time, but the public outcry is forcing state officials to find ways to avoid a repeat of this traffic nightmare.

The principal proposal put forth to deal with this problem is the reversal of traffic on I-26, so that both sides, including the coastal-bound lanes, have traffic headed inland from Charleston to Columbia. Plans to carry this out have been prepared (and posted on the Web) by the South Carolina Emergency Preparedness Division. Traffic reversal on principal roads leading inland from Myrtle Beach and Hilton Head is also planned.

Charleston has approximately 500,000 people, Myrtle Beach has about 200,000 people, and another 250,000 people are spread out along the rest of the coastal strip. (More accurate data, if you would like, are widely available.)

The interstates have two lanes of traffic in each direction, except in metro areas, where they have three. Columbia, another metro area of around 500,000 people, does not have sufficient hotel space to accommodate the evacuees (including some coming from farther north by other routes), so some traffic continues outbound on I-26 toward Spartanburg; on I-77 north to Charlotte; and on I-20 east to Atlanta. In 1999, traffic leaving Columbia going northwest was moving very slowly.

Construct a computer simulation for the problem to investigate what strategies may reduce the congestion observed in 1999. Here are some questions you might consider addressing:

- Under what conditions does the plan for turning the two coastal-bound lanes of I-26 into two lanes of Columbia-bound traffic significantly improve evacuation traffic flow?
- In 1999, the simultaneous evacuation of the state's entire coastal region was ordered. Would the evacuation traffic flow improve under an alternative strategy that staggers the evacuation, perhaps county-by-county over some time period consistent with the pattern of how hurricanes affect the coast?
- What effect would it have on evacuation flow to establish more temporary shelters in Columbia, to reduce the traffic leaving Columbia?
- In 1999, many families leaving the coast brought their boats, campers, and motor homes. Many drove all of their cars. Under what conditions should there be restrictions on vehicle types or numbers of vehicles in order to guarantee timely evacuation? It has been suggested that in 1999, some of the coastal residents of Georgia and Florida, who were fleeing the earlier predicted landfalls of Hurricane Floyd to the south, came up I-95 and compounded the traffic problems. How big an impact can they have on the evacuation traffic flow?

Prepare a technical summary for the state officials explaining the results and conclusions of your study, including relevant results from your simulations.

Project #7: Aircraft Queuing

A common procedure at airports is to assign aircraft (AC) to runways on a "first-come, first-serve" basis. That is, as soon as an AC is ready to leave the gate (push back), the pilot calls ground control and is added to the queue. Suppose that a control tower has access to a fast online database with the following information for each AC:

- The time it is scheduled for pushback
- The time it actually pushes back
- The number of passengers on board
- The number of passengers who are scheduled to make a connection at the next stop, as well as the time to make that connection
- The schedule time of arrival at its next stop

Assume that there are seven types of AC with passenger capacities varying from 100 to 400 in steps of 50. Develop and propose a queuing scheme that takes into account both the travelers' and the airlines' satisfaction. Using a computer simulation, compare the efficacy of your proposed queuing scheme with the "first-come, first-serve" method. Prepare a technical report for the airline officials clearly explaining your results and conclusions.

Project #8: Contest Judging

When determining the winner of a competition such as the Mathematical Contest in Modeling, there are generally a great many papers to judge. Let's say there are $P = 100$ papers. A group of J judges is collected to accomplish the judging. Funding for the contest constrains both the number of judges that can be obtained and the amount of time that they can judge. For example, if $P = 100$, then $J = 8$ is typical.

Ideally, each judge would read each paper and rank-order them, but there are too many papers for this. Instead, there will be a number of screening rounds in which each judge will read some number of papers and give them scores. Then some selection scheme is used to reduce the number of papers under consideration: If the papers are rank-ordered, then the bottom 30% that each judge rank-orders could be rejected. Alternatively, if the judges do not rank-order the papers, but instead give them numerical scores (e.g., from 1 to 100), then all papers falling below some cutoff level could be rejected.

The new pool of papers is then passed back to the judges, and the process is repeated. A concern is that the total number of papers that each judge reads must be substantially less than P. The process is stopped when there are only W papers left. These are the winners. Typically for $P = 100$, $W = 3$. Your task is to develop and propose two different selection schemes with a goal of having the final W papers include only papers from among the best $2W$ papers. (By "best," we mean we assume that there is an absolute rank-ordering to which all judges would agree.) For example, the top three papers found by your method will consist entirely of papers from among the best six papers. Among all such methods, the one that requires each judge to read the least number of papers is desired.

Using a computer simulation, compare and contrast the results of your selection schemes. Which method works best? Prepare a technical report for the organizers of the contest explaining your methods and results.

Project #9: Airline Overbooking

You're all packed and ready to go on a trip to visit your best friend in Minneapolis. After you check in at the ticket counter, the airline clerk announces that your flight has been overbooked. Passengers need to check in immediately to determine whether they still have a seat.

Historically, airlines know that only a certain percentage of passengers who have made reservations on a particular flight will actually take that flight. Consequently, most airlines overbook —that is, they take more reservations than the capacity of the aircraft. Occasionally, however, more passengers will want to take a flight than the capacity of the plane, leading to one or more passengers being bumped and thus unable to take the flight for which they had reservations.

Airlines deal with bumped passengers in various ways. Some are given nothing, some are booked on later flights on other airlines, and some are given some kind of cash or airline ticket incentive.

Build a mathematical simulation that examines the effects that different overbooking schemes have on the revenue received by an airline company in order to find an optimal overbooking strategy, i.e., the number of people by which an airline should overbook a particular flight so that the company's revenue is maximized. Ensure that your simulation reflects the issues above, and consider alternatives for handling "bumped" passengers. Consider how changing the size of the aircraft (and hence the number of passengers onboard) may affect your results. Prepare a technical report for the airline's CEO summarizing your findings and analysis.