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Assignment

You are employed by an OR consulting firm, and have been hired to develop a simulation model for a client company. Since you are from a consulting firm, and not developing a simulation in-house, it is important to build a simulation model that is attractive, easy-to-use, and has clear reporting on the relevant key performance indicators. The client company will base its satisfaction with your work on the following criteria:

1. Good model structure, keeping the simulation as simple as possible.
2. The model should be crisp, attractive, and easy to use. It should reflect the client's processes and thus be intuitive for the client company to navigate.
3. Relevant, clear reporting.

Your project is described in the case study below.

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Case Study – Elevator Simulation in an Office Environment

Elevator controller design and optimization is a challenging problem where a general solution applicable to all scenarios is difficult to achieve. Intelligent elevator controllers may use data on arrival and departure patterns to help service passengers more efficiently. Surveys may be conducted to determine these patterns, but it is much more difficult to survey such issues as ideal elevator idle positions, optimal elevator car assignment, and elevator transport rules. Conducting research in this manner is time consuming, costly, and inflexible. Using a simulator to model the design problem is an excellent solution to these deficiencies. Furthermore, various scenarios can be quickly and efficiently compared. Any modifications in design variables may be experimented with to produce relatively fast results.

Problem:

A new elevator controller is to be designed to replace an old, elementary controller in an office building. There have been complaints that this simple controller is causing unnecessary delays in the increasingly busy office environment. You have been contracted to build an elevator simulation that will provide valuable insight into the design of the new controller. Alternate elevator routing assignments and operating policies are to be evaluated. Policies will be ranked based on queue time, service, time, and queue length.

Details:

Several design alternatives will be considered in this simulation. Table 1 outlines three alternatives to implement in the simulation to model elevator operation rules.

Table 1. Elevator Operation Alternatives

Design Alternative	Description
Normal Operating Mode	• The nearest elevator will be assigned to a request placed by a passenger. • If there are multiple elevators equally close to the requesting floor an elevator will be chosen randomly. • Elevators will only respond to requests for the direction they are moving in • Once an initial passenger is picked-up the elevator will continue to move in the requested direction until all passengers have been picked-up and/or dropped off in the currently moving direction.
Odd Even Mode	• Passengers must choose between two queues. One queue is for elevators that only travel to odd floors and the other queue is for elevators visiting even floors. • All elevators are able to travel to the main floor. • This mode will follow the normal operating policies while conforming to the eligible floors to be visited
High Low Mode	• Passengers must choose between two queues. One queue is for elevators that only travel to the lower half floors and the other queue is for elevators visiting the top half floors. • All elevators are able to travel to the main floor. • This mode will follow the normal operating policies while conforming to the eligible floors to be visited

- Design an elevator simulator that will model a 15 floor office building. The first floor is the main floor. There are 4 elevator cars each with a capacity of 12 people. Other relevant information regarding the elevator is outlined in Table 2 below.

Table 2. Floor and Elevator Specifications

Parameter	Value
Number of Floors	15
Number of Elevators	4
Elevator Capacity	12 people
Passenger Load Time	2.7 s / person
Passenger Unload Time	1.2 s /person
Elevator Speed	0.25 m/s
Inter-floor Distance	4.5 m
Door Open Time	2.5 s
Door Close Time	3 s

- The simulation should keep all the above variables as parameters that can be modified by the user.
- The user should be able to select different operating modes described in Table 1.
- Each floor has a staircase. If a passenger has been waiting in the floor queue for a certain amount of time and the passenger's destination is less than a specified number of floors away, the passenger will use the stairs with a certain probability. The unknown variables are outlined in Table 3 below and should be kept as parameters that can be configured.

Table 3. Rules for Using the Stairs

Parameter	Value
Queue Time (s)	> 90
Travel Distance (# floors)	< 4
Probability for using stairs	50%
Time to walk up one floor	12 s
Time to walk down one floor	10 s

- A study has been performed on the arrival and departure patterns of the office building. There is a high demand for elevators moving up during early morning hours and after lunch and break periods. Similarly, there is a high demand for elevators in the down direction during lunch time, break time, and at the end of the work day. Table 4 identifies the employee arrival patterns for people arriving individually. The arrival pattern is an exponential distribution with inter-arrival times that vary by the hour. Table 5 shows the employee arrival patterns for people arriving by bus. Buses arrive at a fixed interval of 15 minutes. The number of people in an arriving batch of employees is uniformly distributed with upper and lower bounds that vary by the hour. The departure pattern for employees is outlined in Table 6. This table specifies the percentage chance that an employee returns to the elevator to make a service request to the main floor within the specified hour. This time can be assigned to each employee after they have entered the office. The exact departure time should be uniformly distributed over the hour. When the exit time duration expires the employee will arrive at the elevator queue for the floor he/she is on.

Table 4. Employee Inter-arrival Times for Individuals (minutes)

Hour	Monday	Tuesday	Wednesday	Thursday	Friday
0:00-0:59	-	-	-	-	-
1:00-1:59	-	-	-	-	-
2:00-2:59	-	-	-	-	-
3:00-3:59	-	-	-	-	-
4:00-4:59	-	-	-	-	-
5:00-5:59	-	-	-	-	-
6:00-6:59	7	6.5	6.7	7.1	6
7:00-7:59	1	1	1	1	1
8:00-8:59	0.5	0.4	0.6	0.7	0.5
9:00-9:59	1	1	1	1	1
10:00-10:59	5	5	5	5	5
11:00-11:59	7	7	7	7	7
12:00-12:59	6	6	6	6	6
13:00-13:59	3	3	3	3	3
14:00-14:59	10	9	8	8.5	9.5
15:00-15:59	7	6.5	7	8	7
16:00-16:59	6	6	6	6	6
17:00-17:59	10	12	11	12	12
18:00-18:59	55	55	55	56	55
19:00-19:59	59	57	59	58	59
20:00-20:59	59	59	59	59	59
21:00-21:59	59	59	59	59	59
22:00-22:59	-	-	-	-	-
23:00-23:59	-	-	-	-	-

Table 5. Lower and Upper Bounds for Number of Employees Arriving in a Group

	Monday		Tuesday		Wednesday		Thursday		Friday	
Hour	Lower Bound	Upper Bound	Lower Bound	Lower Bound	Upper Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
0:00-0:59	0	0	0	0	0	0	0	0	0	0
1:00-1:59	0	0	0	0	0	0	0	0	0	0
2:00-2:59	0	0	0	0	0	0	0	0	0	0
3:00-3:59	0	0	0	0	0	0	0	0	0	0
4:00-4:59	0	0	0	0	0	0	0	0	0	0
5:00-5:59	0	0	0	0	0	0	0	0	0	0
6:00-6:59	0	1	0	1	0	1	0	1	0	1
7:00-7:59	2	5	2	4	2	5	2	5	2	5
8:00-8:59	10	20	10	19	10	18	10	20	10	21
9:00-9:59	10	15	10	15	10	15	10	13	10	15
10:00-10:59	2	3	2	3	2	3	2	3	2	3
11:00-11:59	2	3	2	3	2	3	2	3	2	3
12:00-12:59	2	4	2	4	2	4	2	4	2	4
13:00-13:59	5	10	5	10	5	10	5	10	5	10
14:00-14:59	1	2	1	2	1	2	1	2	1	2
15:00-15:59	2	3	2	3	2	3	2	3	2	3
16:00-16:59	1	2	1	2	1	2	1	2	1	2
17:00-17:59	1	2	1	2	1	2	1	2	1	2

18:00-18:59	0	0	0	0	0	0	0	0	0	0
19:00-19:59	0	0	0	0	0	0	0	0	0	0
20:00-20:59	0	0	0	0	0	0	0	0	0	0
21:00-21:59	0	0	0	0	0	0	0	0	0	0
22:00-22:59	0	0	0	0	0	0	0	0	0	0
23:00-23:59	0	0	0	0	0	0	0	0	0	0

Table 6. Percentage Chance an Employee Requests an Elevator to Leave the Office (By Hour)

Hour	Monday	Tuesday	Wednesday	Thursday	Friday
0:00-0:59	0%	0%	0%	0%	0%
1:00-1:59	0%	0%	0%	0%	0%
2:00-2:59	0%	0%	0%	0%	0%
3:00-3:59	0%	0%	0%	0%	0%
4:00-4:59	0%	0%	0%	0%	0%
5:00-5:59	0%	0%	0%	0%	0%
6:00-6:59	0.25%	0.25%	0.25%	0.25%	0.25%
7:00-7:59	1%	1%	1%	1%	1%
8:00-8:59	1%	2%	1%	1%	2%
9:00-9:59	1%	1%	1%	1%	1%
10:00-10:59	2%	2%	2%	2%	2%
11:00-11:59	5%	5%	5%	5%	5%
12:00-12:59	30%	30%	28%	30%	30%
13:00-13:59	3%	3%	3%	3%	3%
14:00-14:59	5%	5%	5%	5%	4%
15:00-15:59	2%	2%	2%	2%	2%
16:00-16:59	4%	4%	4%	4%	4%
17:00-17:59	45%	44%	47%	45%	45%
18:00-18:59	0.5%	0.5%	0.5%	0.5%	0.5%
19:00-19:59	0.25%	0.25%	0.25%	0.25%	0.25%
20:00-20:59	0%	0%	0%	0%	0%
21:00-21:59	0%	0%	0%	0%	0%
22:00-22:59	0%	0%	0%	0%	0%
23:00-23:59	0%	0%	0%	0%	0%

- The traffic to each floor is not equally distributed. Table 7 identifies the probability that a floor will be the destination of an employee making an elevator request at the main floor.

Table 7. Probability Profile for Floor Destinations from the Main Floor

Destination Floor	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Probability (%)	7%	8%	13%	3%	15%	14%	3%	6%	6%	7%	4%	7%	5%	3%

- Provide visually pleasing, professional reports on your simulation results that can be accessed from the simulation model (You can link to spreadsheets through dialogs or menus). Your reports should include, but are not limited to: Minimum, Average, and Max Queue Time, Queue Length, and Service Time. Also, have a report on Elevator Idle Time, Stair usage statistics, Ideal Location to Keep Idle Elevators and Elevator Capacity statistics.
  Notes:
  > *Queue time: the time between entering the queue and entering the elevator*
  > *Queue length: the length of a queue (recorded every time an employee enters a queue)*
  > *Service time: the time between entering the elevator and leaving the elevator (If the employee uses the stairs the Service time is the time between leaving the queue to take the stairs and reaching the destination floor)*

- Study the difference, if any, between the Odd/Even and High/Low operating modes. Collect your data on these two modes and present it in a spreadsheet. Figure 1 below illustrates the eligible floors for each operating mode. Divide the operating modes evenly between the 4 elevator cars. Feel free to create your own operating modes and see how they compare to the ones listed above.

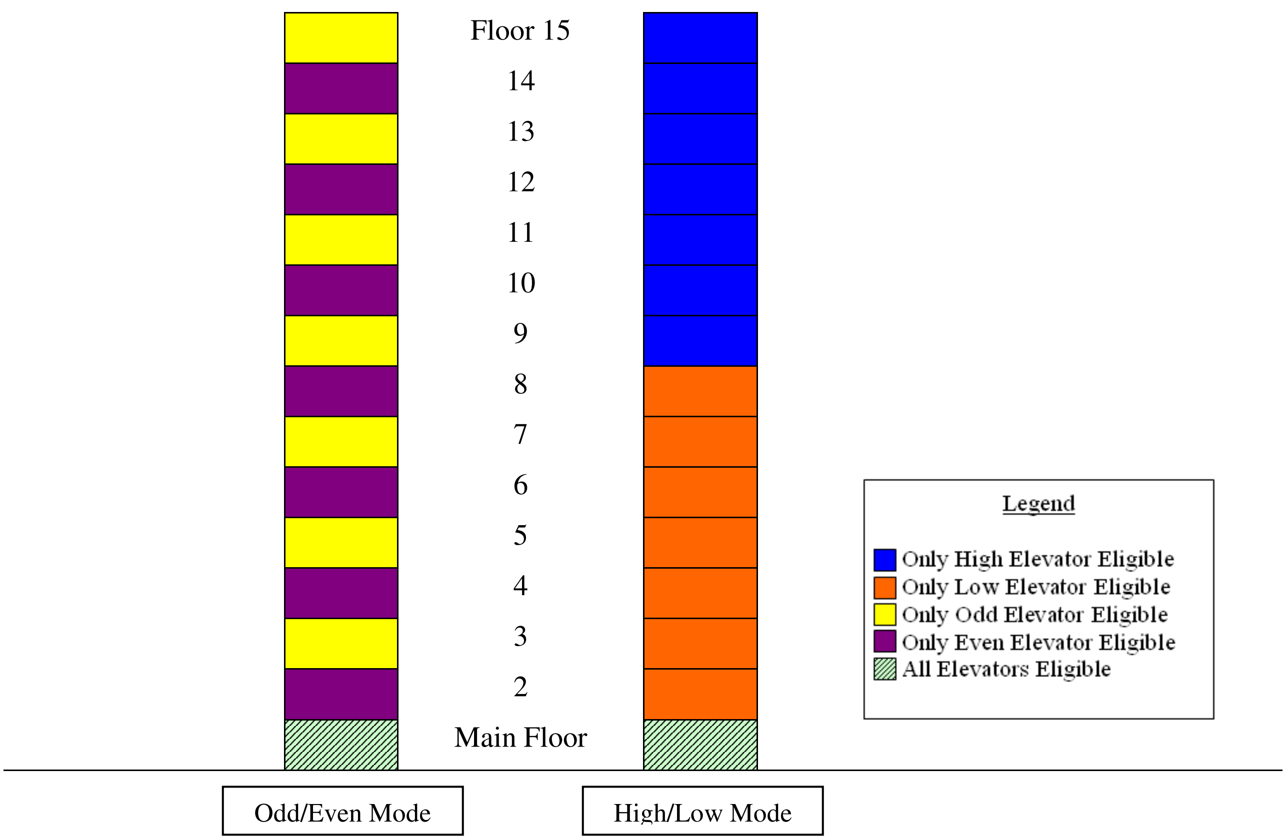

Figure 1. Outline of Eligible Floors for Odd/Even and High/Low Operating Modes

- Finally, ensure your model is flexible enough so that it can be easily configured to model different structures requiring an elevator system. If there are data items that are unclear or unavailable make an assumption. Include any assumptions you have made in your submission.

Deliverable

You have been commissioned to develop a discrete-event simulation model of the Elevator System to determine the optimal elevator controller. Ensure that your results are statistically significant by completing a number of trials to understand potential variability in the results.

In addition, the numbers presented above were collected through preliminary studies and are likely to change as further studies are performed. As the end users of the system will not have knowledge of simulation development, the model should be set up to take inputs and display results through a dialog and spreadsheet-based interface wherever possible.

A detailed project report should also be included. This should include information on what the model does, what assumptions were made, how the results are to be interpreted, any limitations of the model, and the general impact on business profitability that can be expected as a result of implementing the consultant's recommendations.