Homework: Discrete Event Simulation

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The previous homework questions involved a freeway on-ramp with a tool booth. This were modeled using both M/M/1 and M/M/c (or M/M/N) models, but here are simulated directly using the `simmer` R package. A vehicle arrives at the on-ramp, possibly joins a queue, is serviced by the toll booth, and exits the system. The average vehicle arrival rate at this on-ramp is 100 vehicles per hour, or an average of 36 seconds between each arriving vehicle. Each toll booth can service a vehicle in on average 20 seconds.

In order for these results to be comparable to M/M simulations, the arrival and service rates use an exponential distribution where the probability density function $f(x)$ is given by

$$f(x) = \lambda e^{-\lambda x}.$$

100 iterations of each (1-hour) simulation are run, and the values presented here are calculated across all iterations. Additionally, there is a "start-up" time before the system reaches a loaded state. No data from before this time will be used. Based on Figure 1, this time is chosen to be 100 seconds.

The results for both the existing one-booth scenario and the proposed two-booth scenario are presented in Table 1. Note the average number of vehicles in the system is weighted by time, and includes vehicles currently being served. The average wait time is given per vehicle. The probability that there are 3 or more vehicles in the queue is calculated by taking the proportion of the simulation time across all iterations where the queue was three or more vehicles long.

Table 1: Selected Results of Simulation

Toll booths	Average vehicles in system	Average wait time (s)	$P(\geq 3$ in queue)
1	1.54	25.2	0.098
2	1.01	1.9	0.003

The two-booth scenario saves 23.3 seconds per vehicle, and at a value of time of \$10/hr this is 16.2 ¢/vehicle. At an average arrival rate of 100 vehicles per hour, this saves \$16.2/hr. Since the hourly wage is \$25/hr, the additional booth does not make much economic sense.

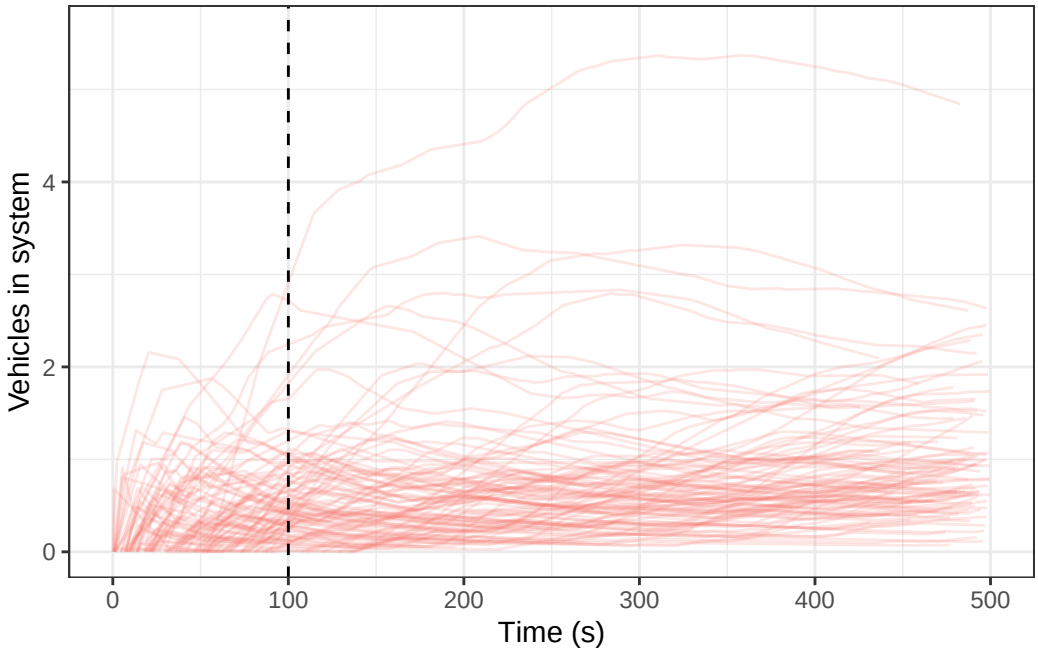

Figure 1: Number of vehicles in the one-booth simulation. The "start-up" time is shown, and no data will be used from before this time.