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In 2004/2005, the course INFOSIM was given by Marjan van den Akker.

Simulation (INFOSIM)
November 10, 2004

Question 1 *(27 points)*

We consider a company providing mobile car repair service (wegenwacht) in a rather small but quite crowded country. For performing repairs the company owns 50 service vehicles. The company operates according to the following strategy. The country is divided into 50 regions to which one service vehicle is assigned. This implies that each service vehicle handles all service requests in its own region.
We consider one of the regions: Utrecht-Oost. In this region requests for repairs arrive according to a Poisson process with an intensity of 1 per hour. Moreover, handling a request, i.e. driving to the car needing a repair and performing the repair takes a time which is exponentially distributed with an average of 30 minutes.

a) For the region Utrecht-Oost, determine the average waiting time of a car requesting repair service and the average number of can waiting for service. *(4 points)*

To increase flexibility and to improve service, the company dicides to omit the strict partitioning into the regions. However, it still wants to avoid that service vehicles travel all over the country. Therefore, a service vehicle is never allowed to handle a repair at more than 100 kilometres from its base station.
Requests for repair service now arrive in a central callcenter according to a Poisson process with an intensity of 60 per hour. When a request arrives, it is checked if there is a free service vehicle within 30 kilometres from the car requesting service. If so, the closest free service vehicle is going to handle the requested repair. Otherwise, the request is put in a queue.
If a service vehicle has finished a repair, it will select a request hom the queue to handle next. The service vehicle will select the request from the car which is nearest to its current location, under the condition that this car is less than 30 kilometres away. However, there is an exception to this rule. If there are requests waiting for more than one hour, these get priority over others and can also be handled by vehicles more than 30 kilometres away. In this category, cars with a longer waiting time get a higher priority.
If a service car is not working on a repair, it will stay at its current location. The time to handle is service request consists of two parts:

- The traveling time which is exponentially distributed with an average of $\frac{d}{80}$ hour, where d is the distance from the service vehicle to the car requesting a repair.
- The repair time, which is exponentially distributed with an average of 20 minutes.

b) Give a discrete-event simulation model to evaluate the average waiting time for a repair, the average number of waiting cars, and the fraction of the time that the service vehicles are busy.

Your model should be based on **event-scheduling**. Event-handlers may be described in words. *(18 points)*

c) Describe how you should validate the above simulation model. *(5 points)*

Question 2 *(23 points)*

We consider a 4-stage production line with one machine per stage. Let the machine in stage i be denoted by M_i. We are dealing with discrete parts, i.e. products such as lamp-sockets, and *not* with process manufacturing, i.e. products like oil. The input material for the line is continuously available. After each of the machines 1, 2 and 3 there is an output bin of limited size; b_i denotes the output bin size for M_i $(i = 1, 2, 3)$. Note that the values b_1, b_2 and b_3 may be different. Only full bins are transported to the next stage. The transportation capacity is not a limiting factor. Each of the machines 2, 3 and 4 have an input buffer of limited size, where c_i denotes the size of the input buffer of M_i $(i = 2, 3, 4)$. Also the values c_2, c_3 and c_4 may be different. If the output buffer of a machine is full and cannot be transported to the next phase, the machine stops. Moreover, all the machines suffer from failures occurring at unpredictable moments in time and with uncertain duration.

a) What are the advantages and disadvantages of large buffers and of small buffers in this production line? *(4 points)*

b) One of the machines has processing times that follow the 5-Erlang distribution with an average of 10. How can we generate these processing times in a program written in an imperative programming language like Java or C++? *(4 points)*

   Note: You do not have to give a program, but just a description or pseudo-code.

c) On another machine the following processing times were observed: 0.45, 1.2, 1.55, 1.75, 2.1, 2.35, 2.5, 2.6, 2.8, 3.1, 3.49, 3.8 and 4.6. Give an empirical distribution based on these numbers, from which the processing times can be generated. *(3 points)*

d) Which theoretical distribution provides a reasonable fit to the numbers for part c)? *(4 points)*

e) Let $45, 48, 51, 46$ and 49 be the average lead time of a product, observed in 5 sufficiently large and independent runs of a simulation of the above production line. Determine $\bar{X}(5), S^2(5)$ and a 95 percent confidence-interval for the expected value μ and explain the meaning of the computed quantities. *(4 points)*

f) The owner of the production line wants to find the buffer sizes that minimize the average lead time of a product. Sketch how you can solve this optimization problem with a local search algorithm. *(4 points)*