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In 2007-2008, the course INFOSIM was given by Dr. Ir. J. M. van den Akker.

Final exam Simulation (INFOSIM)
July 1st 2008

Answers may be provided in either Dutch or English.
All your answers should be clearly explained.
Calculators are not necessary.

The maximum score (100 in total) is as follows:

	Question 1	**Question 2**
a	6	10
b	10	6
c	14	10
d	10	10
e	10	14
total	50	50

Question 1

We consider the company LogEquip which produces equipment and machinery for logistic pro- cesses: for example robots, forklifts, and different types of conveyors. Generally speaking, LogEquip sells two types of equipment. The first type is more 'old-fashioned' in the sense that it is not computer driven, and the second type is computer driven.
In this assignment we consider the service department. This department provides repair and maintenance of equipment at the location of their customers. Service is only provided upon request (by phone or e-mail) from a customer. This may occur 24 hours a day.
For the first type of equipment, one specialized repairman is continuously available, who only works with this type of equipment. This is realized by different persons each working in a shift of 8 hours, i.e., we need 3 persons per 24 hours. Requests for service arrive according to a Poisson process with an average of 10 per 24 hours. The service times follow an exponential distribution with an average of two hours. This includes the traveling time to the customer.

a) Analytically compute the average 'down' time of equipment experienced by customers, i.e. the average time between placing a request until the equipment is repaired/maintained again. If you made any assumptions for the computation explain these?

For the computer driven equipment, service is more complicated. Repair or maintenance pro- ceeds in two steps. The first step is performed by the hardware specialist, who needs on average one hour of traveling time and then works on the equipment for 30 minutes on average. The second step is performed by the software specialist, who needs on average one hour of traveling time and then works on the equipment for one hour on average. The traveling times follow a normal distribution with a standard deviation of 15 minutes and working times follow an exponential distribution.

During each time of the day, there are 2 hardware specialists and 3 software specialist available. Request for repair arrive according to a Poisson process with an average of 28 request per 24 hours.

We first assume that upon arrival of a customer request, the company decides to send a hardware specialist as soon as possible. **Only after** the hardware specialist is finished, a request for the next step, i.e., the software specialist, is made. Requests that cannot be handled directly are handled in a FIFO order.

b) Which are the events that have to be included in an event-scheduling model for this simulation? Draw the event-graph corresponding to these events. For each arc in the graph give the delay in event-scheduling corresponding to this arc.

To improve customer service, the company wants to try a different strategy for initiating the second step. As soon as a hardware specialist starts traveling towards a customer, a software specialist is *requested* to start traveling to the customers 30 minutes later. This implies that if a software specialist is directly available, his expected arrival time at the customer is equal to the time the hardware specialist finishes his repair/maintenance work.
Again, requests that cannot be handled directly are handled in FIFO order.

c) Which are the events that have to be included in an event-scheduling model to simulate the new strategy? Draw the event-graph corresponding to these events. For each arc in the graph give the delay in event-scheduling corresponding to this arc. Give a clear description on how the activities of the software specialist are started in your simulation model. It should be clear in which event-handler(s) this happens.

d) Elaborate on the advantages and disadvantages that may be expected from the new strategy, compared to the old strategy? Give at least two performance measures that can be used to make a good comparison between the strategies? Describe how these should be computed during the simulation.

When assigning a specialist to a request, it might be very beneficial to include the distances between two customers that are subsequently visited by one specialist into account. You may assume that a specialist that has completed his repair/maintenance work at a certain customer and did not get a new request, will stay a the place where he finished until he gets a new request.

e) Give an example of a rule that could be used. Suppose your rule would be used. What would be the state that needs to maintained during the simulation? What are the differences with the state that needs to be used in part (b) and (c)? Explain your answer.
We assume that the state only contains information that is strictly necessary

Question 2

We consider a medium-sized hospital. Part of the patients need surgery. These patients can be divided into m types depending on the surgery that they need. The operation of a patient of type $i\,(i = 1, \ldots, m)$ takes on average p_i minutes. Moreover a patient of type i has to stay in the hospital for d_i days on average and requires on average n_i hours of time from a nurse during each day that the patient stays in hospital. Here the day that surgery takes place is counted as the first day in the hospital.

a) For patients of type 1, the surgery time p_1 follows the 3-Erlang distribution with an average of 90. How can we generate these surgery times in a program written in an imperative programming language like Java or C++ and without using *any* specific random generation libraries?
Note: You do not have to give a program, but just a description or pseudo-code.

The hospital wants to work with a cyclic admission pattern of patients, i.e., for each working day of the week and for each type of patients the management wants to determine a fixed number qit of patients of type i that gets surgery on day $t\,(i = 1, \ldots, m; t = 1, 2, 3, 4, 5)$. In total, the hospital has to accommodate Q_i patients of type i per week. We are given that on day $t\,(t = 1, 2, \ldots, 5)$ the available amount of time in the operation theater is P_t . The number of available nurses on day t equals V_t for $(t = 1, 2, \ldots, 7)$ where $t = 6$ and $t = 7$ correspond to Saturday and Sunday respectively. On these days the number of available nurses is typically lower than on weekdays. Moreover the number of available beds for patients that had surgery equals B.

The management of the hospital wants to make planning in which the utilization factors of the operation theater, nurses and beds are as stable as possible, i.e., the ratio of used and available capacity is more-or-less constant during the week. Note that the planning process is complicated by the fact that the surgery times p_i, the required durations d_i to stay in the hospital and the required nursing time n_i are subject to uncertainty.

b) Suppose p_1 would follow a 10-Erlang distribution instead a 3-Erlang distribution, but with the same average value. Would this improve or deteriorate the performance of the system? Explain your answer.

c) Suppose we run a simulation of the system for 700 consecutive days (i.e. 100 weeks) and we perform 50 of such runs. Let U_{is}^{nurse} be the utilization factor of the nurses on day s ($s = 1, \ldots, 700$) in run i. Explain the concept of steady state. Does this simulation get into a steady state with respect to the quantities U_{is}^{nurse}? Explain your answer.

d) Describe how we should perform a decent output analysis to evaluate the utilization factor of the nurses?

e) Describe the above problem as a combined optimization and simulation problem, i.e. formulate (either in words or formulas) the objective function and the constraints and indicate at which point a simulation has to be performed.