Utrecht University
Faculty of Science
Department of Information and Computing Sciences

Final Exam Simulation, Thursday April 9, 2015, 11.00-13.00 hr.

- Switch off your mobile phone, PDA and any other mobile device and put it far away.
- This exam consists of **7** questions
- Answers may be provided in either Dutch or English.
- All your answers should be clearly written down and provide a clear explanation. Unreadable or unclear answers may be judged as false.
- Please write down your name and student number on every exam paper that you hand in. Hand in this exam completely together with your answers on exam papers.
- A statistical table is handed out separately and should be returned at the end.
- The maximum score (10 in total) is divided as follows:

Question	Score
1	1.5
2	1
3	1.5
4	1.5
5	1.5
6	1.5
7	1.5

Good luck, veel succes !

The dynamic bus station

We consider a dynamic bus station. We assume that we are given a timetable for n buses, with scheduled arrival times $a_i^{\text{scheduled}}$ $(i = 1, \ldots, n)$ and departure times $d_i^{\text{scheduled}}$ $(i = 1, \ldots, n)$ of buses at the station. We assume that the actual arrival times a_i^{actual} have a deviation from the scheduled arrival time according to a normal distribution with average 0 and standard deviation 3 minutes.

The bus company wants to perform a discrete-event simulation study to decide on the required number of platforms. Each platform consists of a front and rear position. A bus that arrives at the station can go to any free platform position, where it has a preference to use the front position of a platform. However if the rear position of a platform is occupied, a bus cannot reach the front position by overtaking another bus. If all reachable positions are occupied, the bus has to wait in a first-come first-served queue. The total amount of time needed to disembark the passengers and embark new passengers at the platform is **subject to uncertainty**; it follows a uniform distribution between 1 and 6 minutes. Bus i can only leave when the disembarking and embarking is finished, but it is not allowed to leave before its scheduled departure time from the time table $d_i^{\text{scheduled}}$. Clearly, a bus cannot leave a rear position, if the front position is still occupied.

Discrete-event modeling

(1) Which events are included in the event-scheduling model for this problem? Draw an event graph and give the time delays on each of the arcs.

(2) One possible performance measure is the average departure delays of buses. Give two other appropriate performance measures and describe how to compute them in the simulation.

(3) Describe three possible actions to validate the simulation model of the dynamic bus station.

Stochastic aspects

(4) Suppose we have performed 10 simulation runs to measure the average departure delay of buses in the rush hour for two situations: 9 platforms and 10 platforms. The following table gives the average delays in minutes for each of the runs.

Run	9 platforms	10 platforms
1	5	4
2	6	4
3	5	6
4	5	5
5	6	5
6	7	7
7	8	6
8	5	4
9	6	5
10	6	6

Determine with a confidence level of 95% if the average delay of buses is changed if we increase the number of platforms from 9 to 10.

(5) A careful study of the arrival times of buses at the station revealed that on average 10% of the buses are too early and 90% are too late. If buses are too early the deviation from the scheduled arrival time $|a_i^{\text{actual}} - a_i^{\text{scheduled}}|$ follows a uniform distribution between 0 and half a minute (30 seconds). If buses are too late the deviation from the scheduled arrival time $|a_i^{\text{actual}} - a_i^{\text{scheduled}}|$ follows an exponential distribution with an average of 2 minutes.

How can we generate the deviations from the scheduled arrival time in minutes in a program written in an imperative programming language like Java or C♯ without using *any* specific random generation libraries or functions?
Note: You do not have to give a program, but just a description or pseudo-code.

Inventory

(6) The special pins attaching the automatic doors to the buses have to be replaced after approximately three years. We consider the company that produces these pins. For the specific type required for our buses, the demand is normally distributed with a known expected value and variance. It is known that the average demand per four weeks is 4000 with a variance of 360 per four weeks. The weekly demands are assumed to be independent and also normally distributed. The company wants to use the (r, q)-model as a basis for its inventory management.

- Explain the (r, q)-model.
- Given the fixed ordering cost 196 and the holding cost 0.2 Euro per item per week, determine the optimal value of q.
- Given a constant lead time of one week and a backlogging cost of 11.2 Euro per item, compute the value of r. What is the size of the safety stock in this example?

Simulation and optimization

The bus company decides that from now on each bus trip arriving at the station has to use a fixed platform, e.g. line 2 with scheduled arrival time 9.06h always uses platform 6 (as described before it uses the front position if this is free and the rear position otherwise). Suppose the number of platforms is given and equals 10 (since each platform has a front and rear position there are 20 positions in total). The question now is, which bus should be assigned to which platform.

(7) We want to solve this as a combined optimization and simulation problem.

- What are the decision variables?
- Define an appropriate objective function.
- Describe an algorithm to solve the above problem based on combined optimization and simulation and clearly explain when you have to perform a simulation.