Utrecht University
Faculty of Science
Department of Information and Computing Sciences

Final Exam Simulation, Tuesday April 16, 2013, 14.00-17.00 hr.

- Switch off your mobile phone, PDA and any other mobile device and put it far away.
- This exam consists of 8 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 description of the modelling assignment is attached.
- The maximum score (100 in total) is divided as follows:

Question	Score
1	15
2	10
3	10
4	10
5	(a) 5, (b) 5
6	15
7	15
8	15

Good luck, veel succes !

The dynamic bus station

We consider a dynamic bus station. We assume that we are given a timetable with expected arrival and departure times of buses at the station. We assume that the actual arrival times have a deviation from the expected 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, a bus cannot reach the front position by overtaking another bus if the rear position of the same platform is occupied. 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. A bus can only leave when the disembarking and embarking is finished, but it is not allowed to leave before its scheduled departure time t^d. 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 delay on each of the arcs.

(2) Describe in pseudo-code the event handler of the event(s) that concern departure from the front position of a platform. You do not have to include the computation of the performance measures, but you should give a definition of the state variables that are used.

(3) Give two performance measures that are appropriate for this simulation study. For each of these performance measures, show how it should be computed within the simulation program.

In the near future, part of the buses will become electric vehicles. These have to charge their battery at the bus station. For this reason, all rear platform positions of the platform will be equipped with charging equipment, which implies that electric buses can charge by parking at such a platform. Electric buses have to use a charging platform, while standard (gasoline) buses can use any platform. For electric buses the charging time follows a uniform distribution between 9 and 15 minutes, during which the passengers also disembark and embark. The timetable indicates which arrivals and departures are by electric buses.

(4) Describe how the event graph has to be adapted to this new situation.

Stochastic aspects

(5) (a) At the bus station, there is an information desk. During opening hours of the desk, customers arrive according to a Poisson process with an average of 40 per hour. The service times follows an exponential distribution with an average of 1 minute. There continuously is one employee on duty at the desk. What is the average queue length before the desk (this excludes the person that is served at the desk)? Explain your answer.

(b) A more careful study of the service times at the information desk revealed that this time follows a 4-*Erlang*(β) distribution where β equals 15 seconds (which consists of 4 exponentially distributed phases with average β) . Since the service time distribution deviates from the exponential distribution, the average queue length computed in part (a) will probably be incorrect. Is the average queue length in this situation smaller or larger than in part (a)? Explain your answer?

(6) How can we generate the service times from part (5b) in a program written in an imperative programming language like Java 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

(7) The batteries of the electric buses have to be replaced after 100.000 kilometers. We consider the company that delivers these batteries. For this specific type, the demand is normally distributed with a known expected value and variance. It is known that the average demand per four weeks is 40 with a variance of 36 per four weeks. The weekly demands are assumed to be independent. 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 100 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 40, compute the value of r. What is the size of the safety stock in this example? *A statistical table is attached.*

Simulation and optimization

The city council has decided that the bus company has to pay a penalty cost for each bus that is departing from the bus station with a delay of at least 2 minutes. The penalty cost amounts to c_i if the bus departs with a delay of i minutes for $i = 2, 3, 4, \ldots, 20$. The c_i values are strongly increasing in i. If the delay is more than 20 minutes or when a trip is cancelled, the cost are also c_{20}.

To avoid these penalty costs the bus company considers using standby buses and drivers at the station. A standby bus can replace a bus which is going to arrive with a large delay, so that the next departure of the delayed bus can be performed on time by the standby bus. The number of standby buses can vary during the day.

(8) To find an appropriate schedule for the standby buses the company wants to use combined optimization and simulation. Describe how combined optimization and simulation can be applied to solve the above problem.