# Exam Modeling of Business Processes
# 18 February 2003

This exam consists of 4 problems, each consisting of several questions.
All answers should be motivated, including calculations, formulas used, etc.
It is allowed to use 1 sheet of paper (or 2 sheets written on one side) with **hand-written** notes.
The minimal note is 1. Questions 1, 2, and 3 each give 2 points when correctly answered, question 4 can give 3 points.
The answers may be written down in English or in Dutch.
The use of a calculator is allowed.

1. An Erlang calculator can calculate the service level, defined as the percentage of callers that waits longer than $t$ seconds, based on the arrival rate $\lambda$, the average service time $\beta$, and the number of servers $s$.
In a call center there are on average 10 calls per minute, that require each on average 3 minutes to answer. The acceptable waiting time is 20 seconds, and the time between the moment a call is assigned to an agent and the moment it is answered by the agent is around 3 seconds.
a. Give the parameter values for the Erlang calculator by which you can calculate the service level in the call center.
b. To obtain a service level of around 80% 35 agents are needed. Define productivity and calculate it.
c. A model is not an exact description of reality. Give 3 aspects in which the Erlang system does not model the call center exactly.
d. The arrival rate doubles to 20. The manager decides to double the number of agents. What do you expect to be the consequences for the costs and the service level? Motivate your answer!
e. Estimate without using the Erlang formula how many agents need to be scheduled to obtain a 80% service level. Motivate your answer.

2. A small airplane has a capacity of 10 seats. There are 2 fare classes. The price of a type 1 ticket is E 200, of a type 2 ticket E 500. Type 1 customers book before type 2 customers. The demand for type 2 tickets is distributed as follows:

| demand | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| probability | 0 | $\frac{1}{10}$ | $\frac{1}{10}$ | $\frac{1}{10}$ | $\frac{1}{10}$ | $\frac{1}{10}$ | $\frac{1}{10}$ | $\frac{1}{10}$ | $\frac{1}{10}$ | $\frac{1}{10}$ | $\frac{1}{10}$ |

a. Without overselling, how many seats would you reserve for type 2 customers?
b. If demand for type 2 is independent of demand for type 1, but equally distributed, what is the expected total revenue?
c. Answer the same questions if overselling does take place and type 1 customers are willing to take another flight for E 100.

3. Consider a system consisting of $n$ parts that each fails, independently of the other parts, after a time that is uniformly $[0, 1]$ distributed, i.e., the density of the time to failure of each component is 1 in $[0, 1]$, 0 otherwise.
a. Give the definition of the failure rate and the system function.
b. Compute the failure rate of the life time of a single component.
c. Let the system consist of $n$ parts in series. Compute the failure rate of the life time of the system.
d. Let the system consist of $n$ parts in parallel. Compute the failure rate of the life time of the system.

4. A project has the following activities:

| Activity | Preceding activities | Duration |
|---|---|---|
| A | - | 2 |
| B | A | 3 |
| C | A | 2 |
| D | C | 1 |
| E | B,D,G | 2 |
| F | - | 3 |
| G | C,F | 2 |

Assume for the moment that there are enough resources.
a. Make a graph representation of this project.
b. Compute the earliest finish time of the project and all earliest and latest starting times of the activities. (Hint: renumber first the activities.)
c. Give the definitions of slack, critical activity, and critical path.
d. Compute in the example project the slack of each activity. What is the critical path?
Suppose that activities B and C use the same resource. Therefore they cannot be scheduled at the same time.
e. What is now the earliest finish time of the project?
f. Prove that the solution to d. gives indeed the earliest finish time possible.