Leibniz Universität Hannover
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Institut für Produktionswirtschaft
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Exam
on
Manufacturing Systems Modeling and Analysis
Winter Term 2018-2019

Hints:

1. The exam consists of **9** pages (including this front page). Please check that your copy is complete and complain immediately if it is not.
2. Answer all questions and solve all given problems.
3. You are given 60 minutes to work on the exam and you can score a total of 60 points.
4. You may answer the questions using either the German or the English language.
5. **Show your work!** If you use a formula to solve a problem, presents it in its general form first!
6. You may use a single double-sided and hand-written help sheet in in letter format or DIN-A4 format with any content you may find helpful to work on the exam.
7. You may use a pocket calculator.
8. For this exam written in a university computer lab you may use the desktop computer provided by the university and the Matlab files related to this exam that have been provided in class and stored locally on this machine for your usage while working on the exam.

Personal data:

Family name	Given name	Matriculation number	Study program

Rating:

Task	1	2	3	Sum
Score				

1. **Analysis of a Markovian three-stage flow line with reliable machines and limited buffer capacities** **(30 P.)**

Consider a three-stage flow line with limited buffer capacity C_1 behind machine M1 and C_2 behind machine M2. The first machine is never starved and the last machine is never blocked. Assume that machines are reliable, i.e., there are no failures and hence also no repairs. Processing times are exponentially distributed with rates μ_1, μ_2, and μ_3 at machines M1, M2, and M3. We assume blocking after service.

Then the state of the system at any moment in time can be described as a vector (n_1, n_2) where n_1 is the number of parts in the system already processed by machine M1, but not by machine M2. Likewise, n_2 is the number of parts already processed by machine M2, but not M3.

a) Assuming $C_1 = \mathbf{2}$ and $C_2 = \mathbf{1}$, draw the diagram of states and transitions for a steady-state analysis. Explain how the case of both machines M1 and M2 being blocked simultaneously is modeled. (18 P.)

b) Assuming the general case of arbitrary non-negative integer buffer sizes C_1 and C_2 and given values of state probabilities $p(n_1, n_2)$, give the equations to compute

i. the production rate PR_1 via machine M1, (2 P.)

ii. the production rate PR_2 via machine M2, (2 P.)

iii. the production rate PR_3 via machine M3, (2 P.)

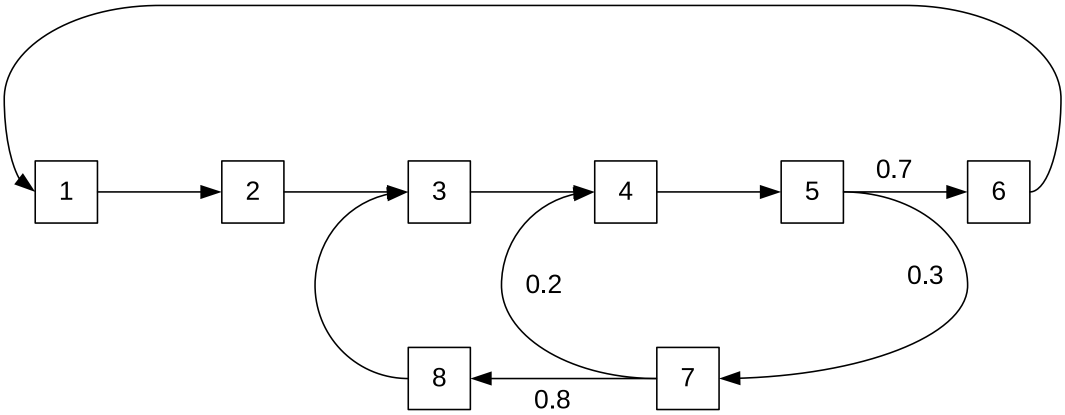
iv. the average inventory $\bar{n}_1$ of work pieces already processed by machine M1 but not machine M2, (2 P.)

v. the average inventory $\bar{n}_2$ of work pieces already processed by machine M2 but not machine M3, and (2 P.)

vi. the average total inventory $\bar{n}$ of work pieces already processed by machine M1 but not machine M3. (2 P.)

2. **Analysis of a closed single-server single-product network** **(15 P.)**

a) Analyze the network of single-server work stations used to produce a single product type that is depicted in the following figure.



The product units are mounted on pallets as they enter the system a station 1. Finished products are dismounted from the pallet behind station 6. The throughput of station 6 is hence equal to the throughput of the system in terms of completed product units. Transportation times as well as the times required for the mounting and dismounting processes are neglectable.

The routing probabilities of the stations performing a Markovian splitting of the departure stream are given in the figure. Assume that the processing times follow an exponential distribution. The following table gives the expected processing times $\mathrm{E}[T_s(i)]$ per station i:

Station i	$\mathrm{E}[T_s(i)]$ [min]
1	12
2	11
3	9
4	10
5	11
6	13
7	20
8	30

Assuming a constant number of $\mathbf{w} = \mathbf{20}$ work pieces circulating in the system and using an appropriate Matlab program, determine

i. the throughput of the system, (1 P.)

ii. the work in process, cycle time, throughput and server utilization at station 1, and (4 P.)

iii. determine the bottleneck of the system and its utilization: (1 P.)

iv. What happens to the throughput and the cycle time of the system as the number of workpieces circulating in the system increases further? Why? (3 P.)

b) Explain and justify

i. the fundamental cycle time equation on which the Mean-Value-Analysis algorithm is based (2 P.)

ii. as well as the conditions under which it yields exact results (2 P.)

iii. and why it leads to an iterative algorithm to determine performance measures for such a closed queueing network. (2 P.)

3. **Batching for setup reduction** **(15 P.)**

Consider a work station that has to be setup before a group or batch of similar items can be processed sequentially. Assume that the batch of size k is build in front of the work station. Individual work pieces arrive with rate $\lambda(I)$ at the work station. The expected processing time for the an individual work piece is $\mathrm{E}[T_s(I)]$ and the expected setup time is $\mathrm{E}[R]$.

a) Give and explain the expected value of the service time for a batch: (2 P.)

b) Give and explain the variance of the service time for a batch: (2 P.)

c) Give and explain the squared coefficient of variation of the service time for a batch: (2 P.)

d) Give and explain the the utilization of the server: (2 P.)

e) Give and explain the expected cycle time of an individual work piece at that station: (3 P.)

f) Explain which condition must be met in order for the system to be stable! (2 P.)

g) Draw and explain the general shape of the expected cycle time of individual work pieces as a function of the batch size. (2 P.)