Otto-von-Guericke-University Magdeburg
Faculty of Economics and Management
- Management Science -
Prof. Dr. Gerhard Wäscher

# Test

# Production Management & Operations Research

## (11072) and (5074)

## February 12, 2011

**Last name: .....** **First name: .....** **Matriculation No.: .....**

Examination: Production Management & Operations Research WS 2010/2011

Examiner: Prof. Dr. G. Wäscher

General remarks:

1. Write your name and matriculation number on this cover sheet and on every other sheet that has been issued to you.
2. Leave a minimum of 4 cm as correction space on the outside margin of each page.
3. Make sure that you have a complete copy of the test. The test consists of **6 assignments**, all of which have to be dealt with. It is not permitted to remove the retaining clip; doing so will be treated as fraudulent behaviour.
4. Please write legibly and number the pages which have been used. For each assignment, put down your answers on a separate sheet. Only pens with permanent ink may be used, while correction pens or ink erasers are not permitted. Make sure that you don't write in red.
5. Always make clear how you have determined your solution (solution path). Isolated solutions without traceable origin will not be accepted.
6. The following aids may be used: writing utensils, non-programmable pocket calculators without communicating and/or data processing functions, dictionaries (without any added remarks only).

**Assignment 1 (14 points)**

**Short Questions (questions 1-7):** Answer the questions in short! You do not need to write complete sentences – keywords are sufficient. (**Two** points for each completed question.)

1) Give a definition of the shadow price of a constraint!

2) Give a definition of the opportunity costs of a constraint!

3) Give a definition of "primary demand" and "secondary demand" as they are used in the Gozinto-Graph-based determination of total demands!

4) Let the following simplex tableau be given, which represents an optimal solution for the following objective function: $x_0 = 200x_M + 250x_W$.
Carry out a sensitivity analysis for the objective function coefficient of $x_M$!

| $x_0$ | $x_M$ | $x_W$ | $s_1$ | $s_2$ | $s_3$ | $s_4$ | RHS |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 1 | $\frac{1}{5}$ | $-\frac{1}{15}$ | 0 | 0 | 440 |
| 0 | 1 | 0 | $-\frac{1}{5}$ | $\frac{1}{10}$ | 0 | 0 | 560 |
| 0 | 0 | 0 | $\frac{1}{5}$ | $-\frac{1}{10}$ | 1 | 0 | 240 |
| 0 | 0 | 0 | $-\frac{1}{5}$ | $\frac{1}{15}$ | 0 | 1 | 860 |

5) The classic EOQ model is based on several assumptions. Name six of these assumptions!

6) Six production orders are to be manufactured in a two-stage production process. The operation times for the corresponding production orders (A, B, C, D, E and F) differ for the two stages, as can be seen from the table below:

| production stage / production order | production stage #1 | production stage #2 |
|---|---|---|
| A | 4 | 3 |
| B | 7 | 5 |
| C | 6 | 4 |
| D | 7 | 7 |
| E | 2 | 4 |
| F | 5 | 6 |

The sequence of stages through which the orders have to pass is identical for all orders. Overtaking of orders is not permitted.

Determine an order sequence by application of Johnson's Algorithm!

7) In order sequencing, processing time-related goals and capacity utilization-oriented goals can be distinguished. Name three processing time-related goals and two capacity utilization-oriented goals!

## Assignment 2 (14 points)

A company produces three types of TV sets: a low-cost, a medium price and a premium version. They want to determine the optimal production program for the following week (planning period): Three kinds of electronic components are needed in production – component A, B and C. The availability of the components is limited: Of component A there are 800 units available, of component B 600 units and of component C 400 units. The capacity at the bottleneck machine is restricted to 2,000 minutes in total (production at the bottleneck requires 12 minutes for the low-cost version, 15 minutes for the medium version and 18 minutes for the premium version of the TV set). The following table gives additional information about how many units of each component are used for each of the TV sets and how much profit contribution is provided by each of the TV sets:

| | low-cost | medium | premium |
|---|---|---|---|
| Component A | 5 | 6 | 8 |
| Component B | 4 | 6 | 8 |
| Component C | 3 | 4 | 5 |
| Profit contribution (€/unit) | 25 | 30 | 45 |

By application of the Simplex Method the following optimal tableau has been obtained:

| $x_0$ | $x_{low}$ | $x_{med}$ | $x_{prem}$ | $s_A$ | $s_B$ | $s_C$ | $s_{prod}$ | RHS |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 5 | 0 | 0 | 5/2 | 5 | 0 | 3,500 |
| 0 | 0 | -1/2 | 0 | 1 | 1/4 | -2 | 0 | 150 |
| 0 | 0 | 1/2 | 1 | 0 | 3/4 | -1 | 0 | 50 |
| 0 | 1 | 1/2 | 0 | 0 | -5/4 | 2 | 0 | 50 |
| 0 | 0 | 0 | 0 | 0 | 3/2 | -6 | 1 | 500 |

$x_0$ : profit contribution;
$x_{low}$ : number of low-cost units to be produced;
$x_{med}$ : number of medium price units to be produced;
$x_{prem}$ : number of premium units to be produced;
$s_i$ : slack variable of the procurement constraint of component i (i = A, B, C);
$s_{prod}$ : slack variable related to the bottleneck in production.

On the basis of this tableau, provide answers to the following questions:

a) What is the optimal product mix and the corresponding profit contribution for the following week? How many units of A, B and C will be needed?

b) The supplier offers one additional unit of component A at a price of 2 €. Would you buy it if you were the production manager? Explain your decision on the basis of the optimal tableau! What would be your answer if – ceteris paribus – one more unit of component C is offered at 4 €?

c) Assume that the supplier of component C increases his production capacity by a considerable amount and can therefore provide as many units of C as you need. How many additional units of C would you buy from him (Give reasons!)? What impact would that have on the company's profit?

## Assignment 3 (18 points)

A company buys a particular component from a supplier. The corresponding demand for the forthcoming eight months (planning period) has been forecasted as follows:

| month [t] | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| demand [$n_t$] | 50 | 40 | 100 | 80 | 50 | 60 | 40 | 70 |

The costs of placing one order (ordering cost rate) are 800 €, the holding costs amount to 4 € per month for each stored product unit (holding cost rate).

The following assumptions hold:

- Ordered products are received at the beginning of each month and can be processed without delays. Likewise, stored products can only be retrieved from the warehouse at the beginning of each month.
- At the beginning of the total planning period inventory is zero. At the end of the planning period inventory is required to be zero. No other inventory restrictions apply.

a) Give a general formulation of the cut-off criterion of the least-unit-cost-heuristic!

b) Determine an ordering policy by means of the least-unit-cost-heuristic!
For this policy, also give the corresponding holding, ordering and total costs of the planning period!

c) Give a general formulation of the cut-off criterion of the part-period heuristic!
Explain the rationale behind it!

**Assignment 4 (18 points)**

4a)

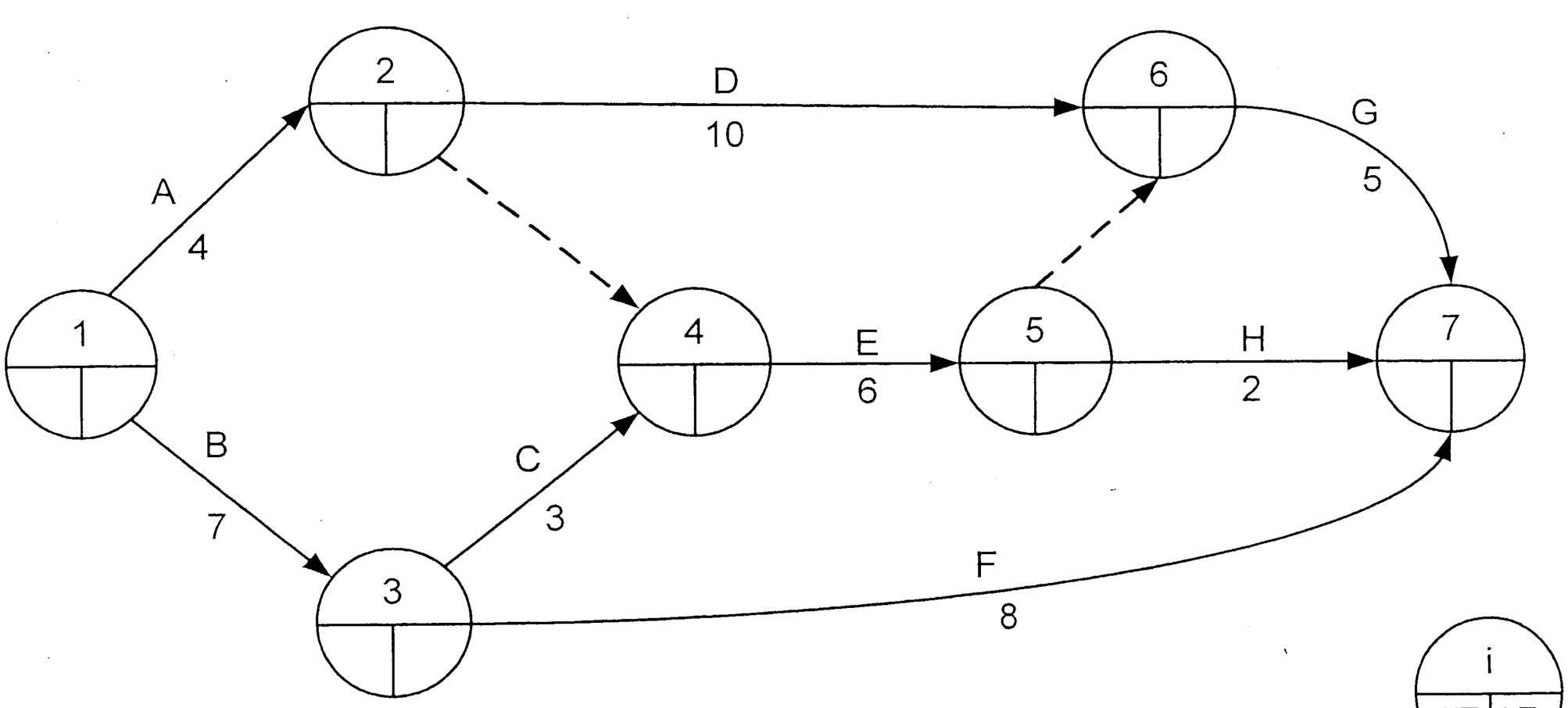
The following list of activities describes the structure of a project.

| activity | direct predecessors |
|---|---|
| A | - |
| B | - |
| C | - |
| D | A,C |
| E | C |
| F | B |
| G | B |
| H | D,E |
| I | F,G |
| J | G |
| K | H |
| L | H,I |
| M | I |
| N | J,K,L,M |

Draw an activity-on-arc network that represents the project structure! Minimize the number of dummy activities and the number of intersections of arcs!

4b)

The following activity-on-arc network represents a project. Names and duration of the activities are given next to the arcs. For each of the events 1 - 7, determine the earliest time of occurrence (ET), the latest time of occurrence (LT) and depict your results in the graph!




For each activity, determine the earliest and latest start time, the earliest and latest finish time, and the total and independent slack! Use the tableau given below!

| activity | (i, j) | $d_{ij}$ | | $EST_{ij}$ | $EFT_{ij}$ | $LST_{ij}$ | $LFT_{ij}$ | | $TS_{ij}$ | $IS_{ij}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| A | (1, 2) | 4 | | | | | | | | |
| B | (1, 3) | 7 | | | | | | | | |
| C | (3, 4) | 3 | | | | | | | | |
| D | (2, 6) | 10 | | | | | | | | |
| E | (4, 5) | 6 | | | | | | | | |
| F | (3, 7) | 8 | | | | | | | | |
| G | (6, 7) | 5 | | | | | | | | |
| H | (5, 7) | 2 | | | | | | | | |

**Assignment 5 (20 points)**

A production manager is about to plan the sequence according to which five orders (A, B, C, D, E) should be manufactured on four production stages (#1, #2, #3, #4). The following table represents the corresponding operation times on each production stage, as well as the total operation time and the total remaining operation times after each production stage (all data given in time units):

| production order | operation time at production stage | | | | total operation time | total remaining operation time | | |
|---|---|---|---|---|---|---|---|---|
| | #1 | #2 | #3 | #4 | | after stage #1 | after stage #2 | after stage #3 |
| A | 4 | 3 | 4 | 5 | 16 | 12 | 9 | 5 |
| B | 3 | 6 | 4 | 10 | 23 | 20 | 14 | 10 |
| C | 2 | 3 | 6 | 4 | 15 | 13 | 10 | 4 |
| D | 2 | 3 | 10 | 3 | 18 | 16 | 13 | 3 |
| E | 5 | 7 | 2 | 3 | 17 | 12 | 5 | 3 |

The sequence according to which the orders have to pass through the production stages is fixed and identical for all orders (#1, #2, #3, #4). Order splitting is not permitted.

Assume that the orders C, D and E will be available at t = 0! The orders A and B will become available at t = 5! Further assume that orders can pass each other! Due to maintenance activities, production stage #3 will be closed for five time units from t = 15 until t = 20!

a) Determine an order sequence for the sequencing problem by means of the Longest Remaining Operation Time (LROT)-Rule! Plot the corresponding GANTT-Chart!

b) Determine the corresponding cycle time, the capacity utilization, the idle time of stage #2 and the waiting time of order A!

c) Consider the following statement:

"In order sequencing, for a given set of orders, the minimization of the cycle time and the minimization of the total idle time are equivalent goals."

Give a general proof for this statement! Do not forget to define all the symbols properly which you have to introduce!

## Assignment 6 (16 points)

The following table depicts the work elements that have to be performed on an assembly line in order to provide a final product. Furthermore, the corresponding operation times (in minutes) and the immediate predecessors of each work element have been listed.

| work element i | operation time $t_i$ [min] | direct predecessor(s) |
|---|---|---|
| 1 | 6 | - |
| 2 | 8 | 1 |
| 3 | 10 | 1 |
| 4 | 3 | 2 |
| 5 | 6 | 3 |
| 6 | 7 | 3 |
| 7 | 5 | 5 |
| 8 | 5 | 5, 6 |
| 9 | 8 | 4, 7 |
| 10 | 9 | 8, 9 |

The desired output rate is 4 units per hour and the goal is to minimize the number of work stations needed.

a) What is the maximal cycle time, which cannot be exceeded if 4 units are to be produced per hour?

b) What is the theoretical minimum number of work stations for the desired output rate?

c) Plot the corresponding precedence diagram for the precedence relationships given in the above table!

d) Assign the work elements to stations according to the method of Helgeson and Birnie!

e) How many work stations are necessary? Also determine the total idle time and the capacity utilization of this solution!

f) What can be said about the optimality of the obtained solution? Explain your answer!