Case study for lecture "Production Systems and Supply Chains"
Tutorial III: Management
Summer term 2023

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Exercise 8: Static lot-size planning

For bottling the beer, the NJB brewers only use new glass bottles. After the consumption of the beer, the bottles are returned, introduced in the circular system, cleaned, and can then be reused by any other brewery.

The manufacturer of the beer bottles annually sells 240,000 bottles. The set-up cost of the machinery for one lot of bottles is 300 €. The inventory cost of material tied up in finished goods is 0.08 € per bottle and month.

Determine the optimal lot size q^* by using the lot size formula according to Harris/Andler

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<u>Solution:</u>
Lot size formula:

$$q^* = \sqrt{\frac{2 \cdot n \cdot c^{lot}}{\tau \cdot c^{inv}}}$$

$$q^* = \sqrt{\frac{2 \cdot 240{,}000 \cdot 300}{12 \cdot 0.08}} = 12{,}274.4$$

Additionally, we calculated the costs associated to the optimal lot size (not asked in the exercise)

$$C(q^*) = \sqrt{2 \cdot n \cdot c^{lot} \cdot c^{inv} \cdot \tau}$$

$$C(q^*) = \sqrt{2 \cdot 240{,}000 \cdot 300 \cdot 0.08 \cdot 12} = 11{,}757.6\ €$$

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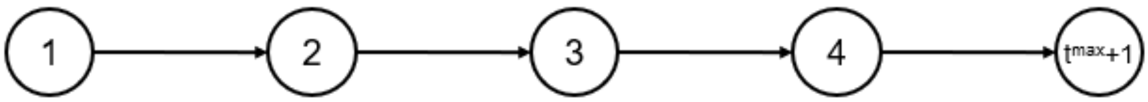
Exercise 9: Dynamic lot size planning

To produce the varieties "Gala Hell", "Crabs#1", and "Brunswiek Alt", different types of brewing malt are needed. The NJB brewers purchase their malt from a malt-house close to Braunschweig and estimate their demand of malt for the next four periods: $(3{,}840 \quad 5{,}440 \quad 5{,}120 \quad 2{,}880)$

The malt-house has to make a decision when producing which quantity of malt. The inventory cost rate for 1 unit of malt is 0.60 € per period, and the set-up of the machines has fixed costs of 6,000 €. The initial stock in the first period is assumed to be $s_0 = 0$.

Determine the optimal lot size policy (q_1^*, q_2^*, q_3^*, q_4^*) for the malt-house using the provided demand for all four periods. Use the provided graph for the solution, and calculate the total cost C^* of the optimal lot-size policy.

Demand: (3,840 5,440 5,120 2,880)
$c^{lot} = 6{,}000$ €
$c^{inv} = 0.6$ € $per\ unit\ and\ period$



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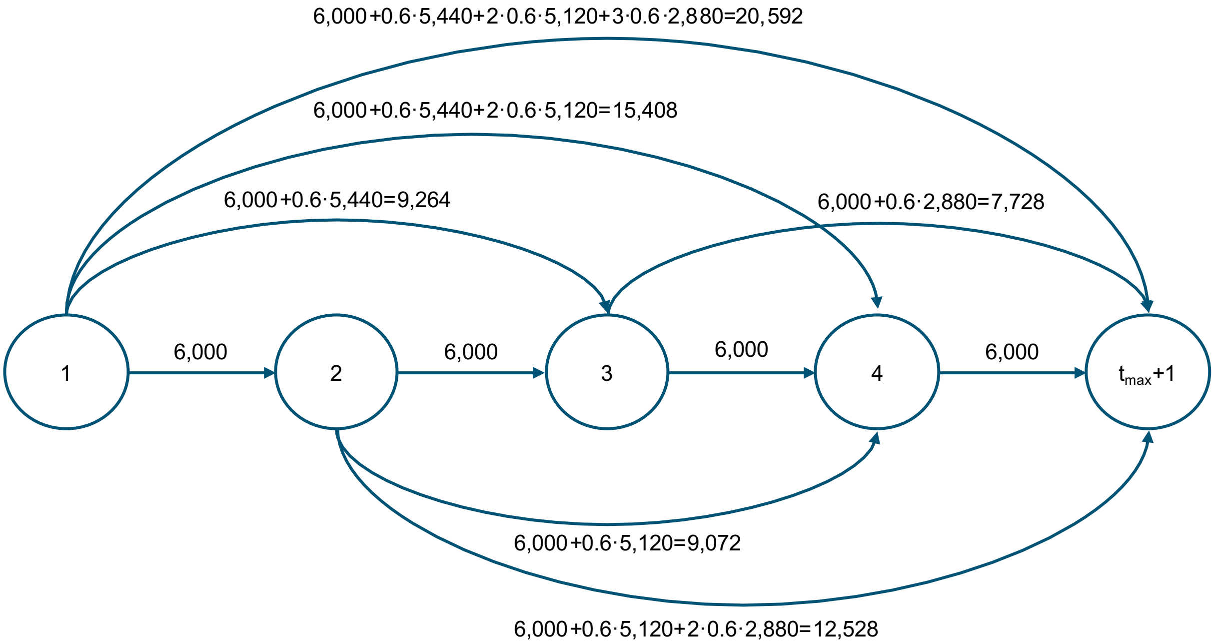
<u>Solution:</u>



$1 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow t_{max}+1$ = Production/ordering "just in time" → 6,000 € + 6,000 € + 6,000 € + 6,000 € = 24,000 €

$1 \rightarrow 2 \rightarrow 3 \rightarrow t_{max}+1$ = 6,000 € + 6,000 € + 6,000 € + 0.6 € * 2,880 € = 19,728

$1 \rightarrow 2 \rightarrow 4 \rightarrow t_{max}+1$ = 6,000 € + 6,000 € + 0.6 * 5,120 € + 6,000 € = 21,072

$1 \rightarrow 3 \rightarrow 4 \rightarrow t_{max}+1$ = 6,000 € + 0.6 * 5,440 € + 6,000 € + 6,000 € = 21,264

$1 \rightarrow 2 \rightarrow t_{max}+1$ = 6,000 € + 6,000 € + 0.6 * 5,120 € + 2 * 0.6 * 2,880 € = 18,528

$1 \rightarrow 3 \rightarrow t_{max}+1$ = 6,000 € + 0.6 * 5,440 € + 6,000 € + 0.6 * 2,880 € = 16,992

$1 \rightarrow 4 \rightarrow t_{max}+1 = 6{,}000\text{ €} + 0.6 * 5{,}440\text{ €} + 2 * 0.6 * 5{,}120\text{ €} + 6{,}000\text{ €} = 21{,}408$

$1 \rightarrow t_{max}+1 = 6{,}000\text{ €} + 0.6 * 5{,}440\text{ €} + 2 * 0.6 * 5{,}120\text{ €} + 3 * 0.6 * 2{,}880\text{ €} = 20{,}592$

The minimum-cost lot-sizing policy corresponds to the shortest path through the directed graph: **1 → 3 → t_{max}+1**

$q_1^* = 3{,}840 + 5{,}440 = 9{,}280$

$q_2^* = 0$

$q_3^* = 5{,}120 + 2{,}880 = 8{,}000$

$q_4^* = 0$

$C^* = 16{,}992€$
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Exercise 10: Location assessment & planning – Weighted sum method

Your help in revising the planning methods has been very helpful to the beer brewers, which is why they are now asking for your support again. They are considering purchasing a new bottling line that will enable efficient bottling of the brewed beer. The first step is to schedule the installation of the plant. Then, it is necessary to plan the sequence for the bottling of the beer types. You are familiar with both planning methods from the lecture, and you would like to apply your knowledge.

The beer brewers already told you about their idea of investing in a new bottling plant. They are enthusiastic about the many advantages of modern plants and want to start planning as soon as possible. The Master Brewer has already thought about which processes are necessary to be able to install a new system. Together you write the operations, estimate their duration, and identify their interdependencies (see the table):

Table 1: Operations for installing a new bottling line

ρ	Operation	Duration of operation [days]	Immediate predecessors
A	Planning of the operation	4	-
B	Tender offer and award of contract	3	A
C	Removal of old plants	9	A
D	Cleaning of the area	2	B, C

E	Painting the walls	3	C
F	Delivery of new plants	4	D, E
G	Installation of new plants	14	F
H	Test and start-up/commissioning	2	G

a) Determine the earliest and latest possible start and end times for each activity using the corresponding MPM network plan. Identify the critical path of the project.

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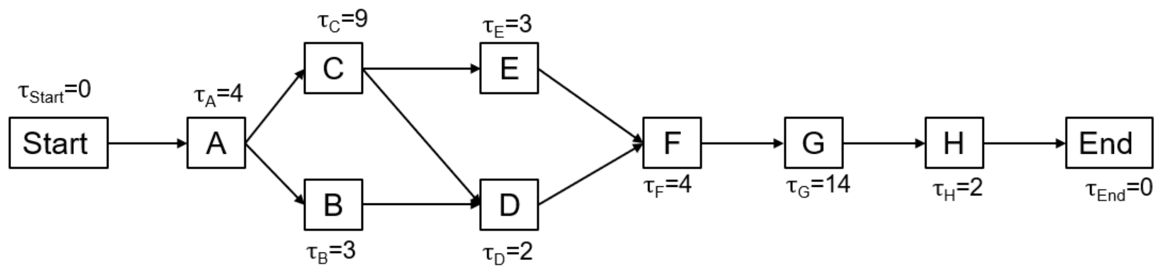
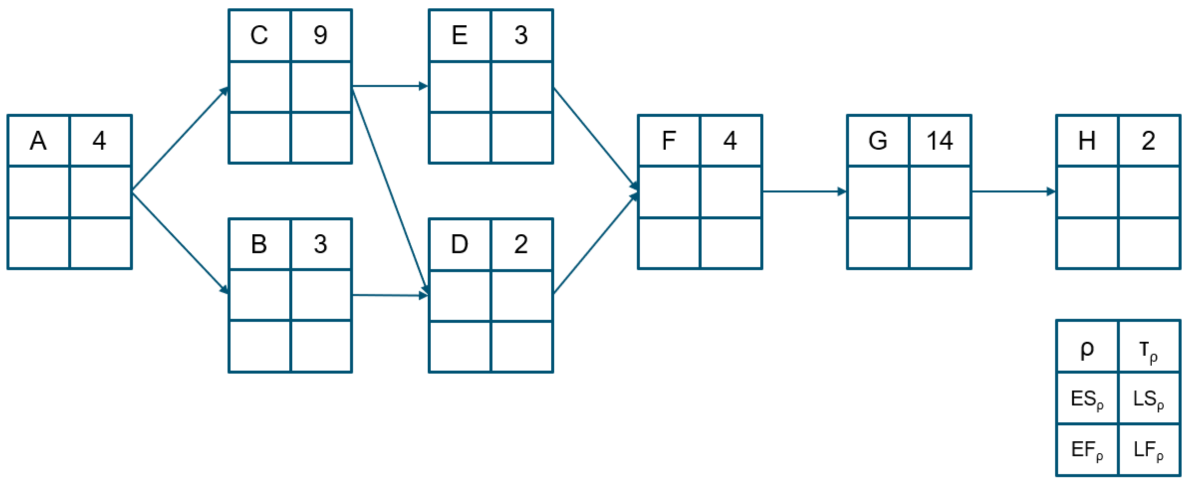
Solution:

Step 1: Elaborate the MPM network plan

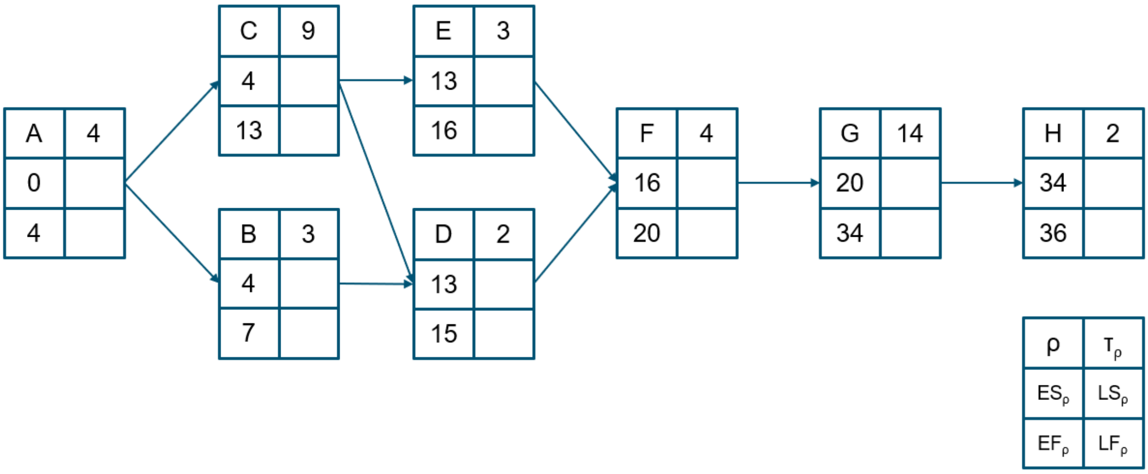
(1) Sketch a simplified dynamic I/O graph to illustrate the process relationships.



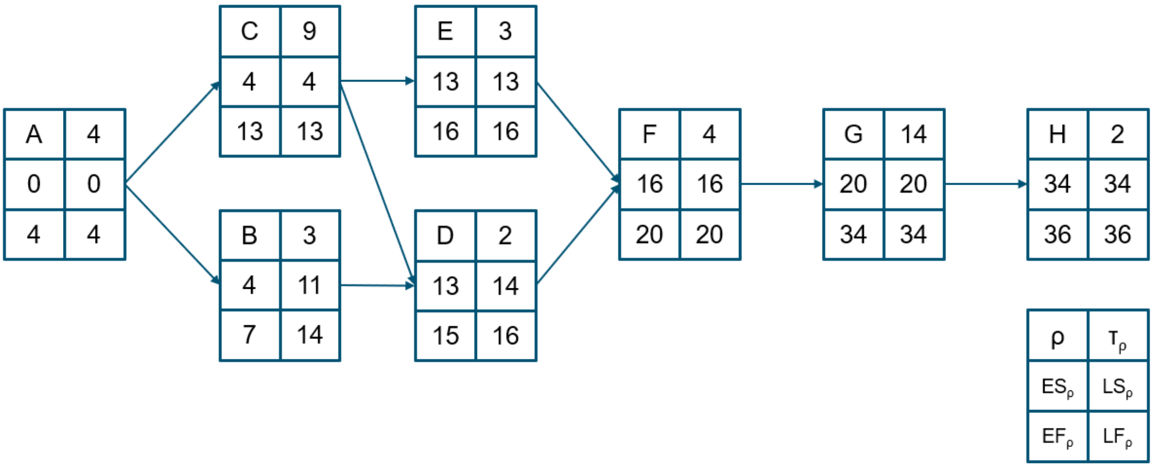
(2) Transfer of simplified dynamic I/O graph into MPM network structure and enter operation durations τ_ρ.



(3) Determine ES_ρ and EF_ρ by means of a forward pass.



(4) Determine LS_ρ and LF_ρ by means of backwards calculation.



Step 2: Calculating buffer times of each operation

Total buffer times TB_ρ of an operation ρ: $TB_\rho = LS_\rho - ES_\rho$

ρ	Operation	LS_ρ	ES_ρ	TB_ρ
A	Planning of the operation	0	0	0
B	Tender offer and award of contract	11	4	7
C	Removal of old plants	4	4	0
D	Cleaning of the area	14	13	1
E	Painting the walls	13	13	0
F	Delivery of new plants	16	16	0
G	Installation of new plants	20	20	0

H	Test and start-up/commissioning	34	34	0

Step 3: Identifying the critical path

The total buffer times of operations A, C, E, F, G, and H are each 0. This means that **the delay of one of these critical operations immediately leads to a delay in the start-up of the filling line**.

→ Critical path: A-C-E-F-G-H

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b) Present the relationships determined in part a) in a Gantt chart (bar chart). Mark the processes on the critical path and the buffer times (all processes start as soon as possible).

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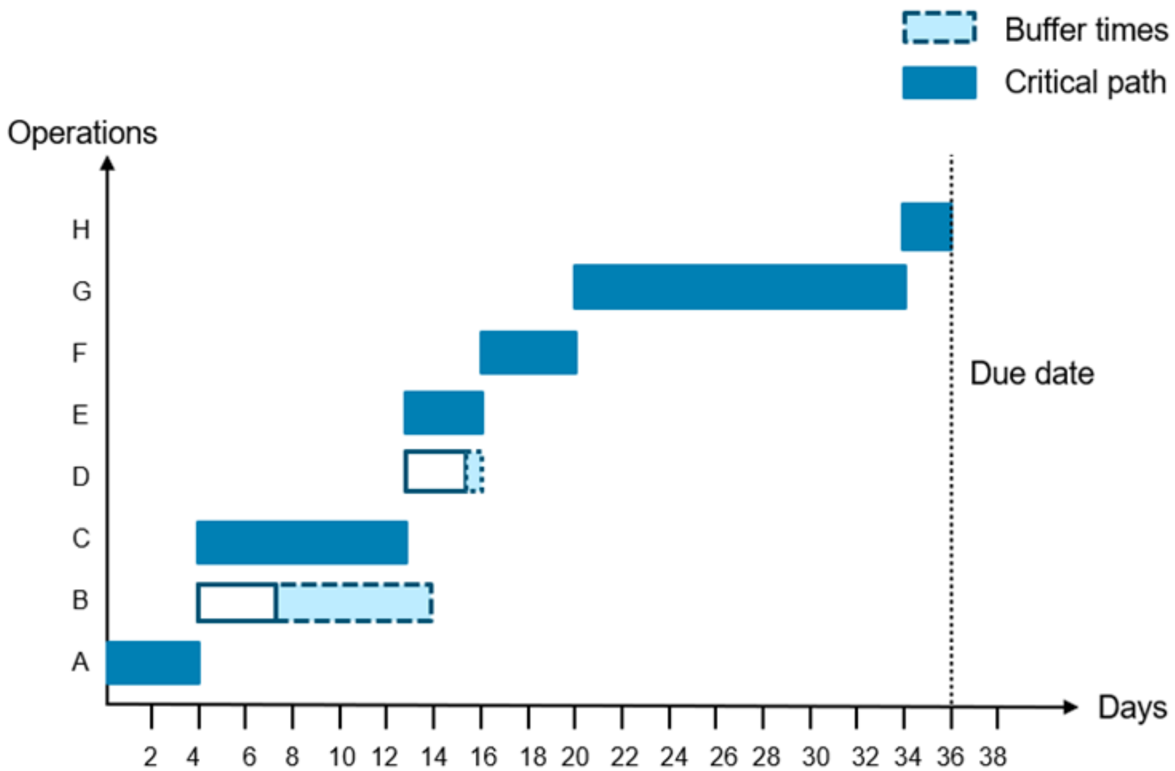
Solution:



The diagram shows the sequence of operations if all operations start at the earliest possible time. The dashed lines show the buffer periods. Within the dashed areas, the individual tasks can be shifted in time without influencing the project end.

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