4.2 SCHEDULING and LOT SIZING

This chapter deals with:

- the importance of scheduling to the performance of a firm,
- the performance measures that are important in selecting a schedule and
- schedules for single and multiple workstations.
- Lot sizing and EPQ

- Previously we have had training about scheduling/timing forward and backwards in chapter 1.3.

Scheduling means the allocation of resources over time to accomplish specific tasks.

Workforce scheduling determines when employees work.

Operations scheduling assigns jobs to machines or workers to jobs.

Operations schedules are short-term plans designed to implement the master production schedule (MPS).

The two basic manufacturing environments are:

A JOB SHOP (Process focused system) is a process focused production system which specializes in low- to medium-volume production utilizing job or batch processes (tasks in this type of flexible flow environment are difficult to schedule because the variability in job routings and the continual introduction of new jobs to be processed) and

A FLOW JOB (Product focused system) specializes in medium- or high-volume production and utilizes line or continuous processes (tasks are easier to schedule because in flow facility the jobs have a common flow pattern through the system).

Single Processor Scheduling (no alternative routing)

In some cases an entire plant can be viewed as a single processor (for example paper machine, car manufacturing production line).

Sometimes a single processor is a bottleneck (machine or cell) that controls the output of the plant because its limited capacity. Try to maximize the utilization of a bottleneck to raise the capacity.

Decide the work priority according

1. to the importance of customers,
2. tardiness (minimize the lateness or earliness)

Allocate your customers to ABC-classes

A class –strategic customers / most profitable (or other vice important) customers which you serve the best way
B-class ok but the service level may vary
C-class – one might try to get rid of these especially if the are not highly profitable (their purchases are very small compared to total sales)

Try always to keep your promises, but if you cannot do that prefer your A-class customer's service level

Typically scheduling is divided to:

Rough planning - > Master Production Schedule MPS (months and weeks of factory load and biddings)

and

Fine Scheduling -> weeks, days, and hours on operation level including routing

-> Work orders start implementation and controlling phase

Rough planning – MPS What are the main objectives, reasoning and steps of it?

TASK 1: Estimating realistic delivery times

Specially needed for sales –
for customer promises

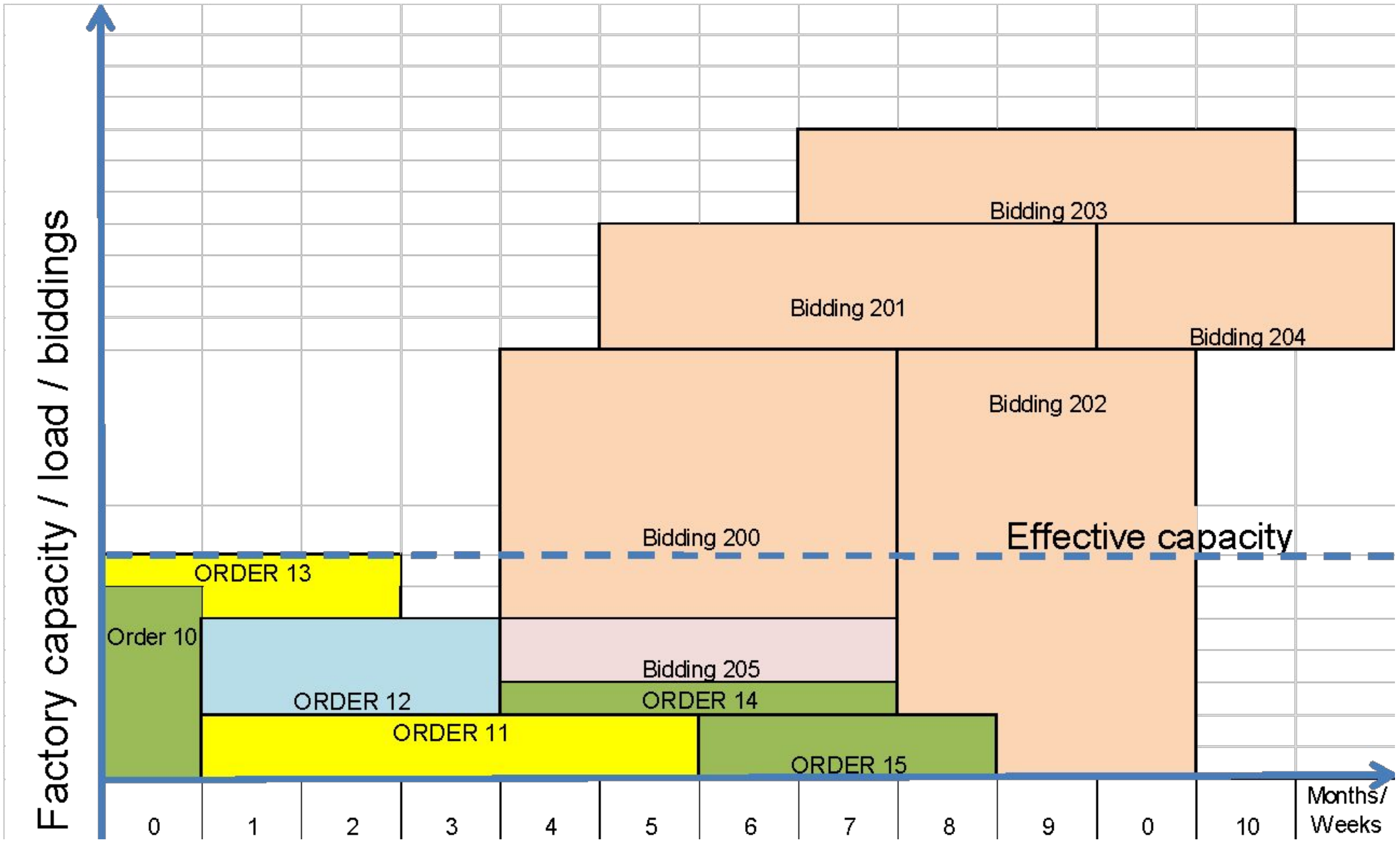
TASK 2: Ensuring the resources needed

Specially needed to keep the delivery time promises given to customer

TASK 3: Controlling / managing the work load

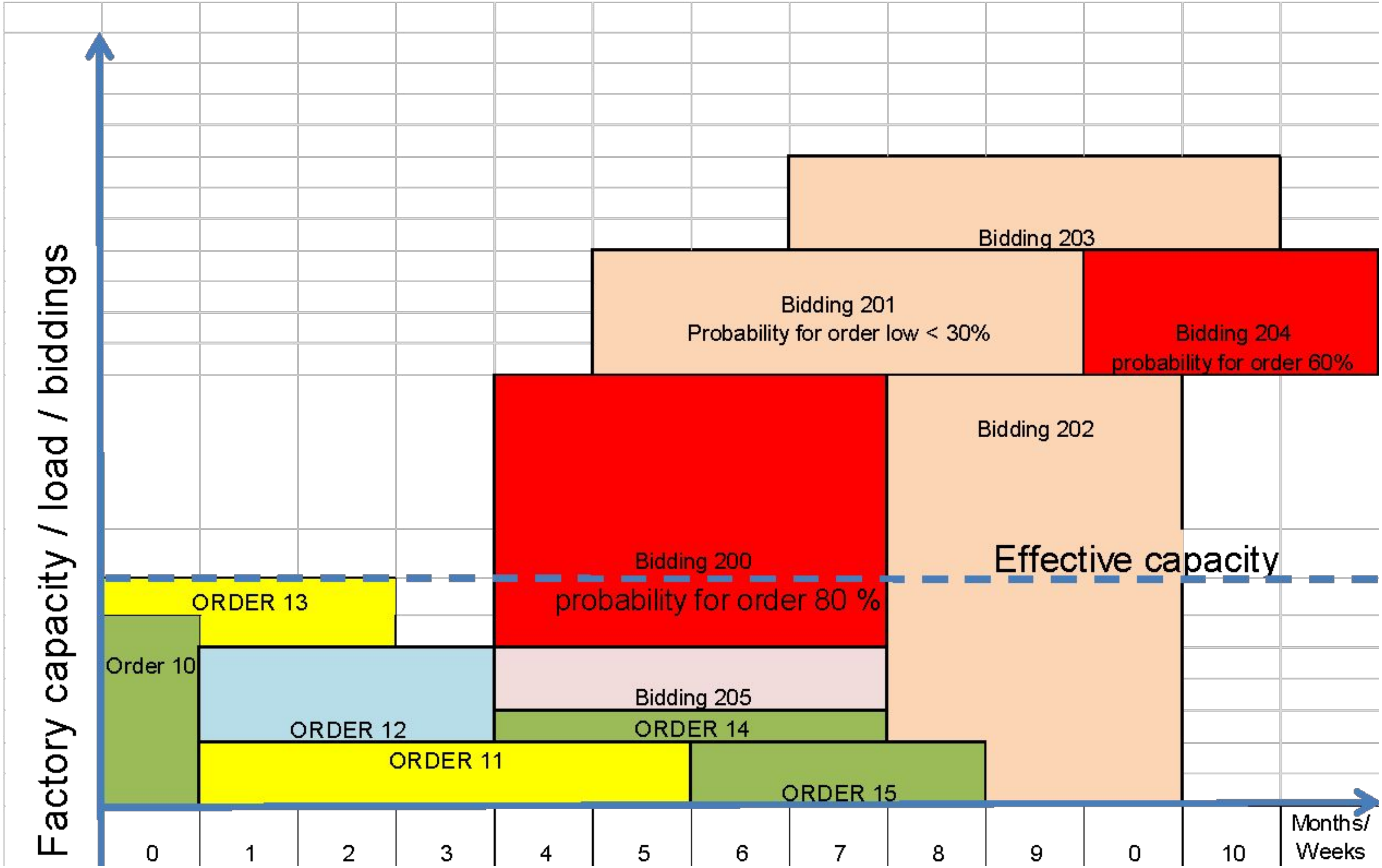
Specially needed for production planning in order to react to changes and at the same time keep the customer promises and the costs low or at least reasonable

MPS + Bids



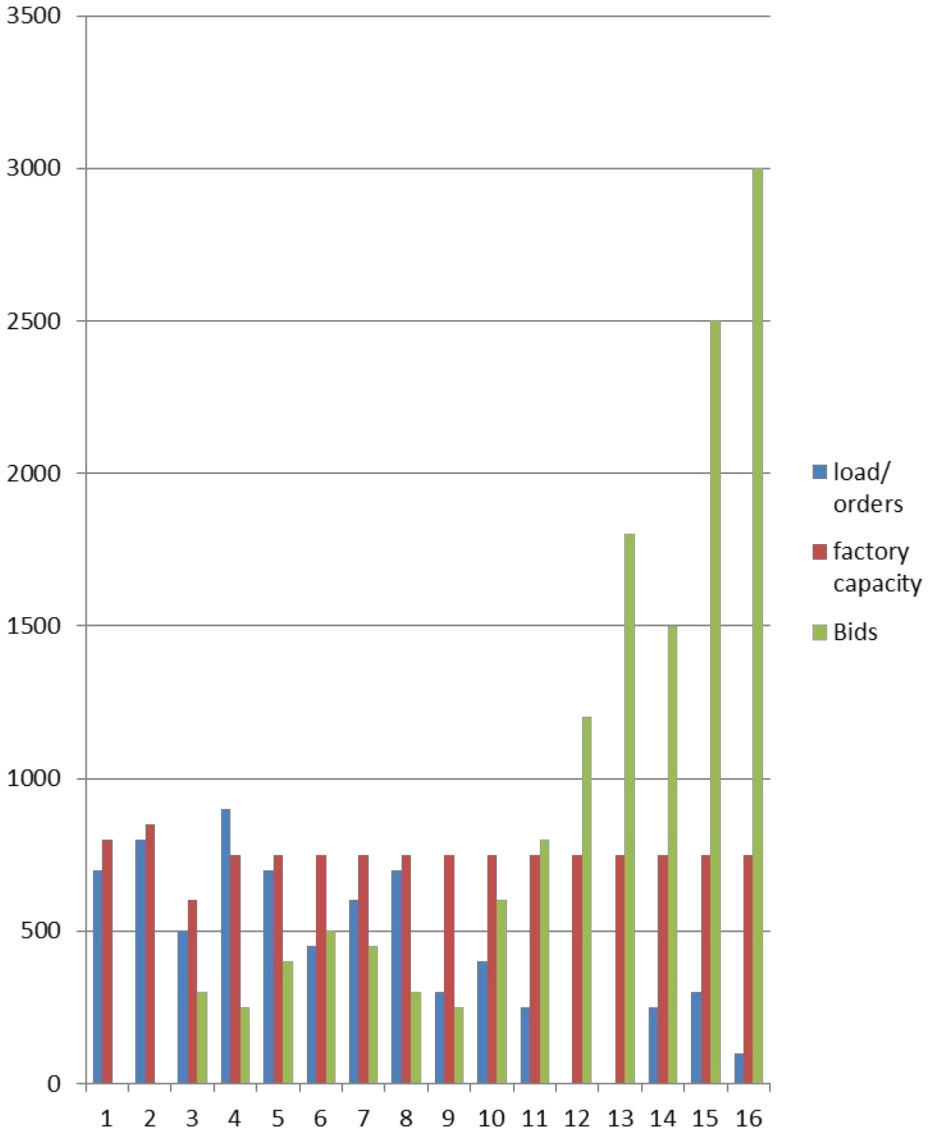
Factory capacity / load / biddings
Bidding 203
Bidding 201
Bidding 204
Bidding 202
Bidding 200
Effective capacity
ORDER 13
Order 10
Bidding 205
ORDER 12
ORDER 14
ORDER 11
ORDER 15
0
1
2
3
4
5
6
7
8
9
0
10
Months/
Weeks

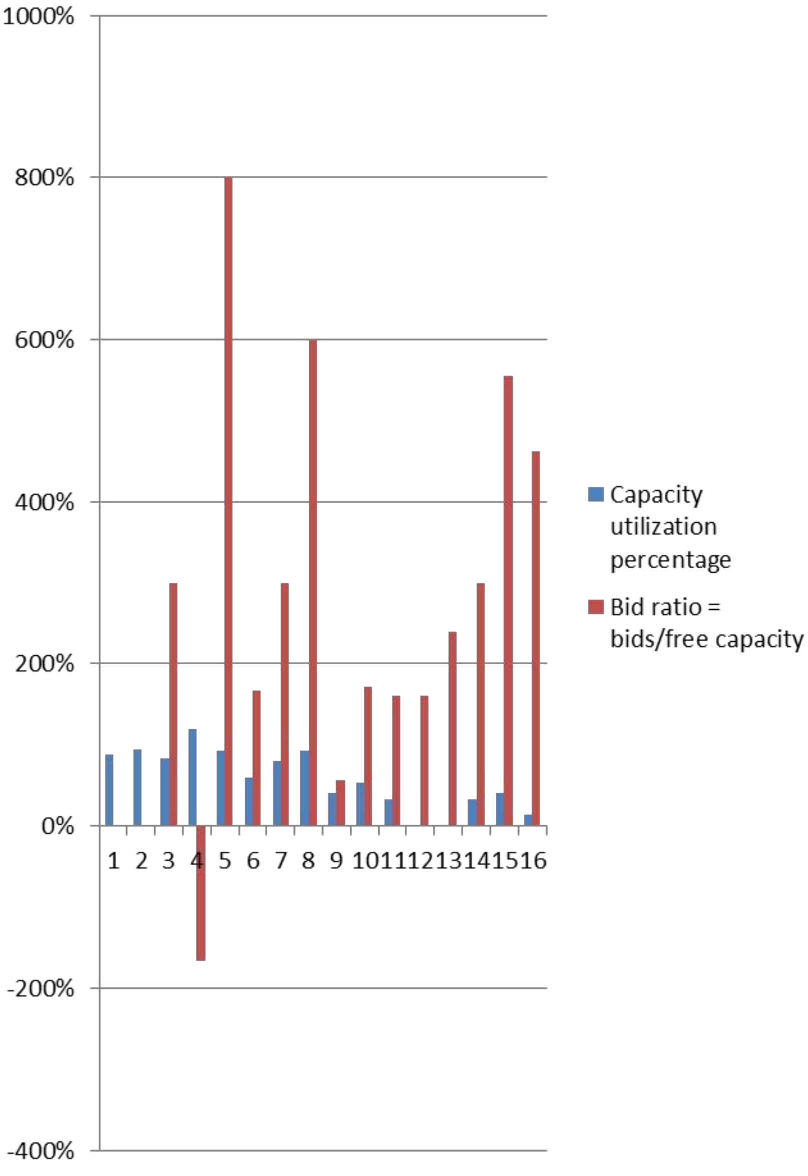
MPS + Bids + probability for order



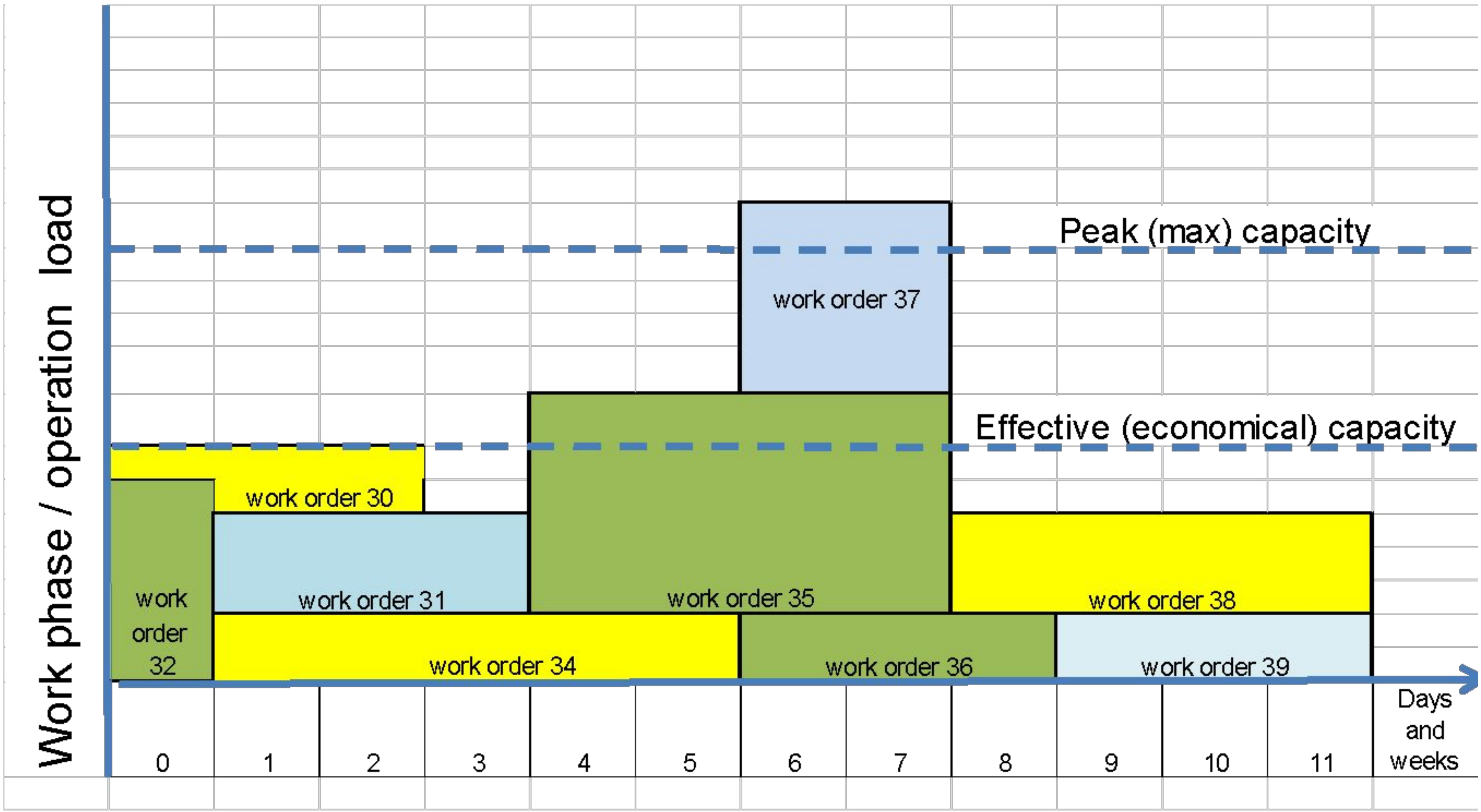
MPS + Bids + capacity utilization + bid ratio

Weeks	load/ orders	factory capacity	capacity utilization	Bids	Bid ratio = bids/free capacity
1	700	800	88 %	0	0 %
2	800	850	94 %	0	0 %
3	500	600	83 %	300	300 %
4	900	750	120 %	250	-167 %
5	700	750	93 %	400	800 %
6	450	750	60 %	500	167 %
7	600	750	80 %	450	300 %
8	700	750	93 %	300	600 %
9	300	750	40 %	250	56 %
10	400	750	53 %	600	171 %
11	250	750	33 %	800	160 %
12	0	750	0 %	1200	160 %
13	0	750	0 %	1800	240 %
14	250	750	33 %	1500	300 %
15	300	750	40 %	2500	556 %
16	100	750	13 %	3000	462 %


3500
3000
2500
2000
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
load/ orders
factory capacity
Bids

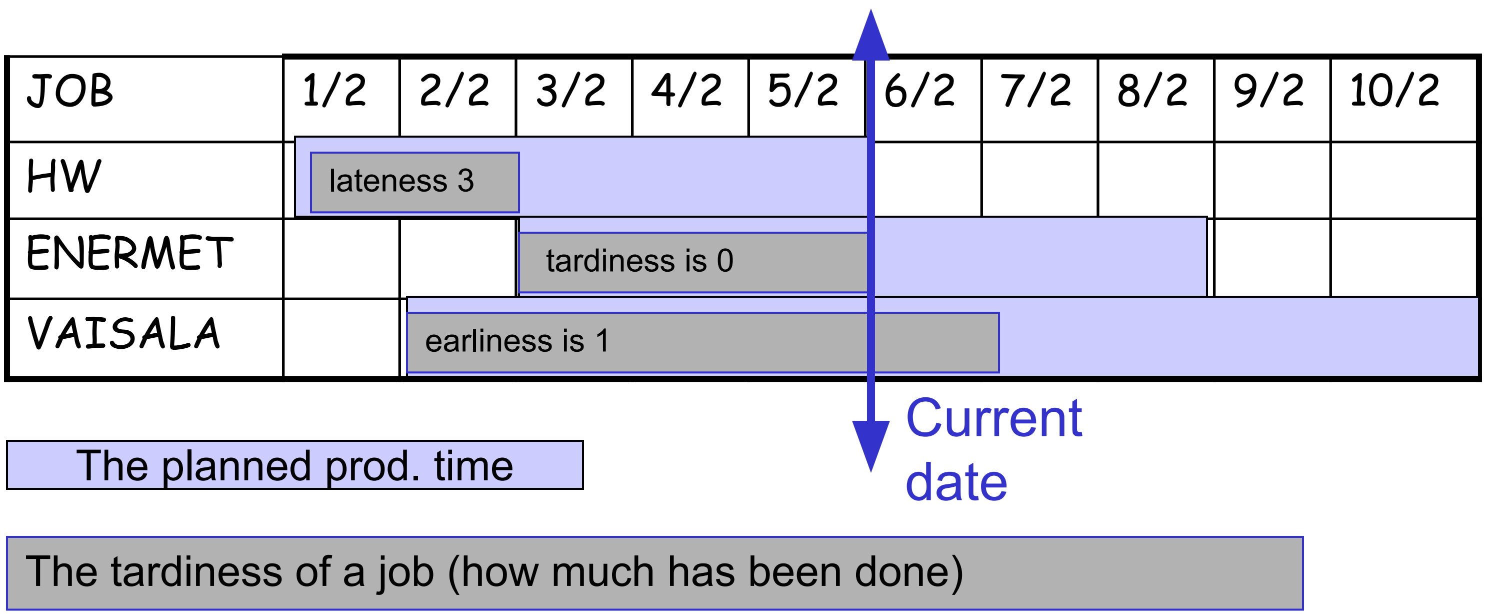

1000%
800%
600%
400%
200%
0%
-200%
-400%
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Capacity utilization percentage
Bid ratio = bids/free capacity

Fine Scheduling -> weeks, days, and hours on operation level including routing

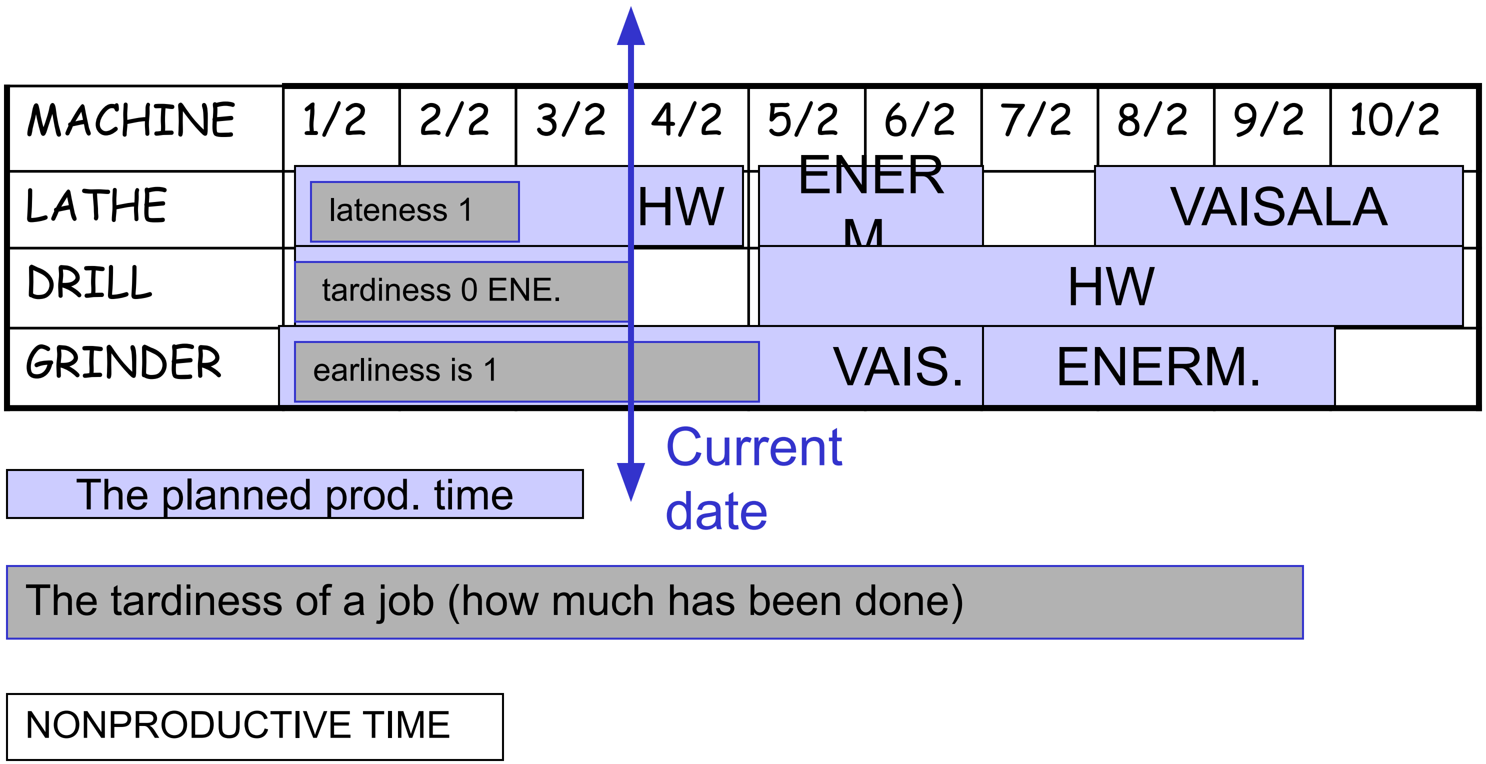


GANTT CHART can be used as a tool for sequencing work on machines and monitoring its progress. The chart takes two basic forms: the job or activity progress chart and the machine chart.

The progress chart displays graphically the current status of each job relative to its scheduled completion date (under).



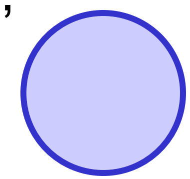
A machine chart depicts the sequence of future work at three machines and also can be used to monitor progress.



CRITICAL PATH METHOD (CPM) offers a systematic procedure for selecting the critical (shortest in time) path. In addition, the amount of slack or free time on noncritical paths may be determined.

The essential characteristics of the graphs:

A circle represents a node. Arrows, or activities leaving the node, cannot be started until all activities incoming to the node have been completed. The completion of all activities incoming to a node is considered an event, as is the start of a project.



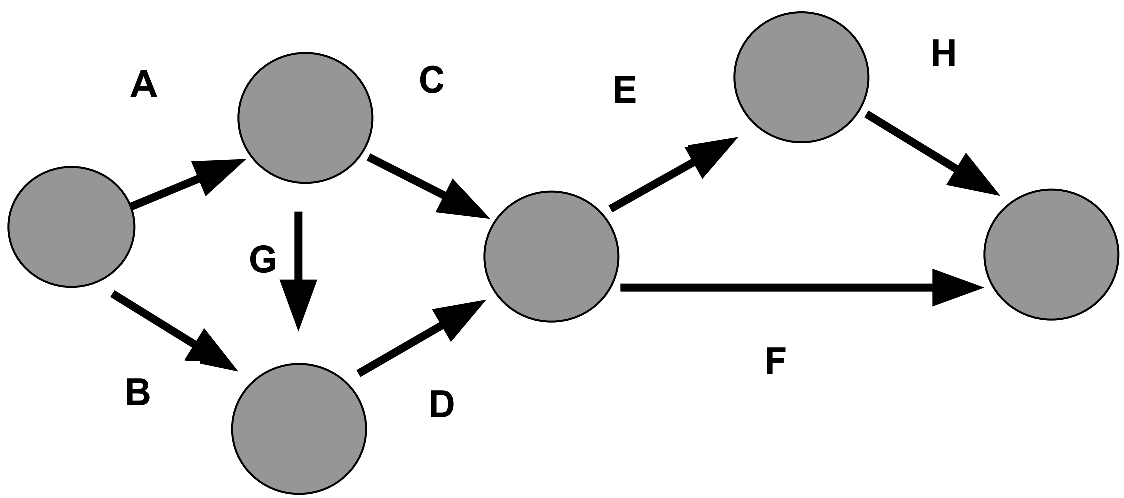
An arrow represents one of the activities of the project. Its length is of no significance. (time is expressed by numbers)

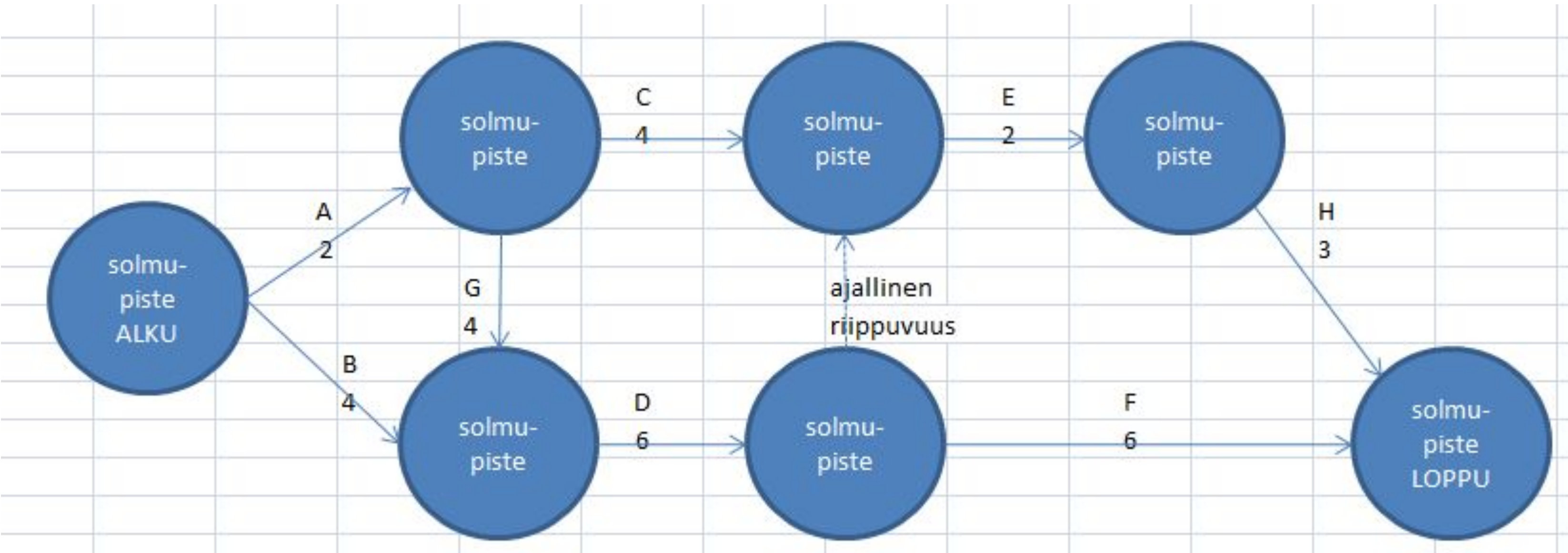
A dashed arrow represents a dummy activity. Dummy activities are used to represent precedence relationships. They are not activities in the real sense and have duration of zero.

Problem 12a. Critical Path, missing dummy arrow

You have the following list of dependencies. How ever the picture is not quite correct. You need to add one Dummy activity arrow to fix the error, and calculate the shortest possible throughput time.

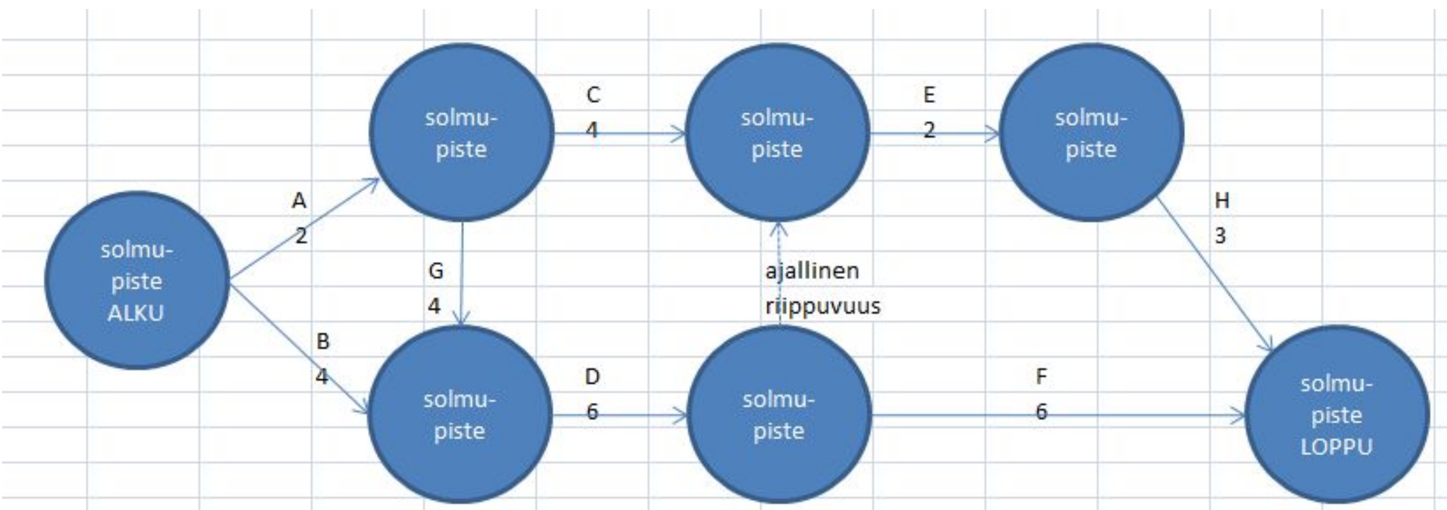
operation	Depends on operation	Time of operation (days)
A	- (which means that operation cannot start	2
B	- before this – below - is finished)	4
C	A	4
D	B , G	6
E	C , D	2
F	D	6
G	A	4
H	E	3




solmu-
piste
ALKU
A
2
B
4
solmu-
piste
G
4
solmu-
piste
C
4
D
6
solmu-
piste
ajallinen
riippuvuus
solmu-
piste
E
2
solmu-
piste
H
3
F
6
solmu-
piste
LOPPU

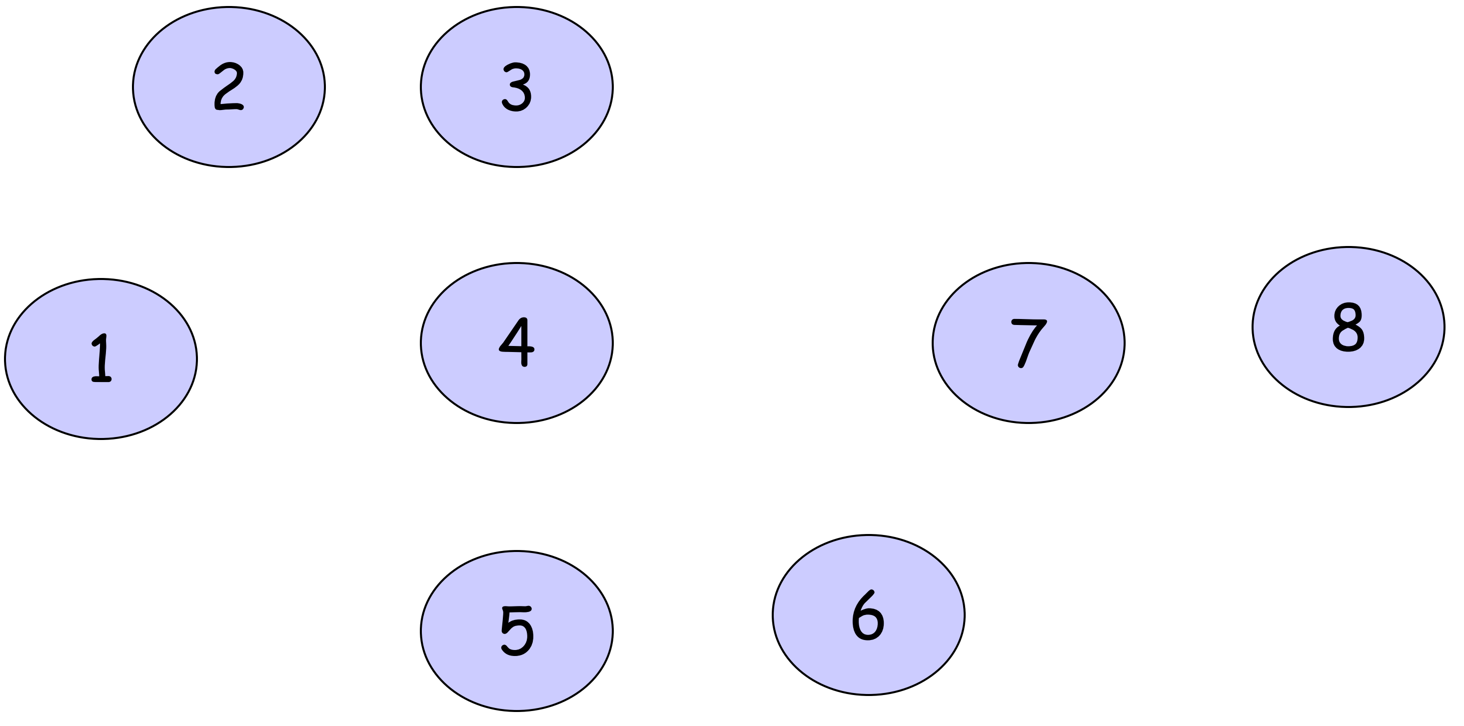
Problem 12a. Critical Path

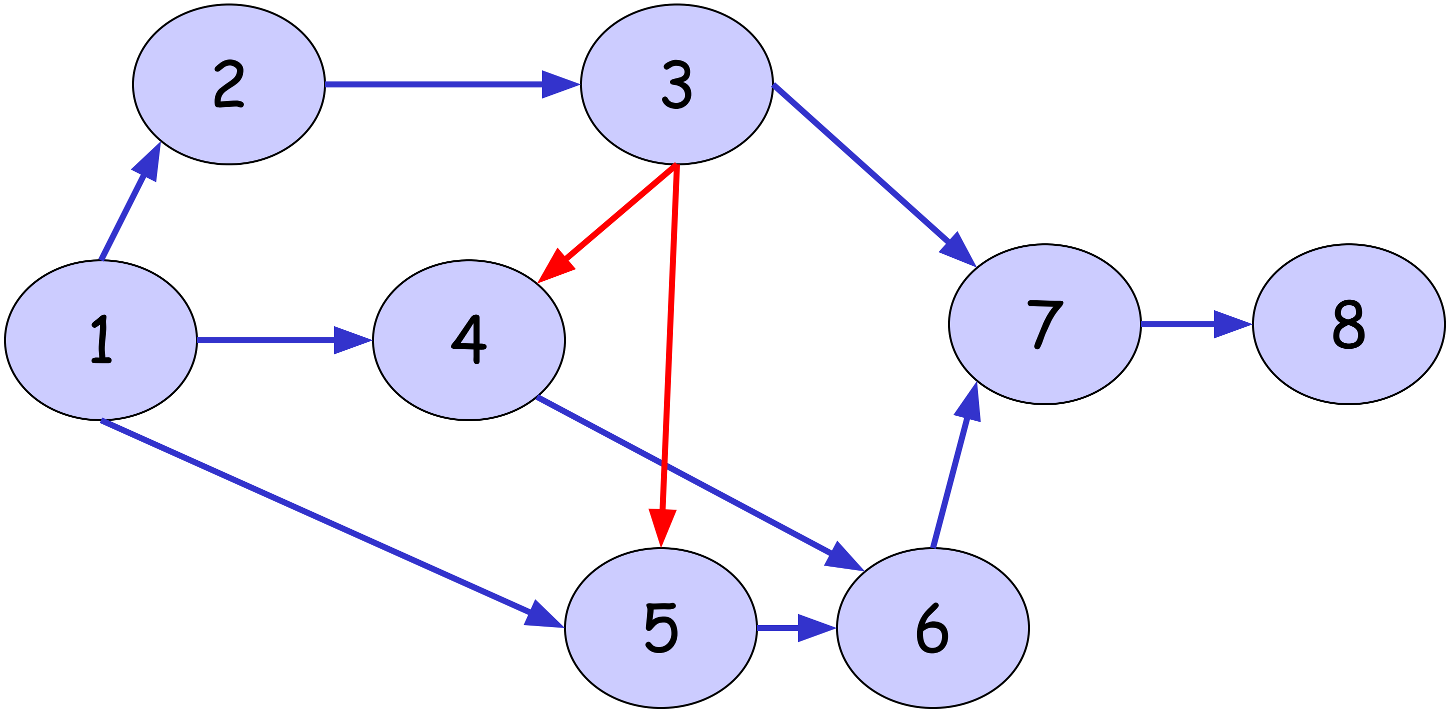
operation	the earliest possible start	the latest possible time to start	difference	
A	0	0 (= 6-4-2)	0	critical path
B	0	2 (= 6-4)	2	
C	2	9 (=18-3-2-4)	7	
G	2	2 (=6-4)	0	critical path
D	6 (=2+4)	6 (=18-6-6)	0	critical path
E	(6+6)=12	13 (=15-2)	1	
F	12	12 (=18-6)	0	critical path
H	14	15 (=18-3)	1	
end	18 =2+4+6+6)	18	0	critical path



Problem example: Rain gauge/wind sensor installation data

Activity	Description	Predecessor	Duration
A	Layout sensing station	None	5
B	Procure rain gauge/wind sensor	None	25
C	Procure telemetry equipment	None	18
D	Construct first 50% of building	A	14
E	Construct remainder of building	D	14
F	Install rain gauge/wind sensor	B,D	4
G	Install telemetry equipment	C,D	5
H	Connect telemetry equipment to rain gauge/wind sensor	F,G	3
I	Final test	E,H	1


2
3
1
4
7
8
5
6


1
2
3
4
5
6
7
8

PERFORMANCE MEASURES:

The amount of shop time for the job is called JOB FLOW TIME (= time of completion – time the job was available for first processing operation) or THROUGHPUT TIME

The total amount of time required to complete a group of jobs is called MAKESPAN (= time of completion of last job – starting time of first job)

PAST DUE or TARDINESS can be expressed as the amount of time by which the job missed its due date or as the percent of total jobs processed over a period of time that missed their due dates.

PERFORMANCE MEASURES:

$$\text{Critical ratio} = \frac{\text{due date} - \text{today's date}}{\text{time needed for finishing job}}$$

/ Waters Donald: Operations Management Producing Goods and Services; page 400, Pearson Education Limited printed in Ashford Colour Press England 2002

WIP, WORK-IN-PROCESS or PIPELINE INVENTORY

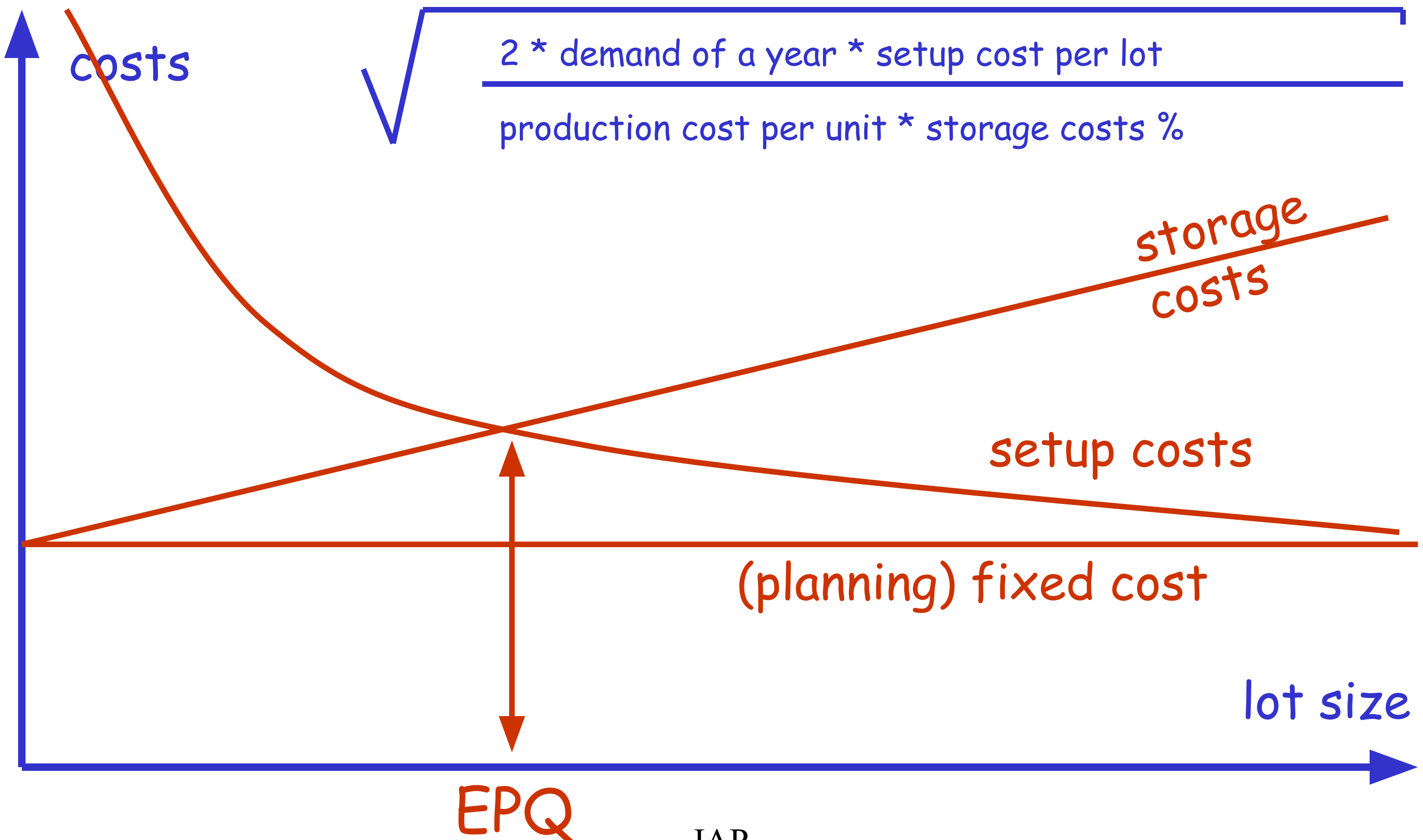
The sum of scheduled receipts for all items and on-hand inventories is THE TOTAL INVENTORY.

UTILIZATION is the percent of work time productively spent by machine or worker.

Problem of Economic batch quantity?

If you consider a factory that needs to produce an output of 1000 units per year, you might think that this could be achieved by producing one batch of l 000, two batches of 500, five batches of 200, and so on, the quantity in the batch defining the frequency with which a batch of products needs to be produced. The number of batches made and the quantities in the batch will have implications for the company in terms of storage requirements, both in-progress and in the store area. It will also have implications for the amount of control required over the particular work areas, suppliers and subcontractors, and for the costs involved. A method that is used to optimise these parameters is called economic batch quantity (EBQ).

Economic Production Quantity, EPQ
Economic Batch Quantity, EBQ



The costs associated with batch production can be categorized as direct and ancillary. Direct costs are those that are associated directly with the production of the product and would include parts costs and process costs. The ancillary costs are those that exist independently of the numbers of product. These will include the costs of equipment maintenance and set-up costs for internally supplied goods, and the purchasing costs for those goods provided by external suppliers. It is usual to divide the ancillary costs for a batch evenly over the number in the batch.

Consequently, because of the stability of the ancillary cost the proportion allocated to each product is lower, the larger the number of products in a batch. However, the problem of producing goods in large batches is that they require you to have a large stockholding, the cost of which increases with the number of units in the batch.

The use of the EBQ method is designed to analyse these problems and provide an optimum solution. The EBQ can be shown graphically and it can be calculated according to the formula:

EBQ = SQR(2SD/IC)

S= ancillary (set up) cost per batch

D = annual usage (units)

I= annual holding cost as a fraction of the stock value

C= unit cost of the item

The main advantage of using the EBQ is that it gives a value which is optimized for a certain data set. There are, however, a number of problems associated with its use that have to be considered. The main problems relate to the assumptions that have to be made, i.e. that unit price and ancillary cost remain constant throughout the year. There is also the problem that the ancillary costs, and more particularly the stockholding costs per batch, can be very difficult to assess. Finally, the EBQ will not often produce a number that is consistent with supply systems.

EXAMPLE of EPQ / EBQ

A company makes telephone booths, for a stable market where the demand is 450 units per month. The booths are made in batches, with all the units in each batch being completed at the same time. Given the following information, calculate the economic batch quantity: Machine set-up cost per batch 150 €, Stockholding cost = 10% of stock value per annum, Unit cost = 37.50 €

EPQ = EBQ = SQR((2 * 450 * 150)/(10% * 37,50)) =

Problem 28. ECONOMIC BATCH SIZE / REPETITIVE ORDER QUANTITIES

Replacement parts are supplied from an inventory by a manufacturer of industrial tools. For a particular part, the annual demand is expected to be 750 units. Machine setup costs are $50, carrying costs are 25 % per year, and the part is valued in inventory at $35 each.

a) What is the economic order quantity placed on production?

b) What is the ROP (reorder point quantity) if it takes 1,5 weeks to set up production and make the parts ?

c) The production rate for these parts is 50 units per week. What is the production run quantity?

Very difficult EPQ and lot size problem:

The demand of an item is 20000 units in a year, and there are 250 working days in the factory per year. The rate of production is 100 units a day and lead time is 4 days. The unit cost of production is € 40,00 per unit, holding cost 25 %, and the set up cost € 20,00 per run.

a) What are the economic production quantity (lot size),

b) the number of runs in a year,

c) the reorder point, and

d) What would be the practical lot size in this case, EPQ or something else?

e) the annual cost in both cases?

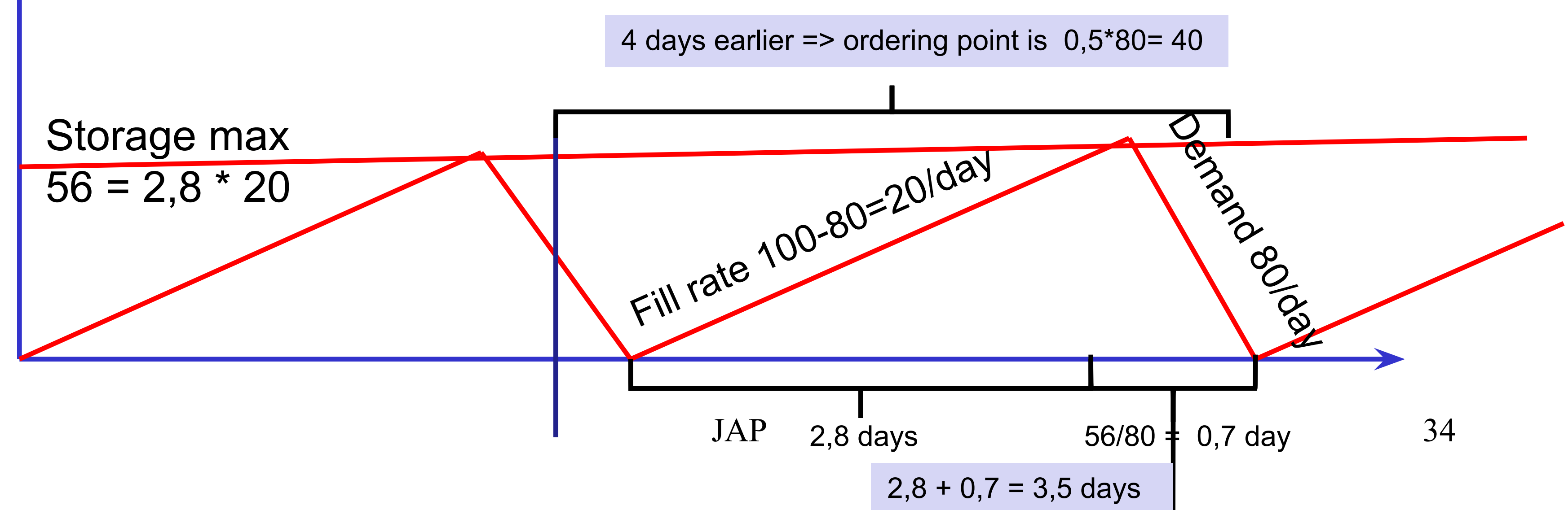
f) How does the 99,7 % requirement of availability of finished goods affect to questions a-d, when you know that the standard deviation of demand during production lead time (throughput time) is 80 units?

EPQ= SQR((2*20000*20)/(0,25*40))= ~~(282 units)~~ 280 units which lasts for 280/80=3,5 days and it is produced in 280/100=2,8 days

Number of runs is 20000/282=71 runs

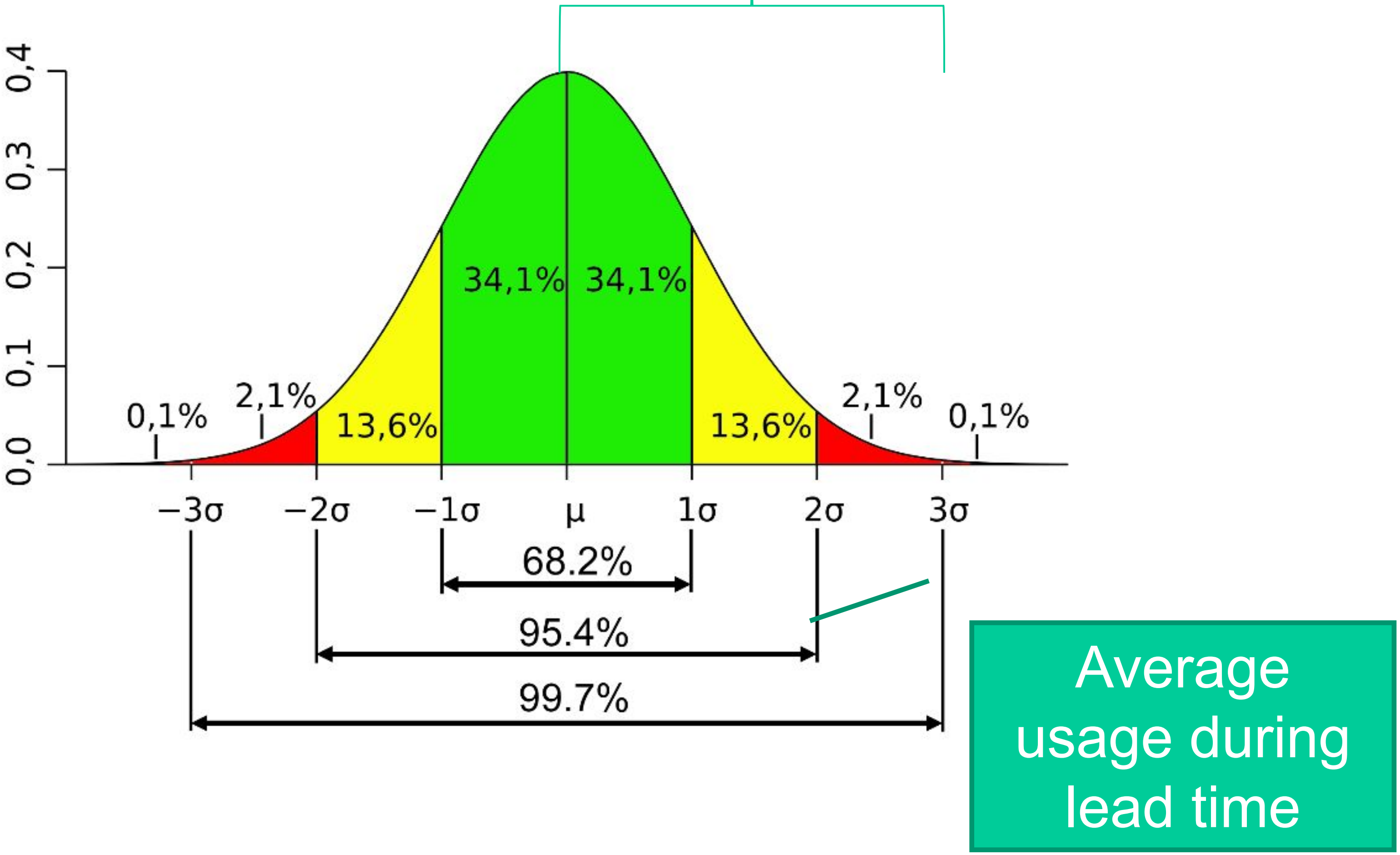
In normal case Reorder Point would be 4 days before the storage gets empty: Safety stock + usage (demand) from production order to production start up = 0 + 4 days*(20000 units/250 day)= 0 + 4 * 80 = 320 units

But in this case the picture tells you the truth better. The reorder takes place when storage level gets to 40 one production cycle earlier.



99,7% safety one gets by safety storage of 3 * standard deviation (80 units) during the lead time (4 days)

=> 3*80 = 240 safety storage



Problem 11. **Arranging the Production Flow – Routing Problem – dynamic programming**

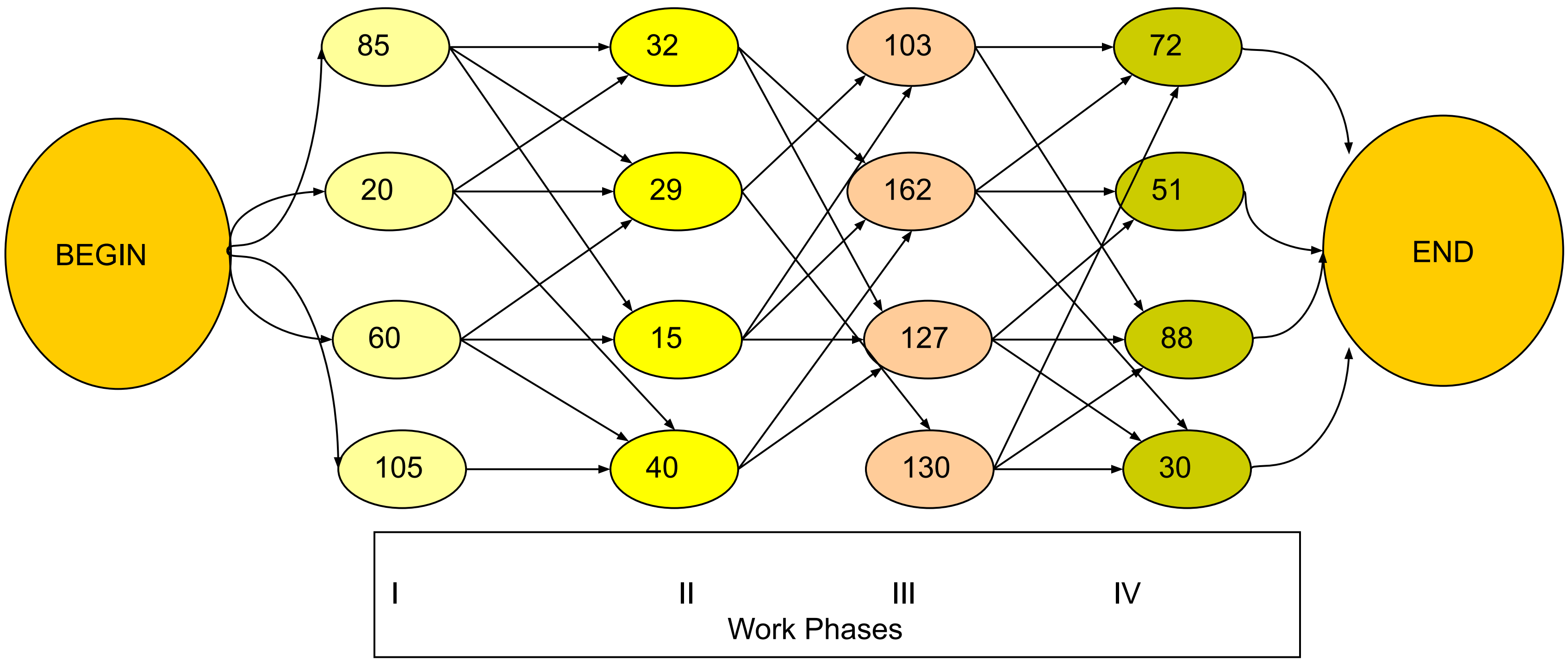
Your job is to plan the production flow in a factory. The product is manufactured in four work phases (I, II, III and IV), and you can choose four different machines/methods for each job (A, B, C and D).

You know the machine hour prices and those combinations in workflow which are possible for manufacturing. All combinations are not suitable, because of technological restrictions. The possible production flows and machine hour prices are shown in the picture below:

Your task is to plan the most economic solution for manufacturing for the case. By doing that you should be able to choose also the next economical solution and so on, for the case you need to increase the capacity or there is a machine breakdown in production.

It is possible to solve the problem in this simple case only by testing and calculating the different possibilities, but when the situation gets more complicated you need to have a computer and an algorithm to solve the problem.

This task is a typical example of dynamic programming, which is a method for finding out optimum solution in a situation of sequence decisions - The previous decision affects the next one.



The idea behind dynamic programming is that to solve a given problem, we need to solve different parts of the problem (subproblems), then combine the solutions of the subproblems to reach an overall solution. Often when using a more naive method, many of the subproblems are generated and solved many times. The dynamic programming approach seeks to solve each subproblem only once, thus reducing the number of computations: once the solution to a given subproblem has been computed, it is stored: the next time the same solution is needed, it is simply looked up. This approach is especially useful when the number of repeating subproblems grows exponentially as a function of the size of the input.

Dynamic programming algorithms are used for optimization (for example, finding the shortest path between two points, or the fastest way to multiply many matrices). A dynamic programming algorithm will examine all possible ways to solve the problem and will pick the best solution. Therefore, we can roughly think of dynamic programming as an intelligent, brute-force method that enables us to go through all possible solutions to pick the best one. If the scope of the problem is such that going through all possible solutions is possible and fast enough, dynamic programming guarantees finding the optimal solution