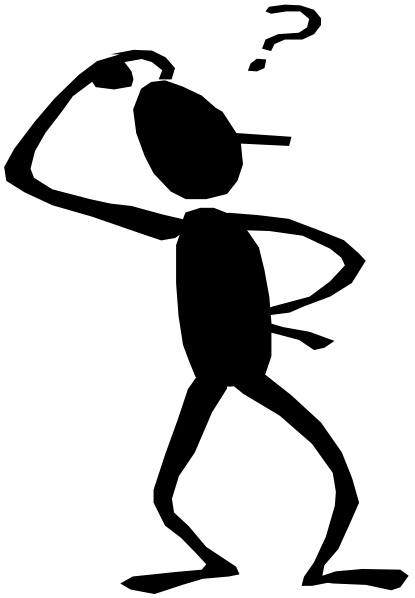
Introduction to Production Planning

Production Planning: what does it deal with?

The Production Manager question is:

- WHAT (… which product …),
- WHEN (… considered some time horizon …),
- HOW (… with which materials …),
- WHERE (… on which workcenter …),
- HOW MUCH (… which lot dimension …) …



Manufacturing, in order to optimize a given objective function, provided that the production plan satisfies all the constraints

Production Planning: what does it deal with?

The problem of Production Planning is highly **complex**:

- Many variables
  - Items (finished products, WIP, raw materials)
  - Production resources (shops, workcentres, operators)
  - Different ways for producing an item (alternative routings, alternative bill of materials)
  - …
- Data volumes
  - Volumes and quality of data to be managed
- Uncertainty
  - External (clients, suppliers, …)
  - Internal (machines, manpower, materials, …)
- Many constraints
  - Internal (manpower, machines, materials, …)
  - External (clients, suppliers, subcontractors, …)
- Conflicting company's objectives
  - Cost minimization
  - Service level maximization

Conflicting company's objectives

Commercial:

- (every single) Product availability (client satisfaction)

Production:

- Regularity of utilization of machinery

Human recourses:

- Regularity of utilization of labor (e.g., no overtime)

Management control:

- Minimization of stocks

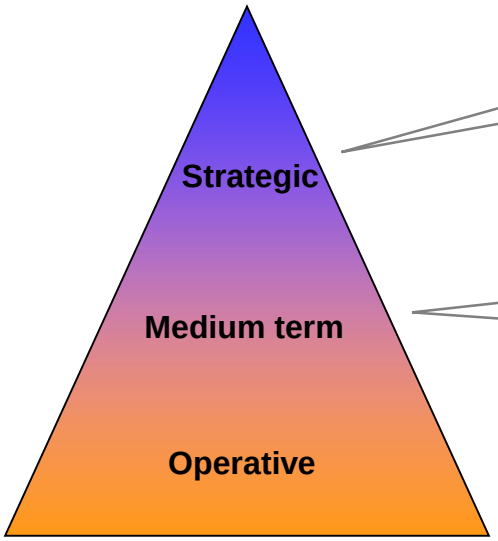
Purchasing:

- Long term view (to obtain discounts)

Production Planning: an hierarchical approach

- The hierarchical approach helps to cope with Production Planning complexity:

Production Planning



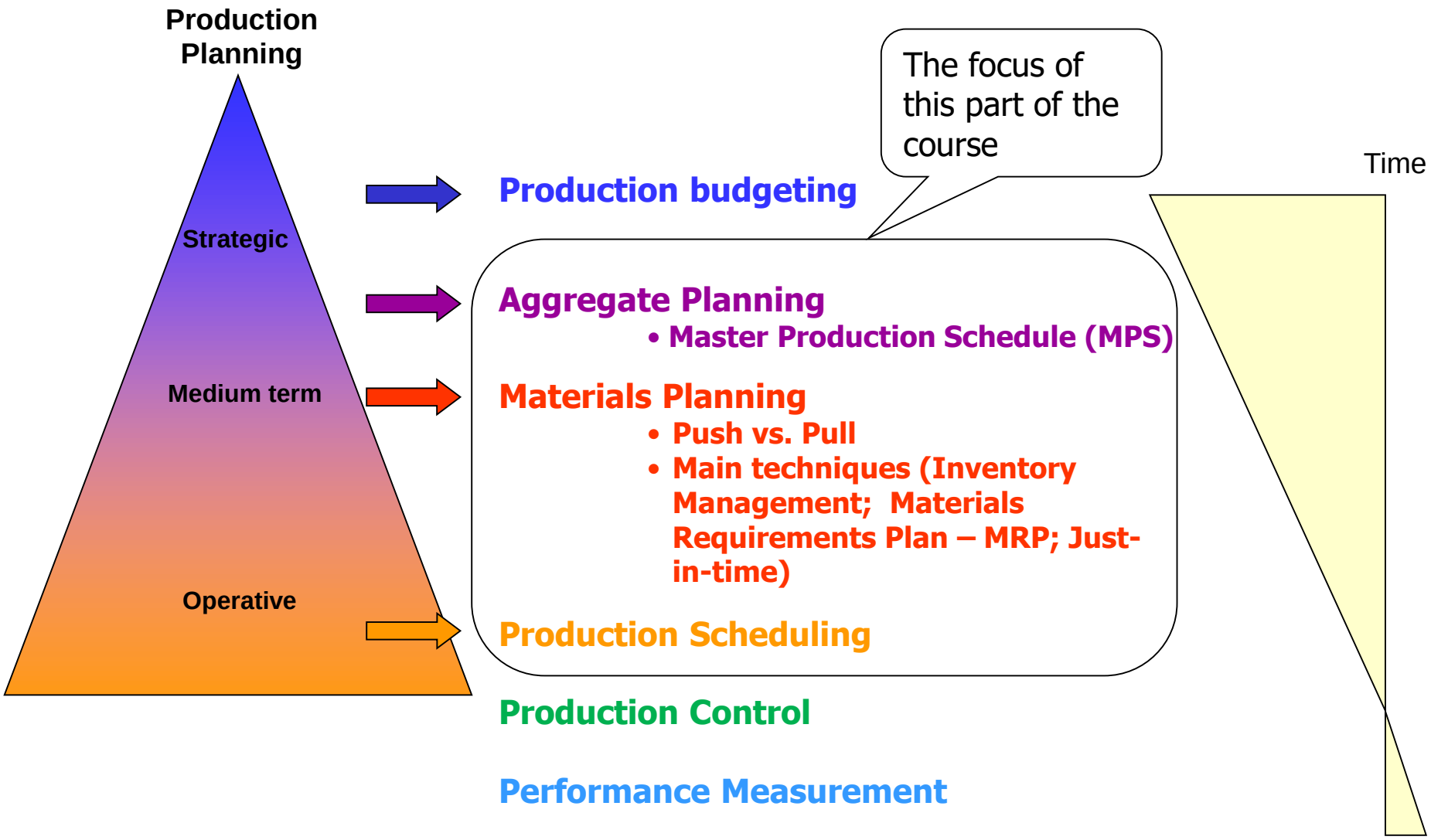
Horizon:	2-5 years
Objectives:	price, quality, service …
Planned item:	the production level as a whole
Decisions:	long term production capabilities (size and scope) ...
Pace:	year

Horizon:	1 year (6 – 18 months)
Objectives:	to fulfil forecasted demand at the lowest cost, to avoid stock-out
Planned item:	product families (groups, types)
Decisions:	when production starts in each period, make or buy tactic ...
Pace:	month / week

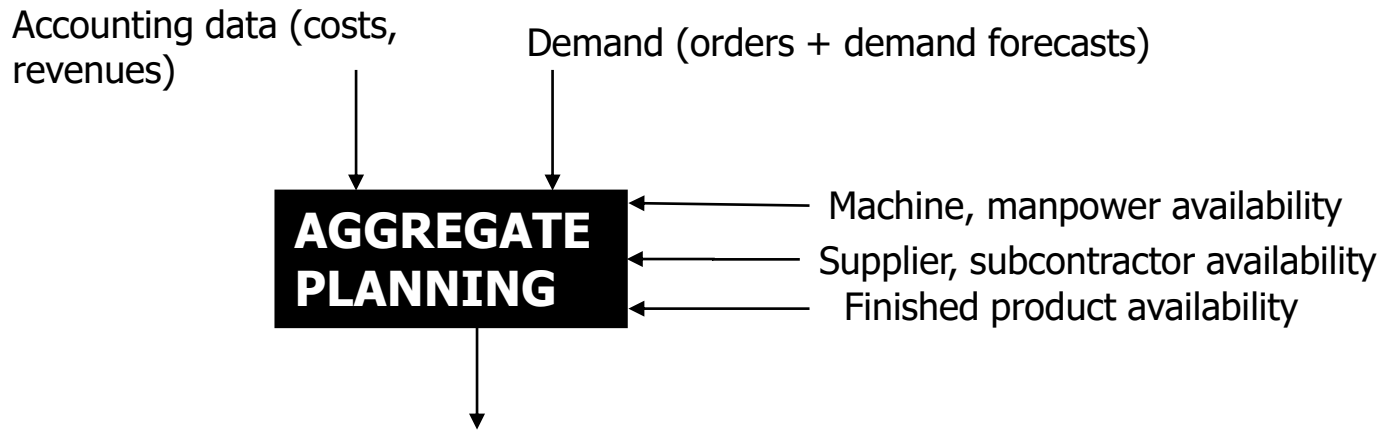
Horizon:	1 week / day (shift)
Objectives:	to effectively fulfil production orders
Planned item:	each (single) part number
Decisions:	when to produce, which workcentre, which sequence, etc.
Pace :	hour / real-time

The highest the detail, the shorter the time horizon, and … the larger volume of data, the stricter the constraints, the lower the economic impact of decisions

Production Planning: an hierarchical approach



Aggregate planning: an overview



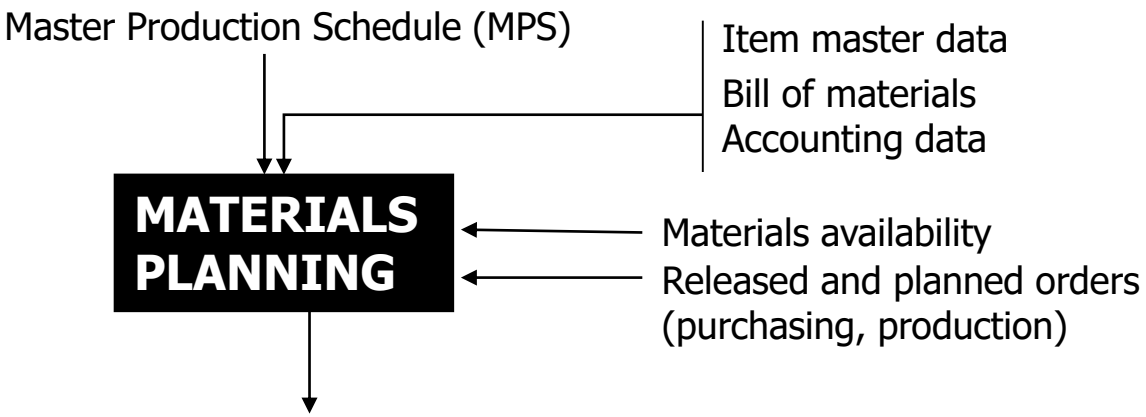
Master Production Schedule (MPS):

How many units of finished products are to be manufactured in the medium-long term?

Notice that:

- Only finished products are considered (not materials)
- Only the most critical production resources (bottlenecks *) are considered

Materials planning: an overview

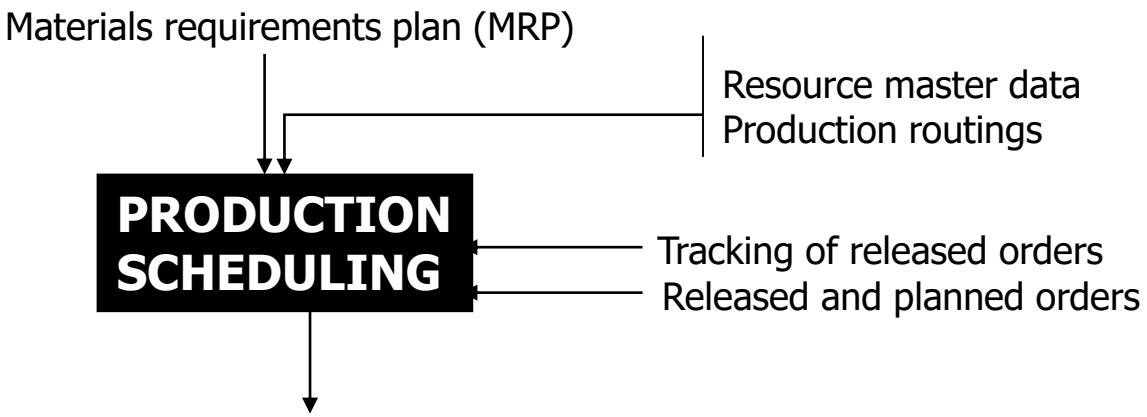


Materials requirements plan (MRP):
Which quantity for each item is to be manufactured/purchased in the short-medium term?

Notice that:

- MPS is a constraint for materials planning
- In case of very simple systems (in terms of bill of materials or production system), this planning phase may be avoided
- The output of this phase is the proposal of production orders and of purchasing orders

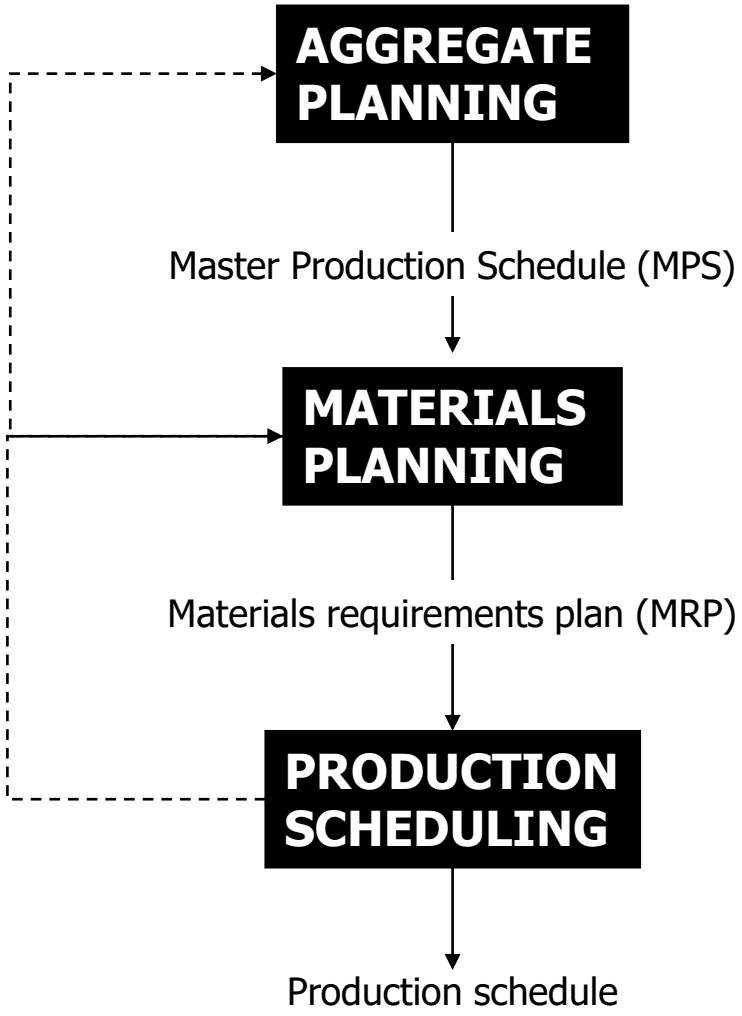
Production scheduling: an overview



Production schedule:

Which production order must the machine work on as soon as the machine will finish the current order?

The whole process: an overview



What about if the problem at some phase results unfeasible?

- e.g. material are not available for producing the production plan
- e.g. machine capacity is not enough for producing the production orders within the planned delivery time

If a phase results unfeasible, the output of the previous phase must be modified, for instance by:

- abandoning the optimal solution of aggregate planning
- using safety stocks

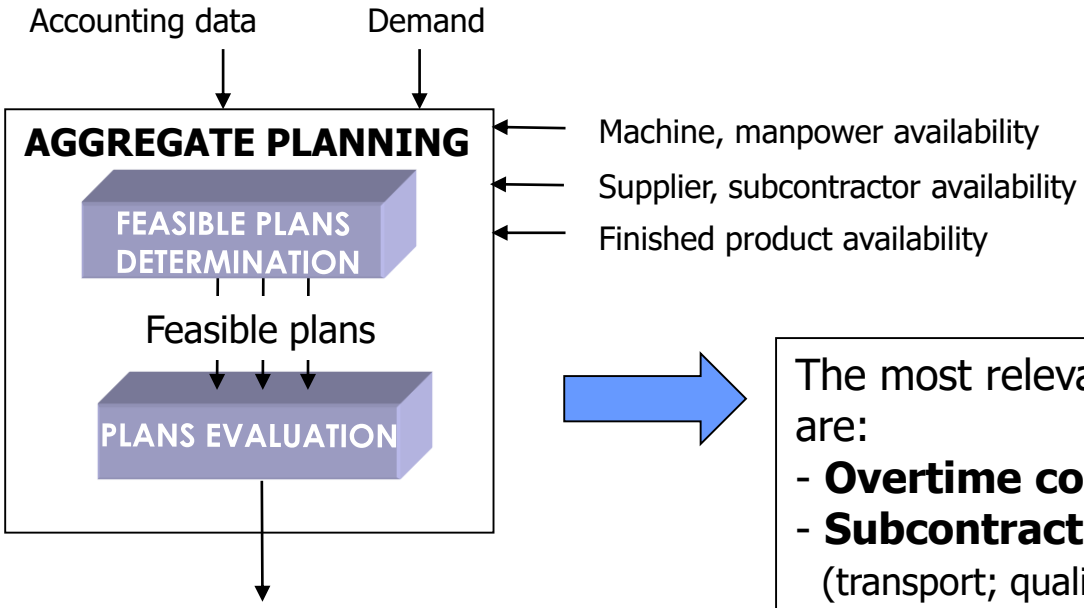
The last constraint to be relaxed is usually demand constraint (i.e. service level)

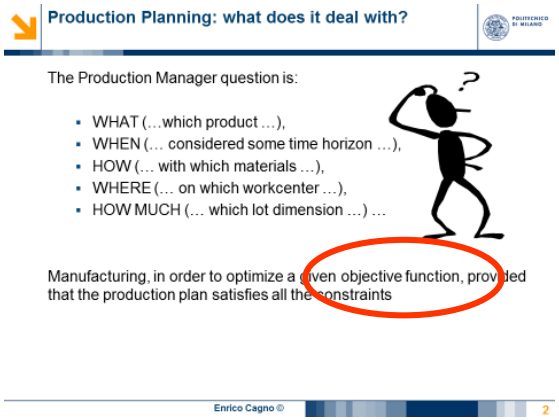
Synthesis

Phase	N.	Organiz. level	Time	Horizon, time bucket	Frequency	Uncertainty	Data	Decisions	Constraints	Object
MPS	1	Central	Discrete	Horizon from 6 months to 2 years, Bucket: week or month	Rolling, From monthly to annual	High (part. demand)	Few and aggregated (families, depts., critical materials)	Demand response strategy; resources arrangement	Weak (MPS sets capacities)	Plan cost
MRP	1	Central	Discrete	Horizon from 3 months to 1 year, Bucket: day or week	Rolling, From daily to weekly	Medium (part. demand)	Numerous (items, bills, ..)	Production and purchasing proposals by item	The structure of the products is considered	Inventory
Scheduling	N	Local (dept.)	Continuous	Horizon from shift to week	Rolling From daily to weekly or by event (resched.)	Medium-low (part. Internal resources and purchased materials)	All (cycle phases, resources, also auxiliary, suppliers, …)	Operativeness (production launch, assignments, sequences, ..)	All (materials, technologies, etc.)	To be defined (efficacy, efficiency)
Control	N	Local (resource)	Continuous	Real Time	Continuous	-	Quantity and quality	-	-	-
Measurement	1	Central	Discrete	In the past. From week to year	To be defined (case by case)	-	All (at different levels of aggregation)	-	-	-

Relevant production costs

Going into depth with aggregate planning…





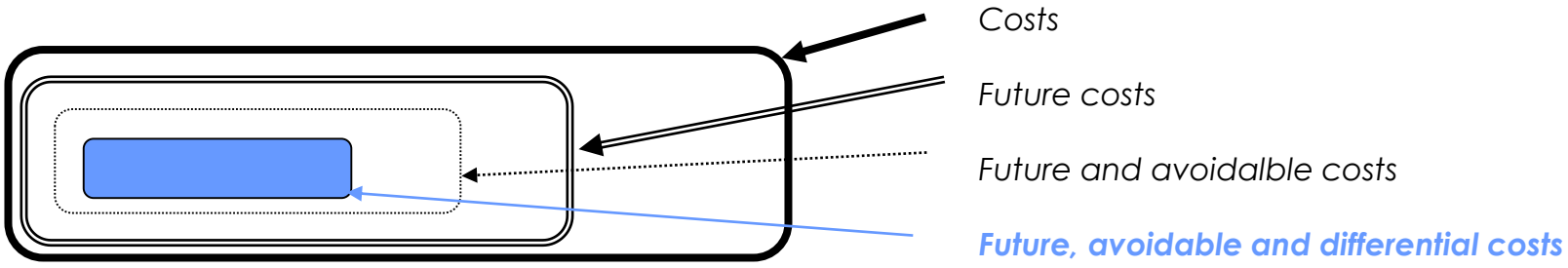
The most relevant costs for production planning are:
- **Overtime cost** (work contract; operator's yield)
- **Subcontracting cost**
  (transport; quality control; know-how; … marginal cost)
- **Stockout cost**
- **Setup cost**
- **Stock holding cost**

Ref. also to:
VARIABLE (i.e. a cost that varies depending on a company's production volume) and **FIXED** (i.e. a cost that does not change with an increase or decrease in the amount of goods or services produced) costs
DIRECT (i.e. a cost that can be easily and completely attributed to the production of specific goods or services) and **INDIRECT** (i.e. a cost that is more difficult to assign to a specific product and calls for a arbitrary rule for assignment) costs

Relevant production costs

We need to determine the most convenient plan (i.e. the plan which minimizes the costs) among several feasible alternatives, then we consider “relevant” a cost that:

- **is a future cost** (past costs are sunk cost!)
- **is avoidable** (if we do not follow plan P1, we do not sustain that cost)
- **is differential between alternative plans** (if in plans P1 and P2 the same quantity of raw material is needed, raw material cost is not relevant since it is not differential)



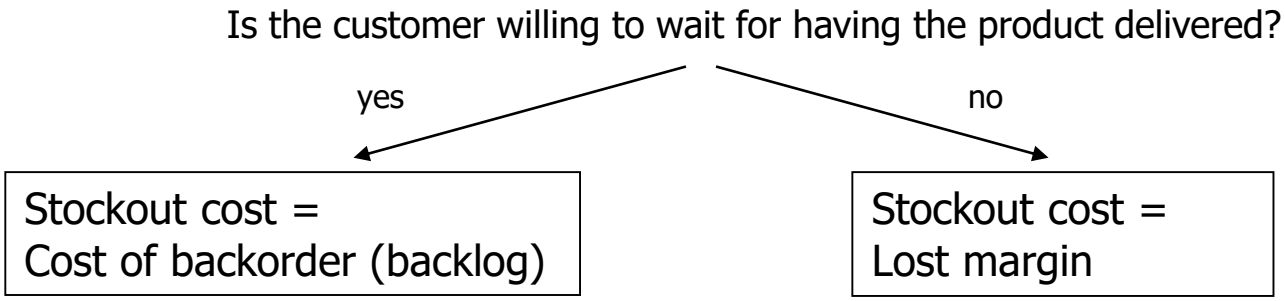
Stockout cost

Stockout cost incurs when current availability of finished product is unable to meet current orders

It applies to both make-to-stock and make-to-order production:

- make-to-stock: the finished product is not available in stock when the customer wants to buy it
- make-to-order: the finished product is not available in the planned delivery date

The stockout cost is different according to the reaction of the customer:



- Lateness penalties (if any, on event and/or amount of delay)
- Expediting costs
- Extra costs of order shipping (in case of split deliveries)
- Extra costs of order administration (double documents)

- Lost margin = Lost revenue (price) – Costs of not yet performed activities (both of production and of procurement)
- Other penalties (if any; see backorder)

IN BOTH CASES:
IMAGE LOSS FOR THE COMPANY!

Loss of other orders
Loss of the customer

Setup cost

Setup cost incurs when:

- the product entering the system (machine) is much different from the previous one (e.g., white painted bicycle after black painted bicycle)
- the production rate of the system (e.g., part/minute) is modified
- … anytime there is a change affecting the setting of the system

The setup cost has two components:

- *Expenses ("out-of-pocket costs")*, e.g.: materials consumed for setting up the machine; specialized operators involved in machine regulation (only if they are a differential cost!); extra-scrap due to machine restart, …
- *Opportunity costs ("imputed (figurative) costs")*: in order to quantify these costs, the planner should answer to the following question "How would I use the system (machine) during the setup time if the system (machine) worked in that time?"

Setup cost

How do we calculate opportunity costs?

CASE 1: The system (machine) is fully loaded (saturated):

- Each minute the system looses for setup is a minute of “lost production”
- The opportunity cost is quantified as the cost of further production capacity (usually: overtime, subcontractor) needed for producing lost production
  - Overtime:
    - how much overtime do I have to pay for recovering the lost production? Say OH the number of overtime hours (remind: operator’s yield in normal time is usually higher than the overtime yield; then if setup lasts SH hours, usually SH<OH)
    - How much does overtime cost? Say OC the cost per hour of overtime (usually higher than normal cost per hour)
    - Then, setup cost = OH * OC
  - Subcontractor costs:
    - How many units of the product do I have to buy from the subcontractor since I have not produced them on the machine? Say SQ this quantity
    - Which is the subcontractor cost for each supplied unit? Say SC this cost
    - Which is the internal variable cost of each unit? Say IC this cost; notice that I save this cost since I buy the product from subcontractor
    - Then, setup cost = SQ* (SC-IC) (but other issues can take place: quality control, know-how loss, …)
  - When no other source of capacity is available, the opportunity cost is quantified as the lost margin:
    - Setup cost = SQ* (unit gross margin) = SQ * (unit price – unit variable cost)

Setup cost

How do we calculate opportunity costs?

CASE 2 : The system (machine) is not fully loaded (saturated):

- A minute of setup does not imply “lost production”
- The opportunity costs is null
- BUT if operators take part in the set-up and their cost is either variable or fixed, but they can be utilized elsewhere, then the opportunity cost is the operators cost (i.e. number of hours for set-up * cost per hour)

Stock holding cost

Stock holding (ownership) cost incurs when an item has been produced or purchased before the moment in which it is consumed:

- Examples:
  - A finished product is manufactured on the basis of demand forecasts (make to stock production)
  - The supplier is very far from the manufacturer so the transportation costs are very high; then the component is purchased in a huge quantity (FTL, full truckload) even if it will be consumed in few units per period during the year

Stock holding cost

The *stock holding (ownership) cost* has two main components:

- *Expenses ("out-of-pocket costs")*:
  - Physical space occupied by the inventory (building, shelving system, utility costs, rent, insurance, taxes, security, etc.)
  - Cost of handling the items (labor, forklifts, energy, etc.)
  - Cost of deterioration, obsolescence, and, generally, product loss (e.g., theft)

- *Opportunity costs ("imputed (figurative) costs")*:
  - Financial opportunity costs: money tied up in inventory, such as the cost of capital. In order to quantify these costs, the planner should answer to the following question "If I make stock now, which utilization of my money am I renouncing?"

Stock holding cost

"If I make stock now, which utilization of my money am I renouncing?"

Let us consider the following situations:

- My company has invested its cash in bonds (i.e., liquidity) having an average yield of 5%/year; moreover an alternative investment exists having a yield of 10%/year
  - The alternative we are renouncing by making stock is to gain the yield of bonds (in fact we can use cash for investing in the alternative investment, if we want)
  - *Opportunity rate* = *i* = 5%/year (i.e. 1 euro in stock for a year costs 0,05 euro to the company)
- My company has no liquidity and a financial institution can issue for us a loan having a burden of 7%/year
  - *Opportunity rate* = *i* = 7%/year (i.e. 1 euro in stock for a year costs 0,07 euro to the company)
  - Notice that *i* remains 7%/year even if a profitable investment exists: making stocks does not imply that we have to renounce the alternative investment since we can borrow the money to invest in the profitable investment though we make stock.
- My company has invested in a profitable investment whose yield is 10%/year, it has no further cash and no financial institution can issue further loan for us
  - *Opportunity rate* = *i* =10%/year (i.e. 1 euro in stock for a year costs 0,10 euro to the company)
  - Notice that if further cash is available, the real alternative we are renouncing is no more the 10% yield per year (we can use cash for investing, if we want) BUT the financial profit of liquidity (e.g. bond yield)
  - Notice that if we can borrow more money from a financial institution, the real alternative we are renouncing is no more the 10% yield per year (we can use loan for investing, if we want) BUT the savings of financial burden of loan

Stock holding cost

By summarizing the previous considerations, here are the possible answers to our question:

"If I make stock now, which utilization of my money am I renouncing?"

Case	**Answer**
The company has liquidity (no debts)	"For making the stock I use the cash, then I renounce to invest it in the most profitable alternative way" (cost = financial profit of bonds)
The company has debts but further money can be borrowed at financial institution	"For making the stock I must ask a further loan, then I renounce to save financial burden on loan" (cost = financial burden of loans)
The company has debts and no further money can be borrowed	"For making the stock I use the money already invested in profitable investment (I disinvest), then I renounce to the yield of that profitable investment" (cost = profit of the alternative investment)

Stock holding cost

Once the percentage opportunity cost *i* [%/year] (*stock holding opportunity cost rate*) is known, the (financial) opportunity cost is calculated as follows:

Opportunity cost = Average Stock Value * *i* [euro/year]

- Where:

  Stock value = Average quantity in stock * Unit variable cost

- Notice 1: only variable costs are considered in the formula!
- Notice 2: pay attention when using, e.g., [%/month] instead of [%/year]:
  - a) discounting (back) is needed
  - b) Average Stock Value has to be calculated on the right time span (e.g., month)

Stock holding cost

Often, all the expenses ("out-of-pocket costs") related to holding stock (physical space, handling, obsolescence/deterioration/loss) are expressed as a percentage Φ of stock value (*stock holding expenses rate*).

Then, the whole *stock holding (ownership) rate* is:

$$Cm = i + \Phi \quad [\%/year]$$

The whole stock holding cost formula becomes:

$$\text{Stock holding cost} = \text{Average stock value} * Cm \quad [euro/year]$$

Sometimes (ref. 3PL - third part logistics) both expenses (c_i) - in particular - and opportunity costs (c_Φ) can be expressed as [euro/unit*year] so that:

$$\text{Stock holding cost} = \text{Average quantity in stock} * (c_i + c_\Phi) \quad [euro/year]$$