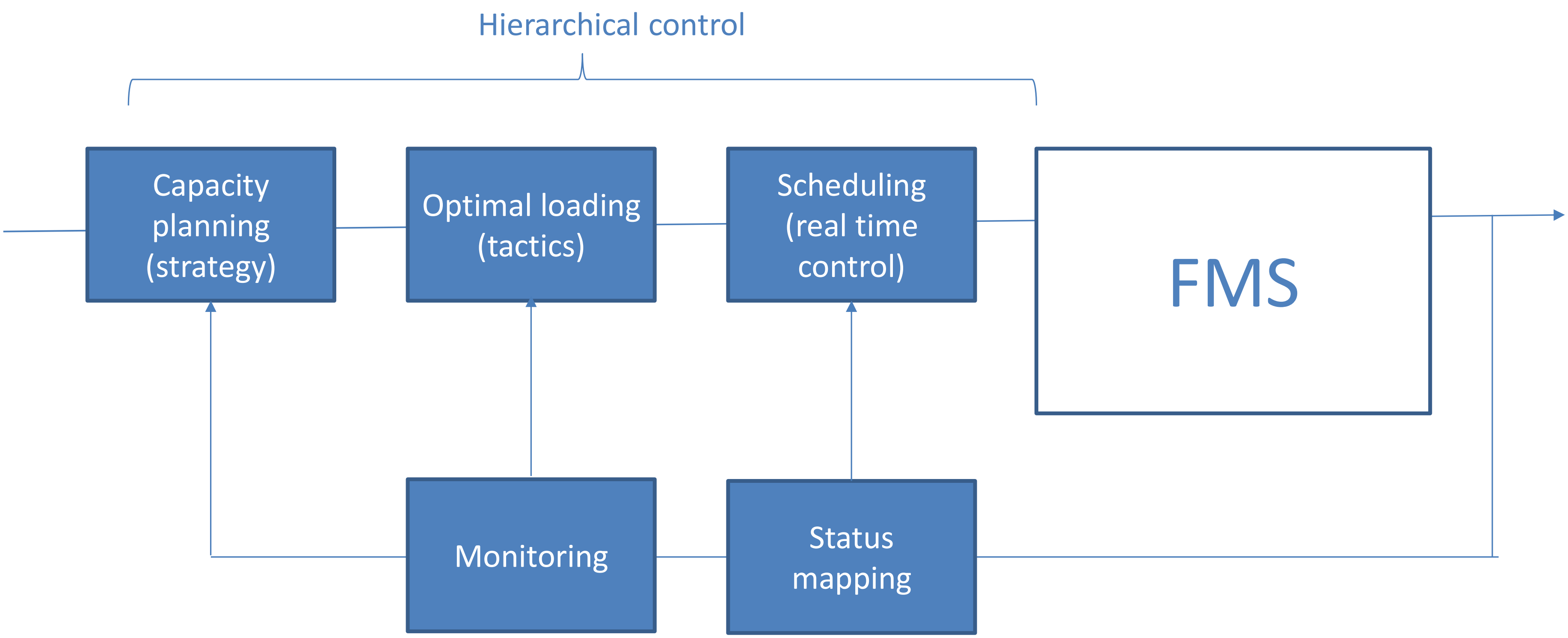
# Planning and scheduling

# Planning in Automotive

- The production planning in Automotive is extremely complex involving different Company functions.
- The development of the Long-range plan (from 5 to 10 years) is done yearly with monthly update.
- It is deployed for all production plants and include first a vision of the product, then an analysis of demand evolution vs available capacity, then a multiple scenarios comparison and finally a plan of investment that will represent the fund to cover the following initiative.
- Limiting to the demand, further to the Long-Range Plan, the Plant Organization is based on an Operative Plan with 18 months vision updated and discussed month by month, where the vehicle demand plan is submitted to bottleneck analysis.
- Powertrain plan is more subject to daily variation
- Inside a plant the production plan is distributed line per line.
- In the FMS period a great importance was given to the line Planning.

# FMS management system



# Linear programming

- The linear programming is a very important tool in the hand of a planner since there is an easy-to-implement algorithm able to define the optimal solution.
- A linear programming problem can be described as:

$$\min F(x1, x2, \ldots xn)$$

Submitted to the constraints:

$$a1x1 + a2x2 + \cdots + anxn = 0$$

$$b1x1 + b2x2 + \cdots + bnxn \geq 0$$

The optimal solution (x1,x2…xn) can be found with the Symplex algorithm

# Capacity Planning

- In an FMS, the first step to be done-consider we are in an extreme flexible environment- is the selection of the max production feasible in the line horizon (normally one week).
- This selection could be done by the following;

$$\min T$$

$$\textit{(for each machine j)} \qquad \sum_{1}^{N} i \; qij^{*} \; ti <= T$$

$$\textit{(for each part i)} \qquad \sum_{1}^{M} j \; qij = Qi$$

# Optimal loading

- For a shorter horizon (normally one shift), the planning must be tuned with the details.
- First, it is necessary divide the long period in slices, so Qi becomes QRi.
- Then for each slice, with a preprocess define the optimal tool configuration then enable qji>0 only for the machines that have the right tool for the part i.
- Of course, there are much other condition to follow (multiple operations, special machines,…) that can be added in the linear constraints or manager with heuristic approach in pre or post processes.
- Then rework the symplex with:

$$\min T$$

$$\textit{(for each machine j)} \qquad \textstyle\sum_1^N i \; qij{*}\, ti <= T$$

$$\textit{(for each part i)} \qquad \textstyle\sum_1^M j \; qij = QRi$$

$$\textit{(for machine j without the tools for i)} \; qij = 0$$

# Scheduling

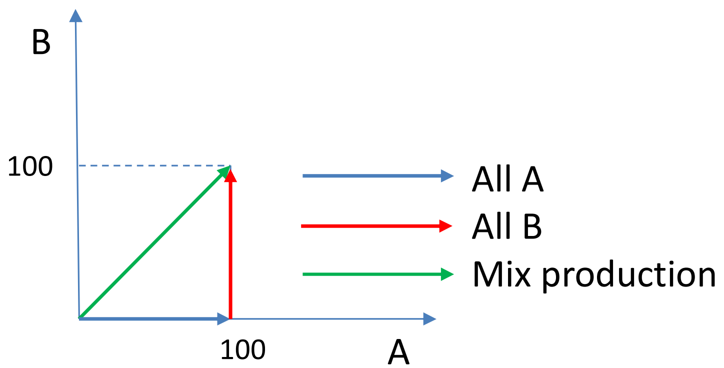
- The Planning is a methodology that apart from production can have other applications but not as wide as for the scheduling.
- In the real time FMS management, following the plan for the short term require to take a decision for each component to introduce in the system.
- It is a problem of defining the optimal order of production respecting certain rules given by the plan.
- This is a problem of daily management of ordinary life,
- **The most general principle of Scheduling suggests to give priority to the shortest tasks in order to satisfy the larger number of customers.**
- There are 2 considerations: one bad and one good.
- The bad is that unfortunately this principle cannot be used in our FMS problem.
- The second, good, is that exist another algorithm that can give us support optimizing the sequence,

# Mix production

- To formulate the proposed algorithm, very simple as a concept but not equally in the mathematical description, it is necessary remember a general law:

**A cumulated production aligned to the final mix minimize the inter-operational stock**

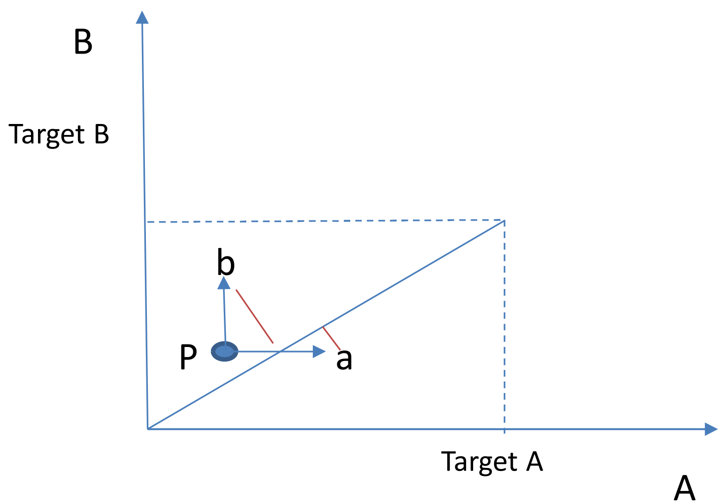
- This law can be easily understood without mathematical demonstration.
- Let assume a mixed production A and B with a target of A=100 and B=100 e.g. machined parts.
- The delivery of an A and a B allows the assembly of a product P(A,B).




- If we produce all A, we have a stock of 100 A before starting to deliver a product P. Instead in the mix production the stock is 0.
- In the case of single product production, the rate of production of A (and after B) is 100% stressing more the system vs the mix production that requires only 50%

# A useful algorithm

- To guarantee to mix production, in a mix of N components, it is necessary select the part i (i=1,N) that minimize the distance from the optimal mix.
- In the example below if we are in a generic situation P we have two possible chioices A to go in the status a or B to go in the status b.
- The mix line  connects the origin with the target point T(A, B)
- The best solution is the one that is closed to the mix line




- If we calculate the distance of b to the mix line and a to the mix line it is clear that the choice A is the best
- So, the algorithm is:
  - For any "next" part to be produced after asset of production Q (q1,q2,…qi,…qN)
  - define all the alternatives Q1, Q2,…QN where Q1=(q1+1,q2,..qN); Q2=(q1, q2+1,…qN) and so on
  - Calculate the distances to the line of Q1,Q2,… QN and select the case where the distance is minimum

# Applications

- This algorithm can be used in several cases: inside an FMS to minimize the needs of fixtures, in a resequencing warehouse to minimize the production unbalance, to generate an optimal loading starting from any conditions,
- The distance formula can exactly be the geometry formula of distance of two points or a functional of the squared errors
- The algorithm can so be formulated as:

Select case ĩ $(1, N)$: D(ĩ) =min, where

$$D(i) = \sqrt{(q1/qtot - m1) ** 2 + \cdots + ((qi + 1)/qtot - mi) ** 2 + \cdots + (qn/qtot - mn) ** 2}$$

and:

qi= quantity of part i already produced
qtot=$\sum_1^N qi$
T(i) = production target of part i
mi=fraction of the mix 1= T(i) / $\sum_1^n j\, T(j)$

# Real time control

- The best structure got to have a real time controller of a production line has been defined as: