Flexibility

The flexibility challenge

Around 1980 the social conflicts ended in western world, opening a period of economical growth.

The consumers got aware of the upgraded conditions and started to think that a car "black only" was not a satisfying condition.

The **flexibility** became the new challenge for the industrial world and specifically for Automotive.

Multiple versions for the same product started to become the normality, various internal and external features for the vehicles, different powertrains for each car, different characteristics for the same engine.

The impact on the industrial world was tremendous. It was clear from the beginning the problem would have been solved only with the **support of Information technology** (the CIM concept was last fashion) and a new approach on Logistics and Supply chain.

For the first time the transfer line model is challenged in its limit and a parallel model instead of series is proposed in machining thanks to a new concept machine: **the CNC machining center**.

Flexibility definition

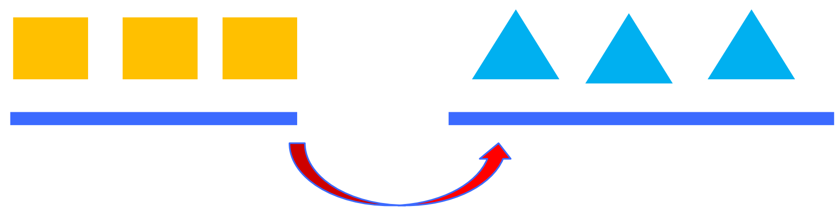
Ability to work in an assigned field of the productive mix with medium costs of production and conversion in case of new needs from the market

Adaptability	Produce and commercialize different products with the same machinery, limiting investment and time to market
Convertibility	Capability to modify the plant in order to re-use it for a brand-new production
Versatility	Control burden costs modifying the products mix, from a lighter to a heavier model or viceversa
Elasticity	Absorb negative or positive demand variations without an unbearable increase of the unit costs or investment

Base capabilities

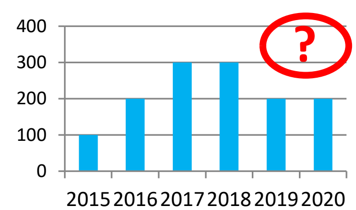
1 mix

2 conversion



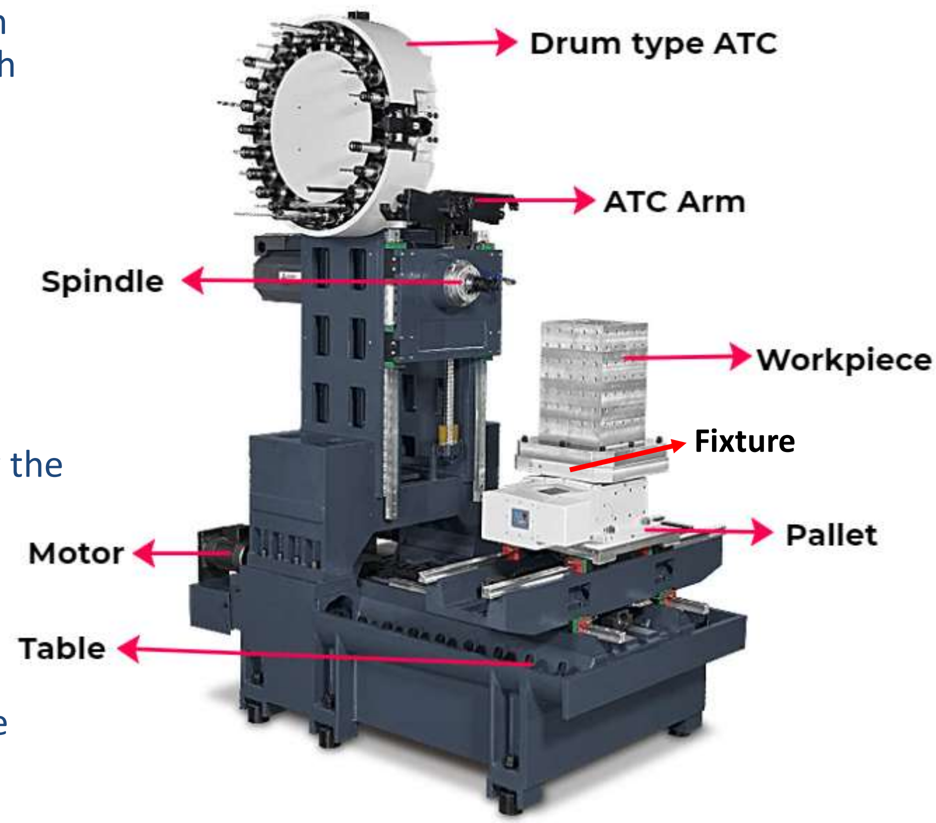
3 volume

Production capacity
VS
demand evolution

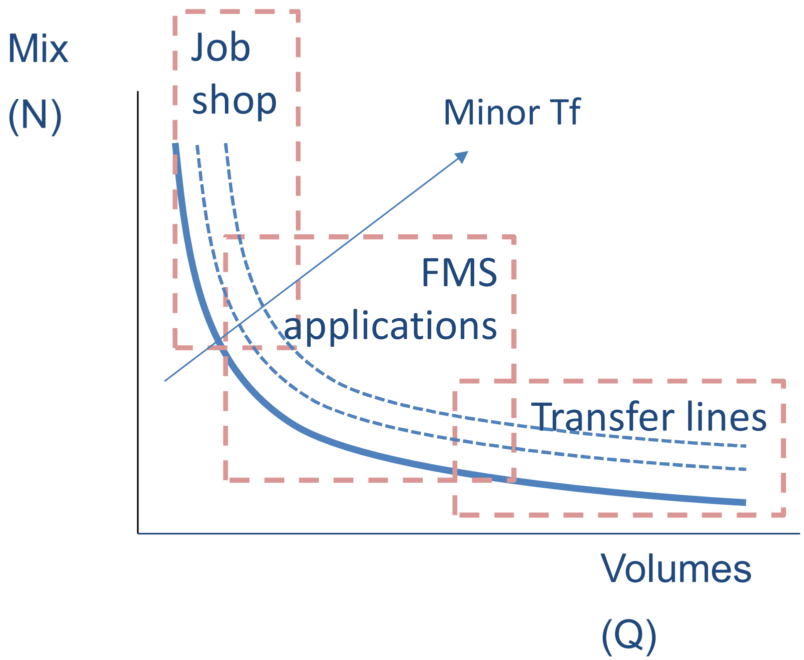


A new machine: CNC machining center

- A CNC machining center is a CNC machine tool that can perform different operations like milling, drilling, tapping and boring with high accuracy and minimal time.
- It consists of:
  - **a spindle** that moves in the work area to execute the operation
  - an **automatic tool-changing mechanism** that enables it to use multiple cutting tools during the machining process.
  - a **table with pallet and fixture** to keep part in precise position.
- Normally the axis are 5, not all on the spindle, of which three cartesian and two rotating: z is the spindle rotation axis, x and y the horizontal and vertical ones, orthogonal to the spindle, A the rotation around x and B the rotation around y.
- Mounting a probe onto the spindle the MC can act as a measurement machine
- The acronyms MC or CNC are equivalent in the use even if there are a lot of CMC machine not properly MC, so CNC is imprecise



The AT Kearney law



$\sum_1^N i$ qi* ti= T*M

Where:

- T is the considered time
- M is the number of spindles
- Qi quantity to be produced of part i in time T
- Ti machine time of part i
- N number of parts

Setting:

- Tf (the average weighted time of parts of the same family) $= \frac{\sum_1^N i \text{ qi} * \text{ti}}{\sum_1^N i \text{ qi}}$
- Q= $\sum_1^N i$ qi/N

We have: **Q * N = T * M / Tf**

Initially the FMS started as an application of a computer to manage the logistics in a job shop but with the consolidation of MC's they become a new machining entity

Flexible Manufacturing System (FMS)

"A Flexible Manufacturing System consists of several CNC machine tool equipped with a work piece and tool change handling device, a work piece store, automatic control and supervision by a central computer. Automatic cleaning, deburring, inspection and, if necessary, manual operations may be integrated. These are interlinked by an automatic work piece flow".

(prof. Warnecke – Fraunhofer Institurte for Production Automation, 1985)

- CNC machine tool
- Automatic cleaning/deburring
- Inspection
- Manual operations
- Automatic material handling
- Work piece storage
- Computerized supervision system

Degree of maturity of the technology with consequent result

Evolution of the FMS

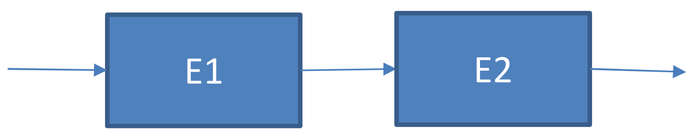
- The introduction od MC's inside the production factories was very successful. Gradually the job shop were transformed in department of MC's of different dimensions, precision and complexity.
- On the other hand, the first attempt to connect CNC create flexible department was not equally successful.
- The best examples were reached with small group of machines, low variability and evolution, reduced SW.
- The main problem was the reliability od the first MC's very complex for the technology of 70's and 80's.
- Another problem was the attempt to use an FMS for family of objects too different.
- At the end of 90's the technology of MC's offered a high efficiency and a great numbers of MC's started to be put in huge lines (50-100 machines) but with higher volumes and reduced variability showing the convertibility and elasticity as the major asset of the FMS.
- Gradually the term FMS was replaced by CNC automatic line.
- The content of the Automatic management system was definitively limited to the monitoring and handling system.

Flexibility pushes parallel approach

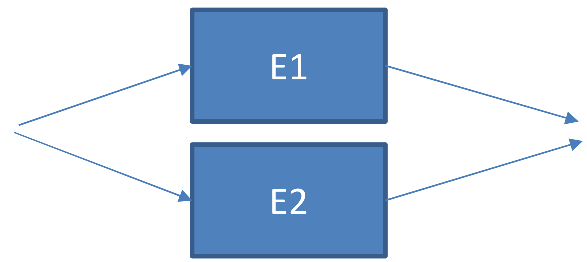
- We have seen that the transfer lines were the basis of all the mass production growth.
- They were characterized by a rigid serial process so as for the synchronous lines in assembly.
- The flexibility revolution showed issues in the “total serial” approach and it has been natural to develop solutions with “parallel” operation approaches, taking benefit by the experiment done to look for a better social compliance in the production processes.
- Any extremization seldom takes to the optimum according to the Roman’s statement “IN MEDIA STAT VIRTUS”.
- After the explosion of flexibility period some compromise were found to optimize PRO’s and CON’s of the different approaches,

Series vs parallel efficiency

- We have already defined the technical efficiency of a production system as the ratio between the effective production *cycle time (=effective work time=total available – breakdown and repair) and the total available time.
- $E = \frac{EWT}{TT} = \frac{TT-BR}{TT}$
- Where TT is the total available time and BR the downtime for breaks and repairs.
- Let consider two simple systems:



Production of 2 machines in series= production only if both are running
ES=EWT/TT= (TT –BR1-BR2 + overlapping of BRi)/TT
In terms of probability:
E series = 1-(1-E1)- (1-E2) +(1-E1)(1-E2)=
1-1+E1-1+E1+1-E1-E2+E1*E2=
=E1*E2 and in case of identical machines =E**2



Production of 2 machines in parallel= the sum of the single one, so being EWT= (E1*TT+E2*TT) and the total available time= 2 TT
E parallel= EWT/2TT= (E1*TT+E2*TT)/2*TT=(E1+E2)/2
and in case of identical machines =E

Exercise

- We have two machines. Each has 0,9 efficiency. Which is the resultant system efficiency when they are in series or parallel? For different machines 0,9 and 0,8?

E series = 1-(1-E1)- (1-E2) +(1-E1)(1-E2)= 1-1+E1-1+E1+1-E1-E2+E1*E2= =E1*E2 and in case of identical machines =E**2	E parallel= EWT/2TT= (E1*TT+E2*TT)/”TT=(E1+E2=/2 and in case of identical machines =E**2

- Identical E= 1-0,1-0,1+(0,1*0,1)=0,81 or **E=0,9**2=0,81**
- Different E= 1-0,1-0,2+(0,1*0,2)=0,72 or **E=0,8*0,9=0,72**

- Identical **E=0,9**
- Different **E=(0,9+0,8)/2=0,85**

In both cases the parallel is more efficient of series

- The problem is more evident with 10 identical machines:

- **E= 0,9**10= 0,35**

- **E=0,9**

Benchmark of Series vs Parallel

Someone could ask why for years the series was preferred if the parallel is more efficient ?
Let's compare the PRO's for each solution

PRO'S SERIES

- Each operation is simpler so could be cheaper or require less skill if manual
- There is a distribution of technology along the line so that it is possible to focus each track for gages, logistics, spare parts and so on
- In other words
  - BETTER COST
  - EASIER MANAGEMENT
  - SIMPLER FLOWS

PRO'S PARALLEL

- Less influence of breakdown with a higher efficiency
- In case of flexibility, if a product is heavier than another has just a slower process but there is no loss of manpower or machine missed load
- In other words:
  - MAJOR EFFICIENCY
  - MORE FLEXIBILITY