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INDUSTRIAL PLANTS II

Chapter two ï part 2

Maintenance of Industrial Plants

Economy

DOUBLE DEGREE MASTER IN

ñPRODUCTION ENGINEERING AND MANAGEMENTò

CAMPUS OF PORDENONE

UNIVERSITY OF TRIESTE

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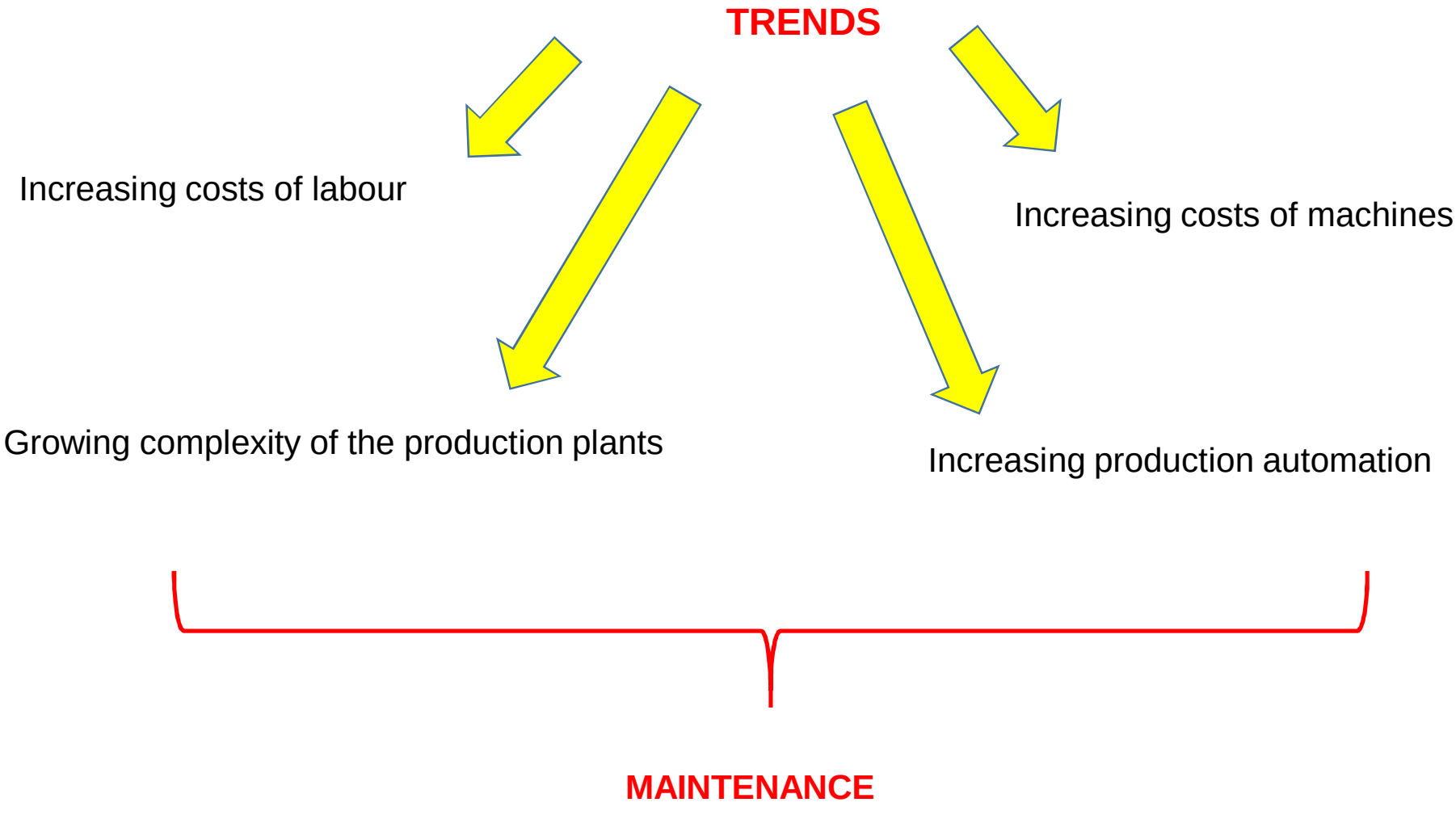
ECONOMIC MATTERS OF MAINTENANCE



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MAINTENANCE DEFINITION

According to UNI EN 13306, Maintenance is the 'combination of all managerial, financial, engineering actions, foreseen during the life cycle of an industrial asset, allowing or restoring a system to a state of functionality".

From a cost-benefit point of view, maintenance is considered a cost and not a pure value-added factor.

Nevertheless, maintenance is subject to the cost-benefit analysis associated with the successful use of the system in order to maximize the benefit obtained from the good functioning of the system. Therefore it has to be organized in order to maximize its efficacy at the lowest costs in safe conditions

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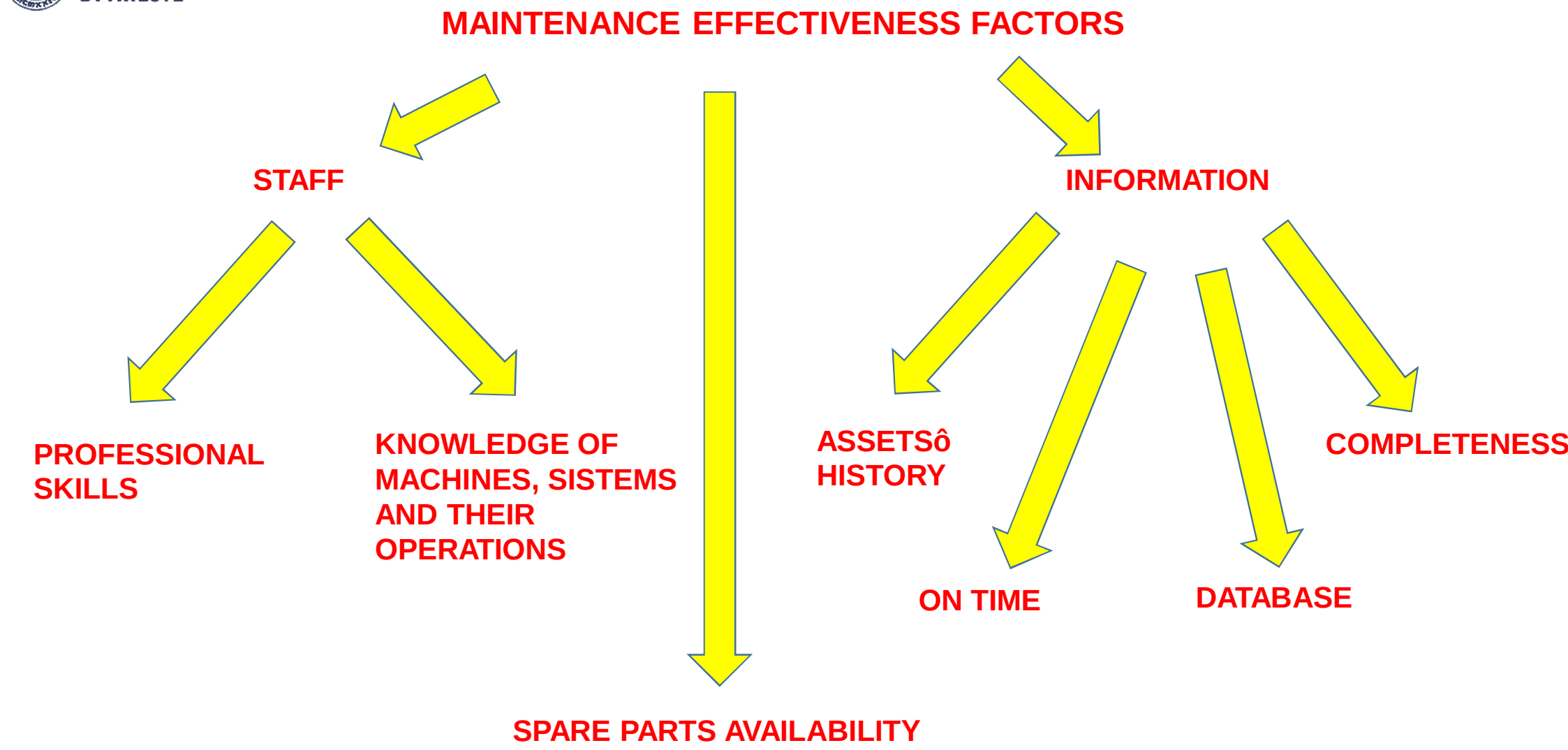

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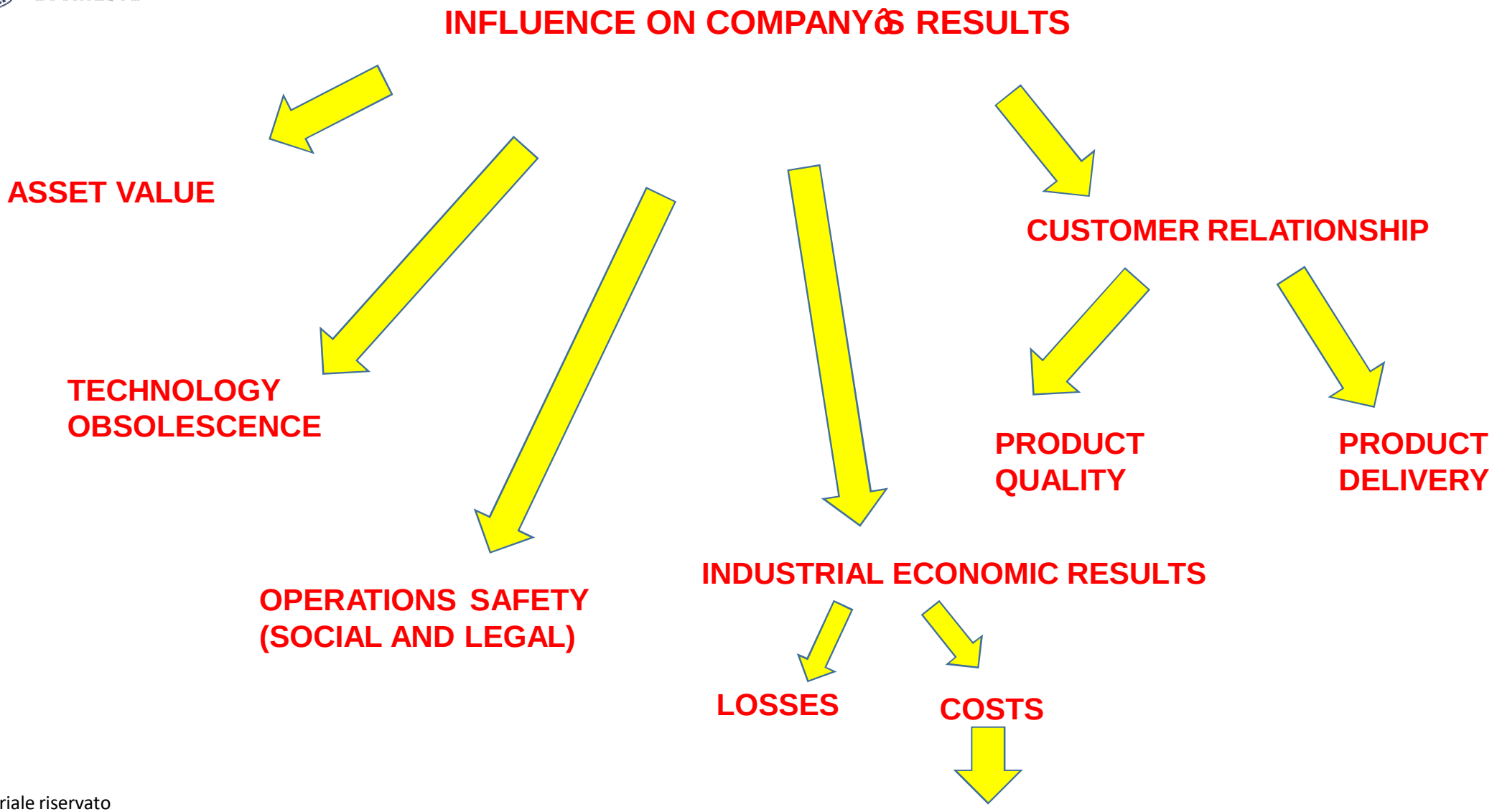

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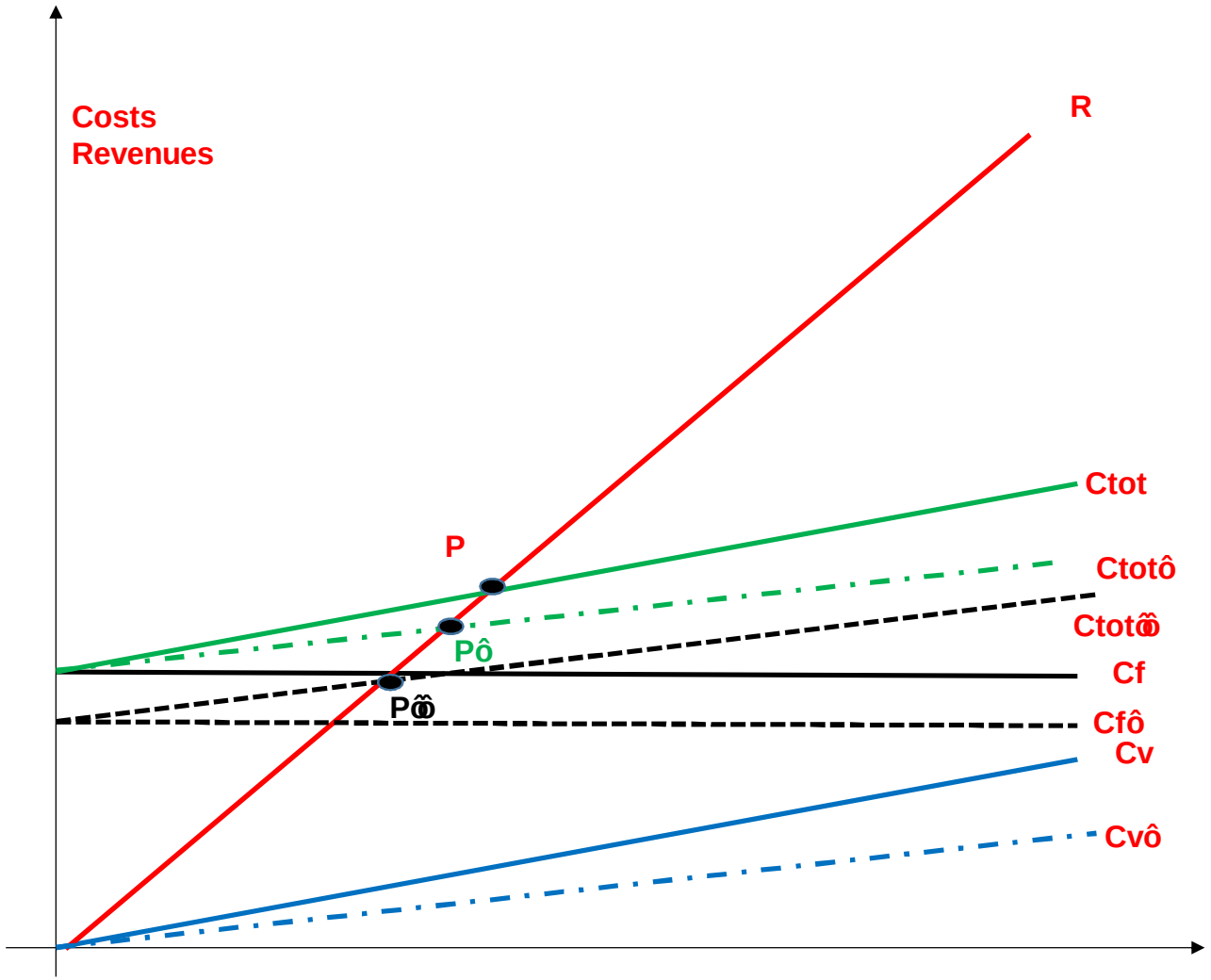
INDUSTRIAL ECONOMIC RESULTS



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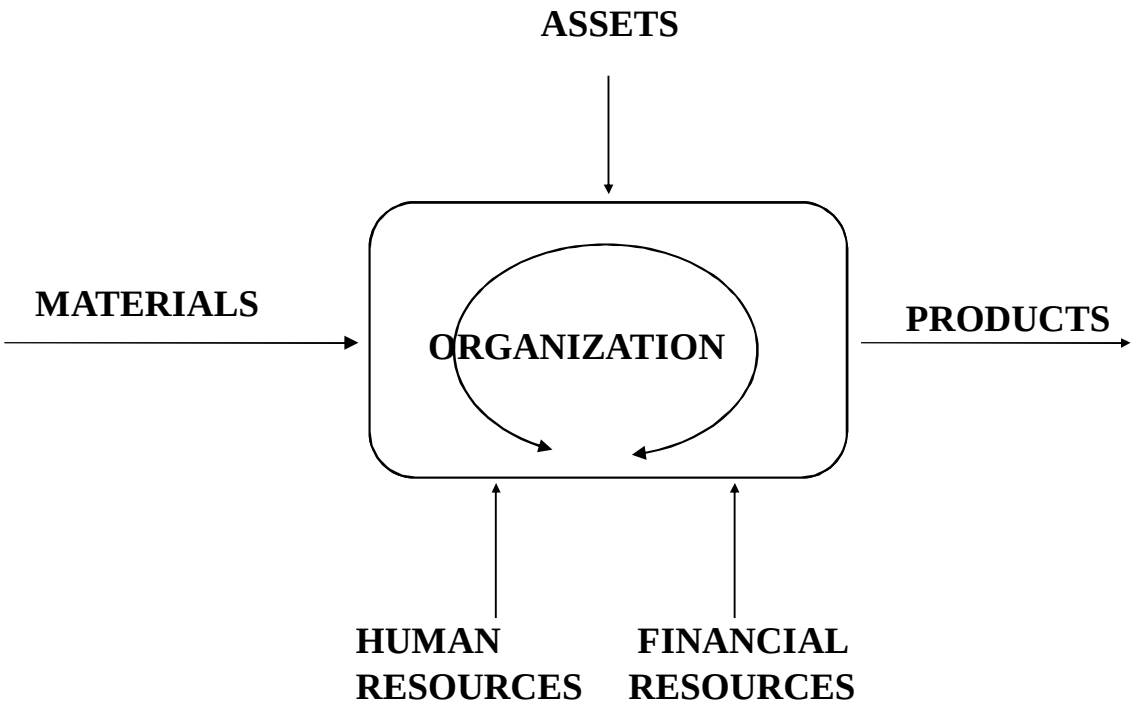
PRODUCTION SYSTEM GENERAL MODEL
PRODUCTION FACTORS



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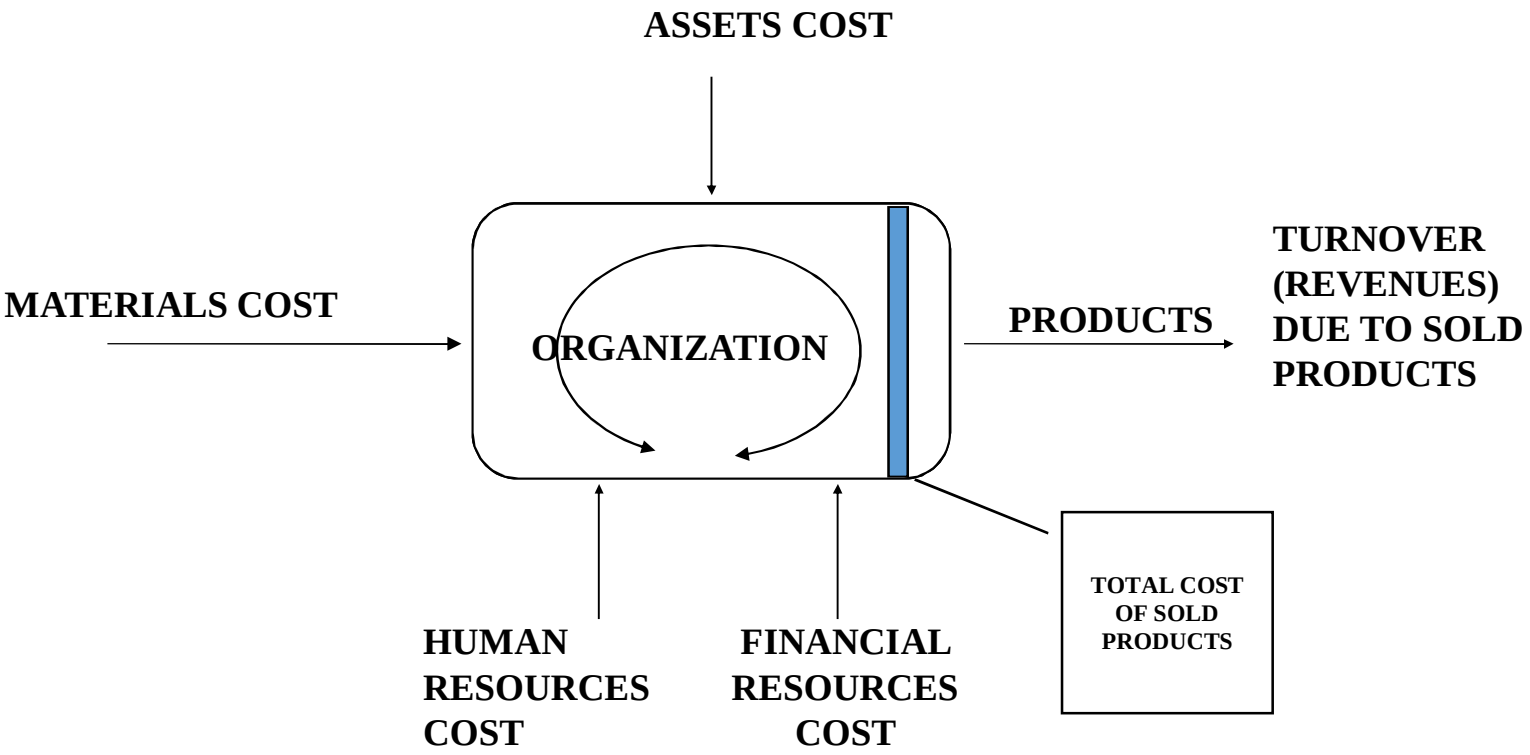
PRODUCTION SYSTEM GENERAL MODEL
PRODUCTION COSTS



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SEMPLIFIED PROFIT AND LOSS ACCOUNT

A) VALUE OF SOLD PRODUCTS AND SERVICES (TURNOVER)

B) COST OF SOLD PRODUCTS AND SERVICES

C) RESULT (DIFFERENCE A - B)

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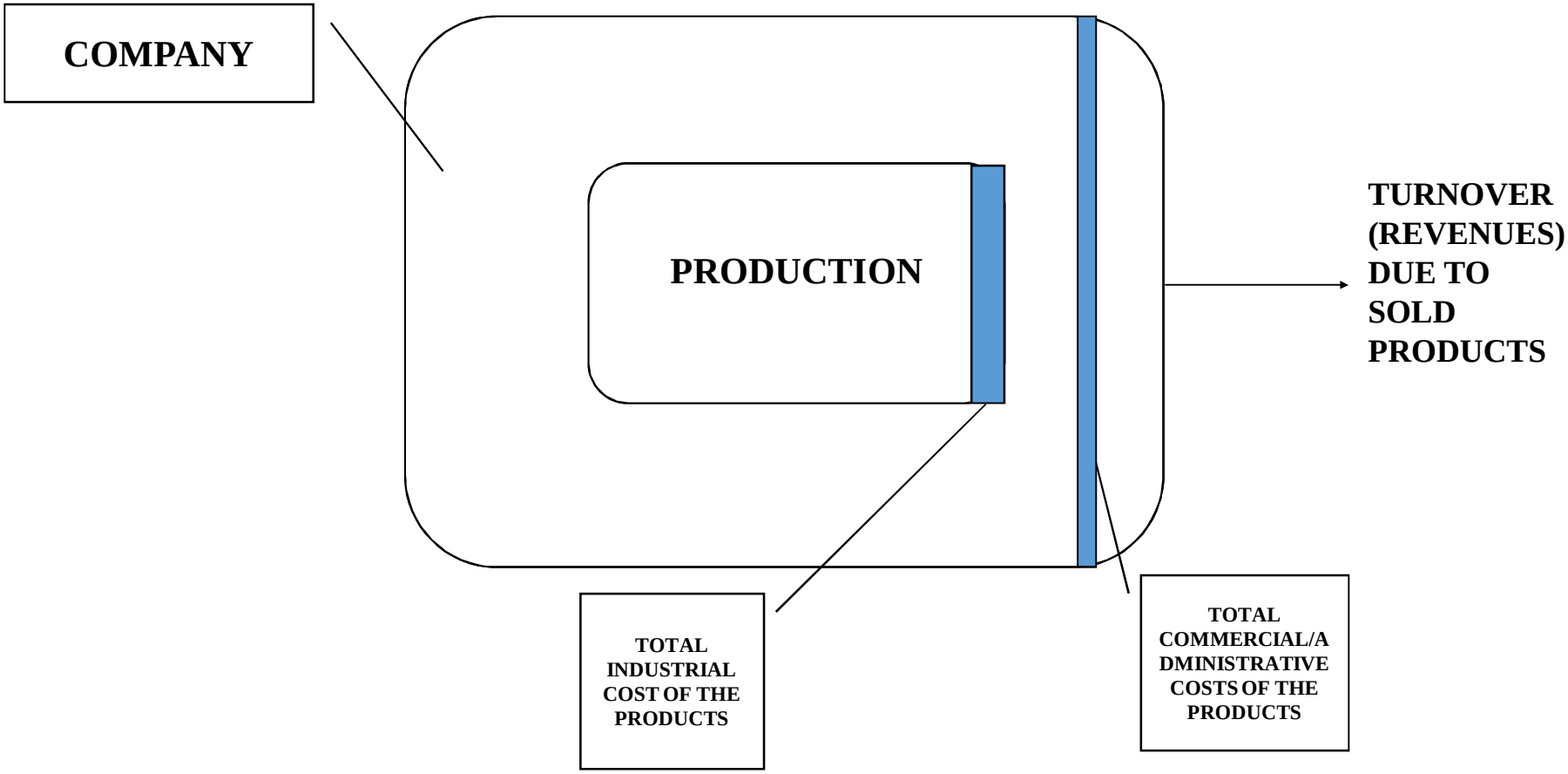
INDUSTRIAL COSTS OF SOLD PRODUCTS



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PROFIT AND LOSS ACCOUNT

A) VALUE OF SOLD PRODUCTS AND SERVICES (TURNOVER)

B) STANDARD COST OF SALES PRODUCTS AND SERVICES

C) +/- INVENTORIES OF FINISHED PRODUCT

D) +/- VARIATION TO THE STANDARD

E) CONTRIBUTION MARGIN (A-B- C -D)

F) COMMERCIAL AND ADMINISTRATIVE EXPENSES

G) OPERATING RESULT (DIFFERENCE E -F)

H) FINANCIAL INCOME AND EXPENSES

I) VALUE ADJUSTMENTS OF FINANCIAL ASSETS

J) EXTRAORDINARY INCOME AND EXPENSES

K) PROFIT BEFORE TAXES (G-H-I-J)

L) TAXES

M) PROVISIONS

N) PROFIT (LOSS) FOR THE YEAR (K-L-M)

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Introduction of maintenance policies

Economic problem of maintenance

Maintenance can contribute to the reduction of both production costs (fewer stops lead to higher productivity) and of the variable part of the same (in practice 50% of the total maintenance costs are variable costs). By reducing fixed costs, you get additional overall cost and profitability benefits.

A survey carried out in the USA on the main companies in different product sectors, showed an **average annual maintenance cost equal to 6% of the initial plant investment** (average value that may undergo significant variations in relation to specific situations and influenced by numerous factors non-technical). In the case of Italy, it can be seen that this value is **4-5% of the initial investment**, while the **operating cost is around 8% per year**.

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COMPANY COSTS

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CABBAGES AND CARROTS
(M. DETOEUF, CEGOS ï FRANCIA)

CABBAGES:	**2 kg**	**1,5 ú/kg**
CARROTS:	**1 kg**	**1 ú/kg**

BUS:	**RETURN TICKET**	**2ú**
	HOURLY TICKET	**1ú**

1) **HOW MUCH DO CABBAGES AND CARROTS COST?**
2) **AND WHAT IF I HAD BOUGHT ONLY THE CARROTS BECAUSE ON SALE?**
3) **WHAT IF I TAKE MORE THEN ONE HOUR?**

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CABBAGES AND CARROTS
(M. DETOEUF, CEGOS ï FRANCIA)

		TRASPORTATION			
		RETURN TICKET	HOUR TICKET		
CABBAGES		4,33	3,67		IN RELATION TO THE WEIGHT
CARROTS		1,67	1,33		
CABBAGES		4,20	3,60		IN RELATION TO THE UNITARY COST
CARROTS		1,80	1,40		

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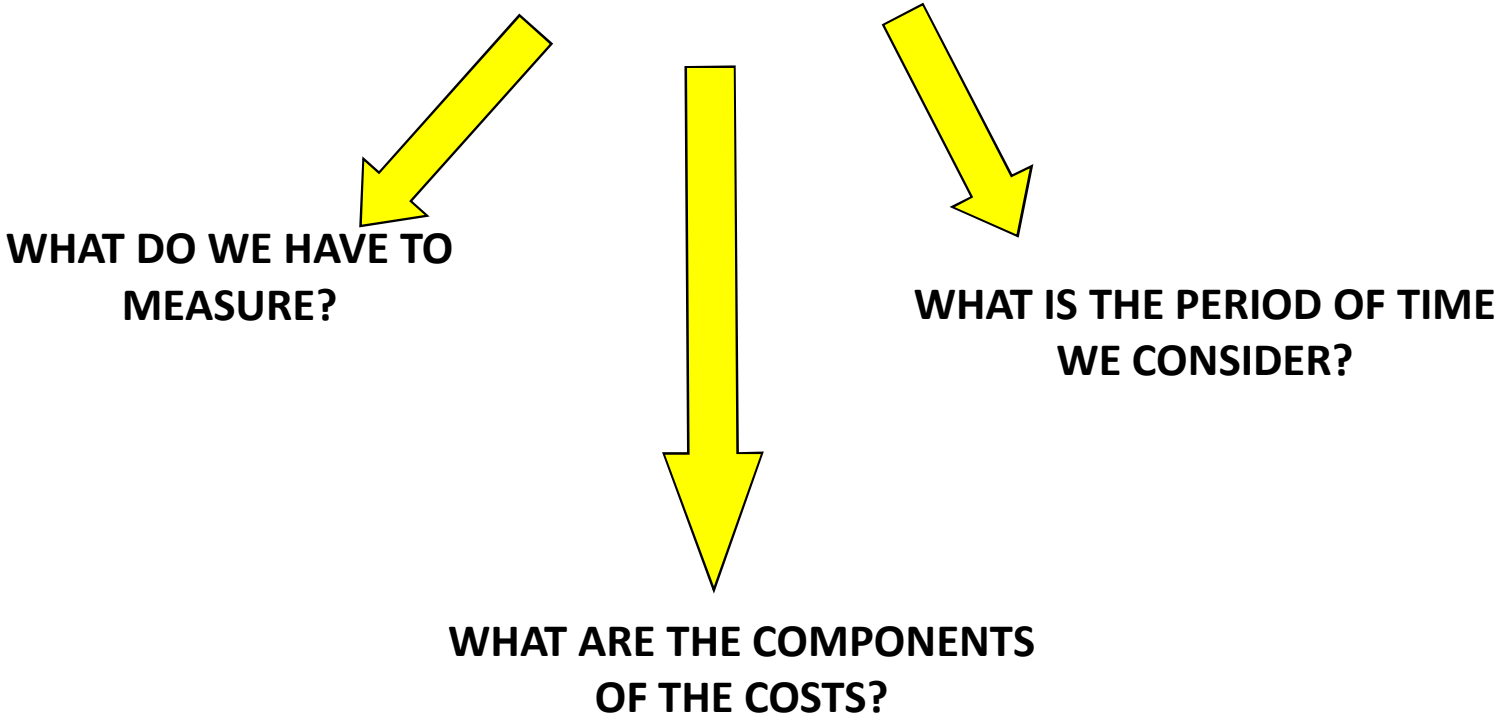
COMPANY COSTS



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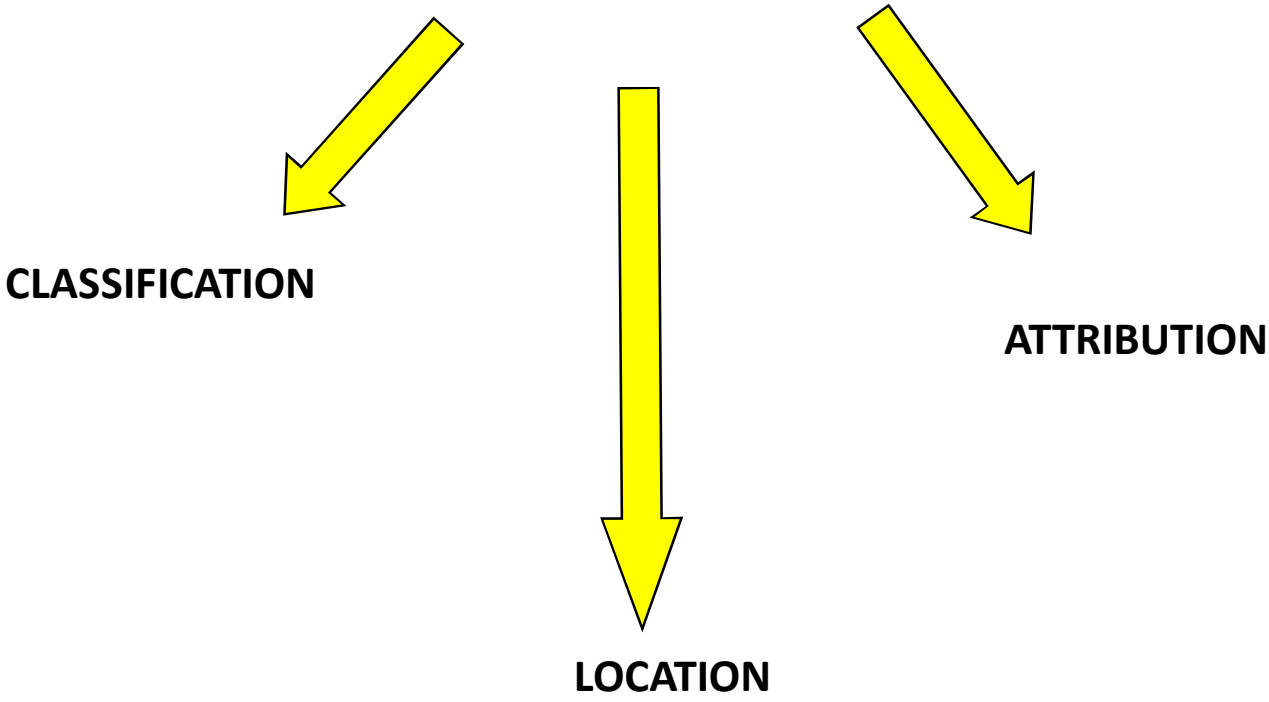
COMPANY COSTS



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PRODUCTIVE FACTORS COSTS

CLASSIFICATION

- **ACCORDING TO THE USE DURING THE TIME**
- **ACCORDING TO THE REFERENCE**
- **ACCORDING TO THE VARIABILITY OF THE PRODUCTION VOLUME**
- **ACCORDING TO THE ACTUAL EXPENDITURE**
- **ACCORDING TO THE TIME OF HAPPENING**
- **ACCORDING TO THE POSSIBLE CONFIGURATIONS**

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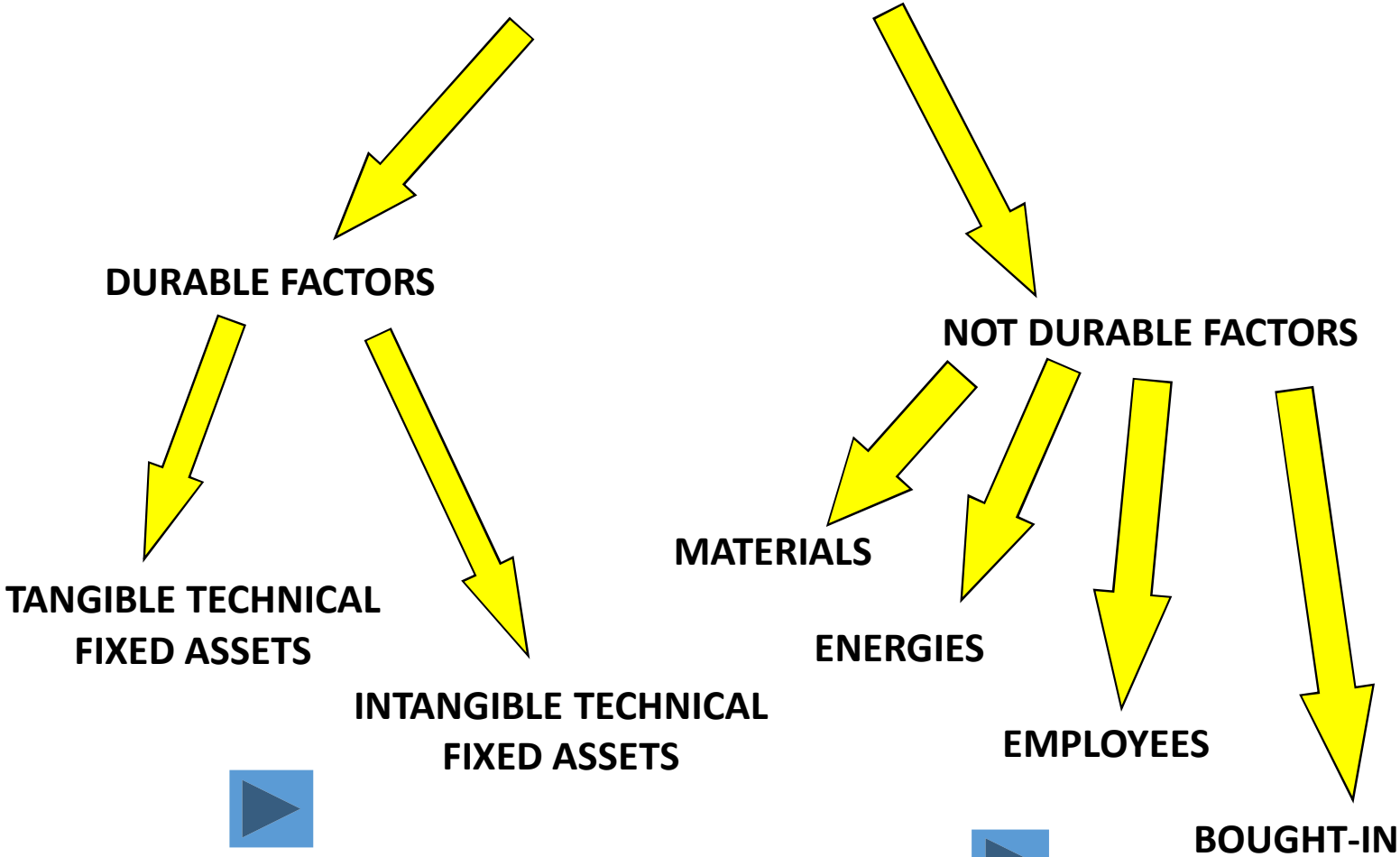
PRODUCTIVE FACTORS COSTS

(CLASSIFICATION ACCORDING TO THE USE DURING THE TIME



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PRODUCTIVE FACTORS COSTS

(CLASSIFICATION ACCORDING TO THE USE DURING THE TIME

TANGIBLE TECHNICAL FIXED ASSETS:

- Buildings
- Land
- Plants
- Machines
- Molds
- Equipment
- Transportation means
- Information systems
- ----------

INTANGIBLE TECHNICAL FIXED ASSETS :

- Brand names
- Patents
- R&D
- Customers
- Products Portfolio
- Corporate image
- Selling Network
- é é é é é

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PRODUCTIVE FACTORS COSTS

(CLASSIFICATION ACCORDING TO THE USE DURING THE TIME)

MATERIALS:	**- Raw Materials**
	- Components
	- Semifinished parts
	- Subsidiary Materials
	- Consumables
	- Bought-in finished products
HUMAN RESOURCES:	**- Direct**
	- Indirect
	- Overheads (Structure)
ENERGIES:	**- Electric Energy**
	- Water
	- Gas
	- Steam
	- ……

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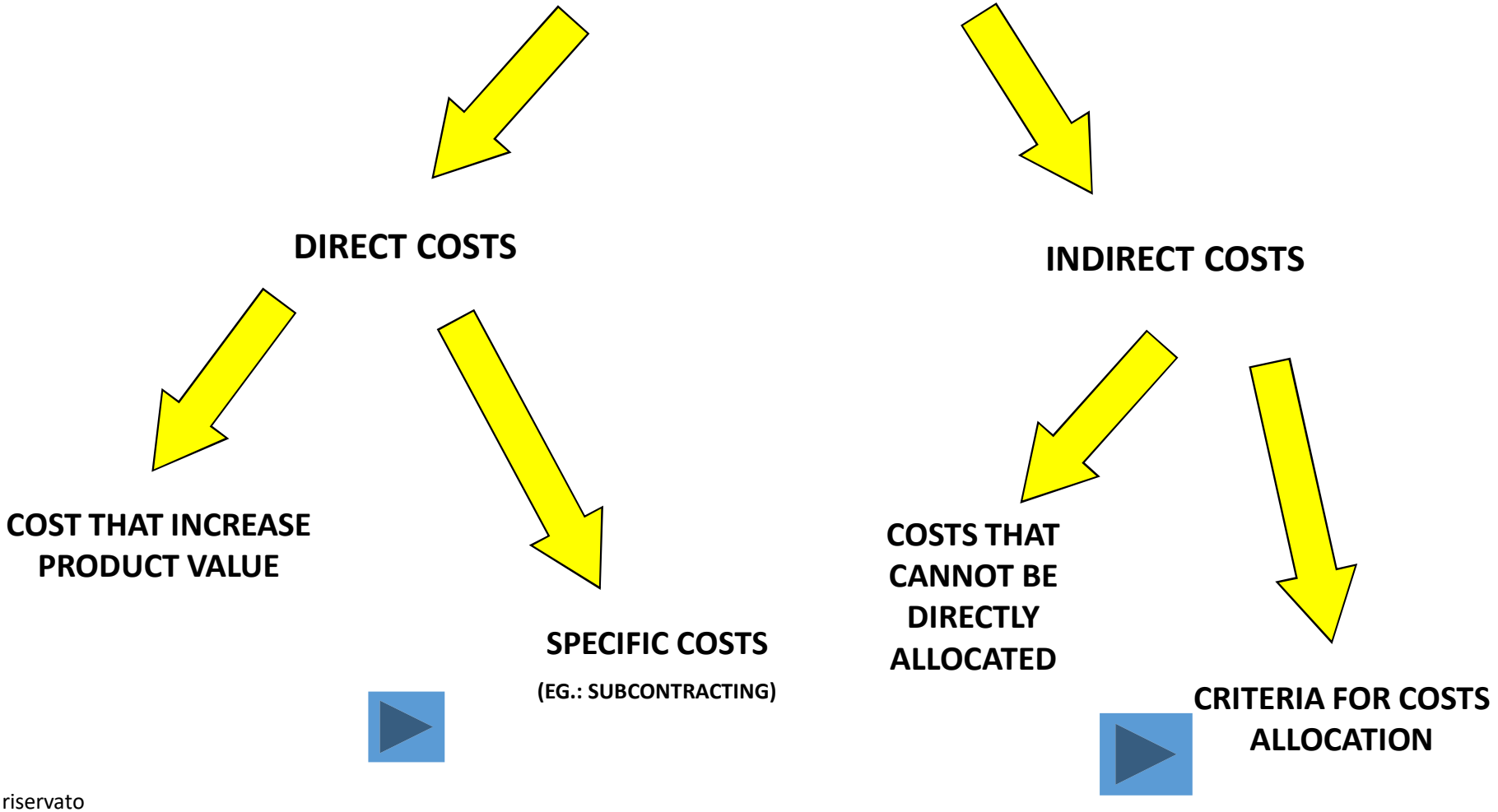
PRODUCTIVE FACTORS COSTS

(CLASSIFICATION ACCORDING TO ALLOCATION)



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PRODUCTIVE FACTORS COSTS

(CLASSIFICATION ACCORDING TO ALLOCATION)

PRODUCTION DIRECT COSTS:

- Direct Materials
- Direct workers
- Subcontracting
- Depretiation of Specific Jigs
- .....

TECHNICAL DIRECT COSTS:

- Specific Prodtuct Engineering
- Prototypes
- Specific tests
- .....

COMMERCIAL DIRECT COSTS:

- Commissions
- Sales force specific for the product
- Specific advertising campaigns
- .....

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PRODUCTIVE FACTORS COSTS

(CLASSIFICATION ACCORDING TO ALLOCATION)

GENERAL PRODUCTION COSTS:	**- Indirect Workers (eg.: fork lift drivers, warehouse workers, maintenance worker……)**
	- Workshop General costs (Overheads for supervision, infirmary, cleaning …)
	- Energies
	- Depretiations rents,leasing fees…
	- .....
GENERAL TECHNICAL COSTS :	**- Product design and development, engineering**
	- Test, Trials, Control
	- technical consultancies
	- .....
GENERAL COMMERCIAL COSTS:	**- human resources cost**
	- Sales forces travel costs
	- Advertisingand promotion , exhibitions
	- rent of offices,warehouse, building in general…
	- Market researches
	- .....

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PRODUCTIVE FACTORS COSTS

(CLASSIFICATION ACCORDING TO ALLOCATION)

GENERAL ADMINISTRATIVE COSTS:	**- administrative overhead costLegal**
	- Legal and notary consultancies...
	- Bank expenses
	- Insurance
	- Entertainement expenses
	- .....
GENERAL FINANCIAL COSTS:	**- Overdraft interest and fees**
	- Bond and mortgages bonds
	- .....
GENERAL TAX COSTS:	**- IRPEG**
	- IRAP
	- .....

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PRODUCTIVE FACTORS COSTS

(CLASSIFICATION ACCORDING TO ALLOCATION)

ALLOCATION CRITERIA

GENERAL INDUSTRIAL COSTS:

- **Used material volumes**
- **Used direct hours**
- **Consumed machine hours/kW/h**
- **Material costs**
- **direct manpower/total employees**
- **production volumes (pieces)**
- **production value (€)**
- **production area (m2)**
- **variable first cost**
- **.....**

GENERAL COMMERCIAL COSTS :

- **Sales volumes (pieces, €)**
- **Turnover,margins**
- **.....**

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PRODUCTIVE FACTORS COSTS

(CLASSIFICATION ACCORDING TO PRODUCTION VOLUMES VARIABILITY)

FIXED COSTS

Costs that do not change significantly according to the production volumes variation

VARIABLE COSTS

Costs that change significantly according to the production volumes variation (within certain limits)

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PRODUCTIVE FACTORS COSTS

(CLASSIFICATION ACCORDING TO PRODUCTION VOLUMES VARIABILITY)

VARIABLE / SEMIVARIABLE COSTS

- Raw Materials
- Components,Parts
- Labour cost
- Energies
- external subcontracting
- Indirect workers
- Scraps
- workshop overhead costs
- ……..

FIXED COSTS

- Plant Director
- Cost Control
- Quality Assurance
- Material management
- Engineering
- Product Development
- Laboratory
- Internal Maintenance
- Employees
  - general costs
  - Survellaince
  - Infirmery
  - Cars
  - Services.....
  - EDP
  - .....

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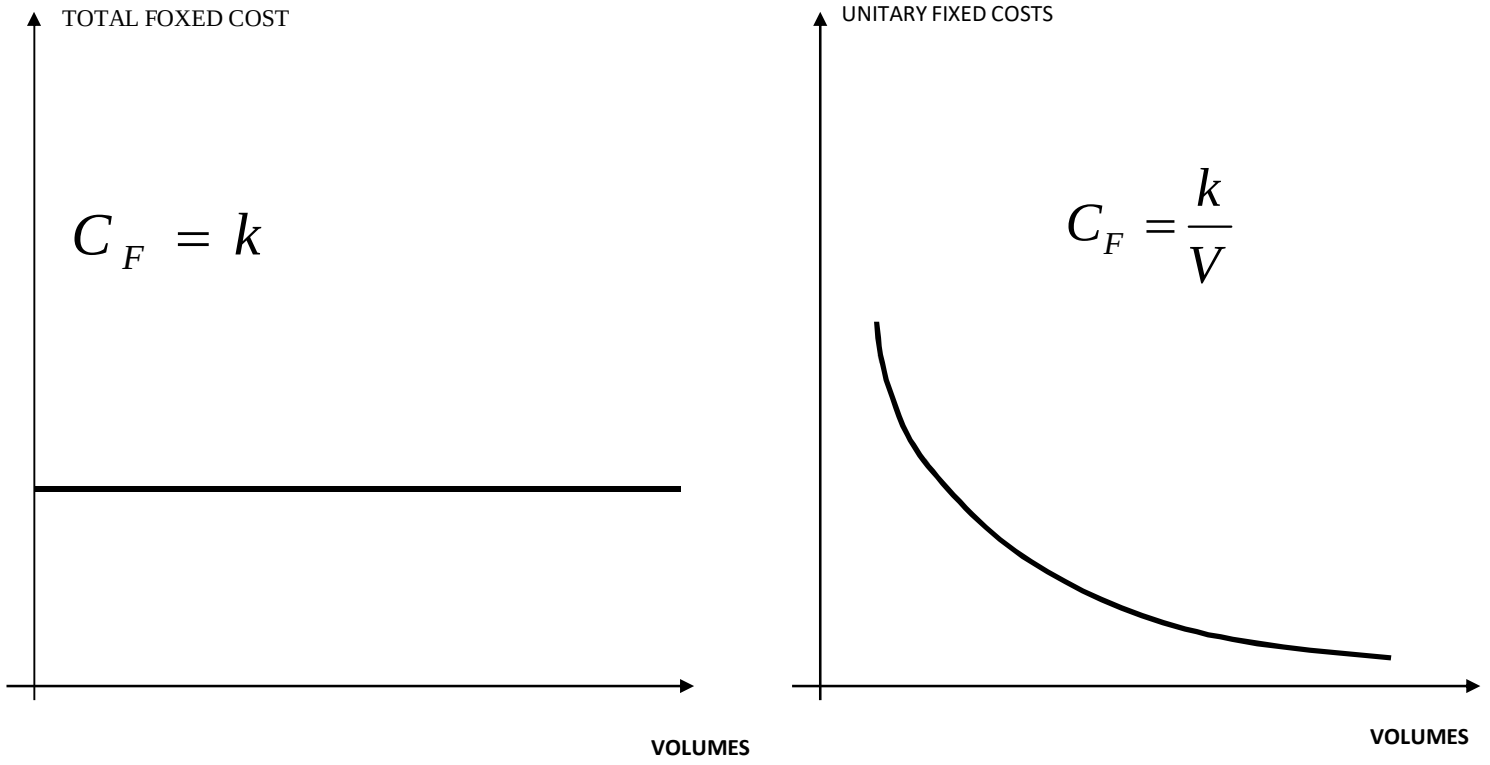
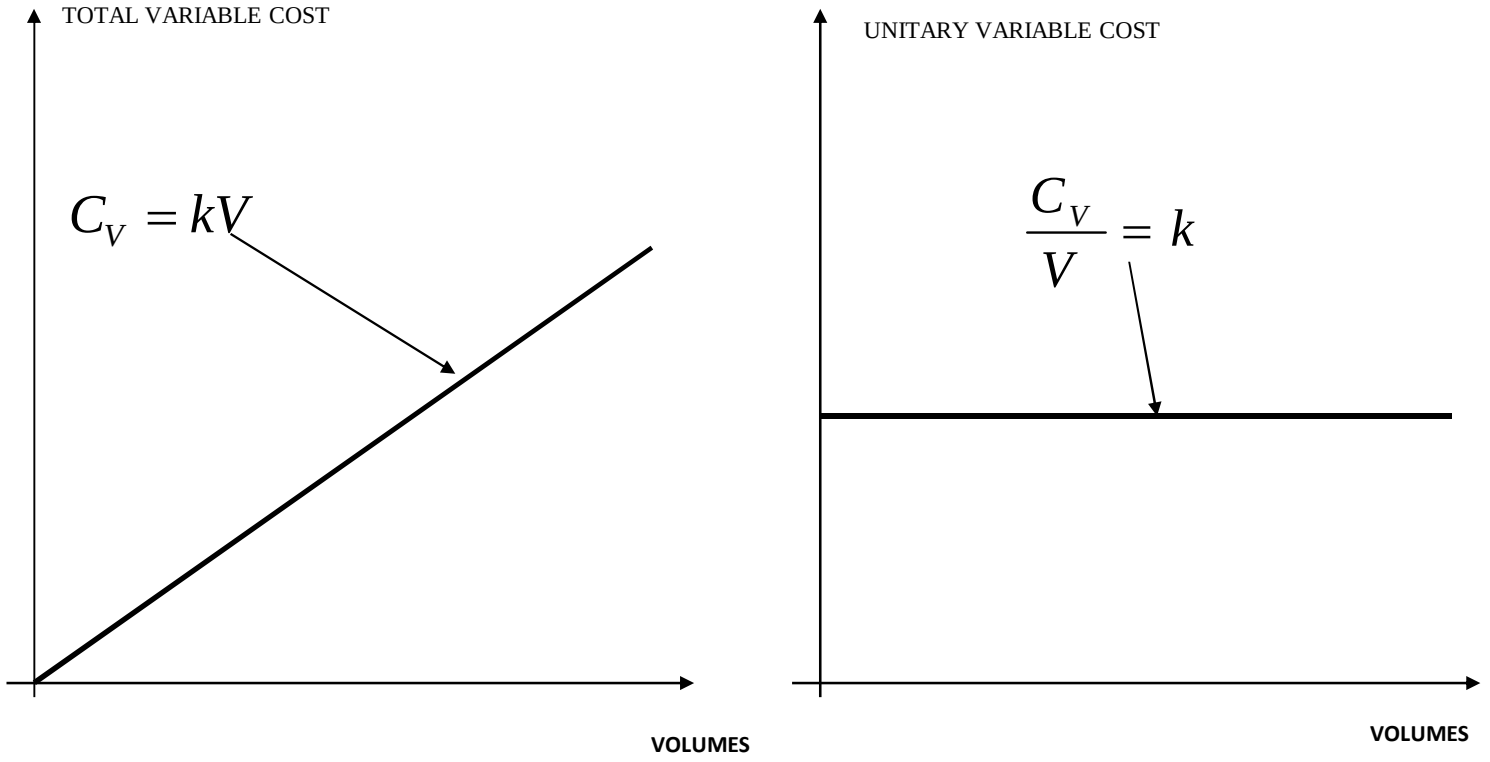
FIXED AND VARIABLE COSTS

A) FIXED COST ACCORDING TO PRODUCTION VOLUMES CHANGE



FIXED AND VARIABLE COSTS

B) VARIABLE COST ACCORDING TO PRODUCTION VOLUMES CHANGE



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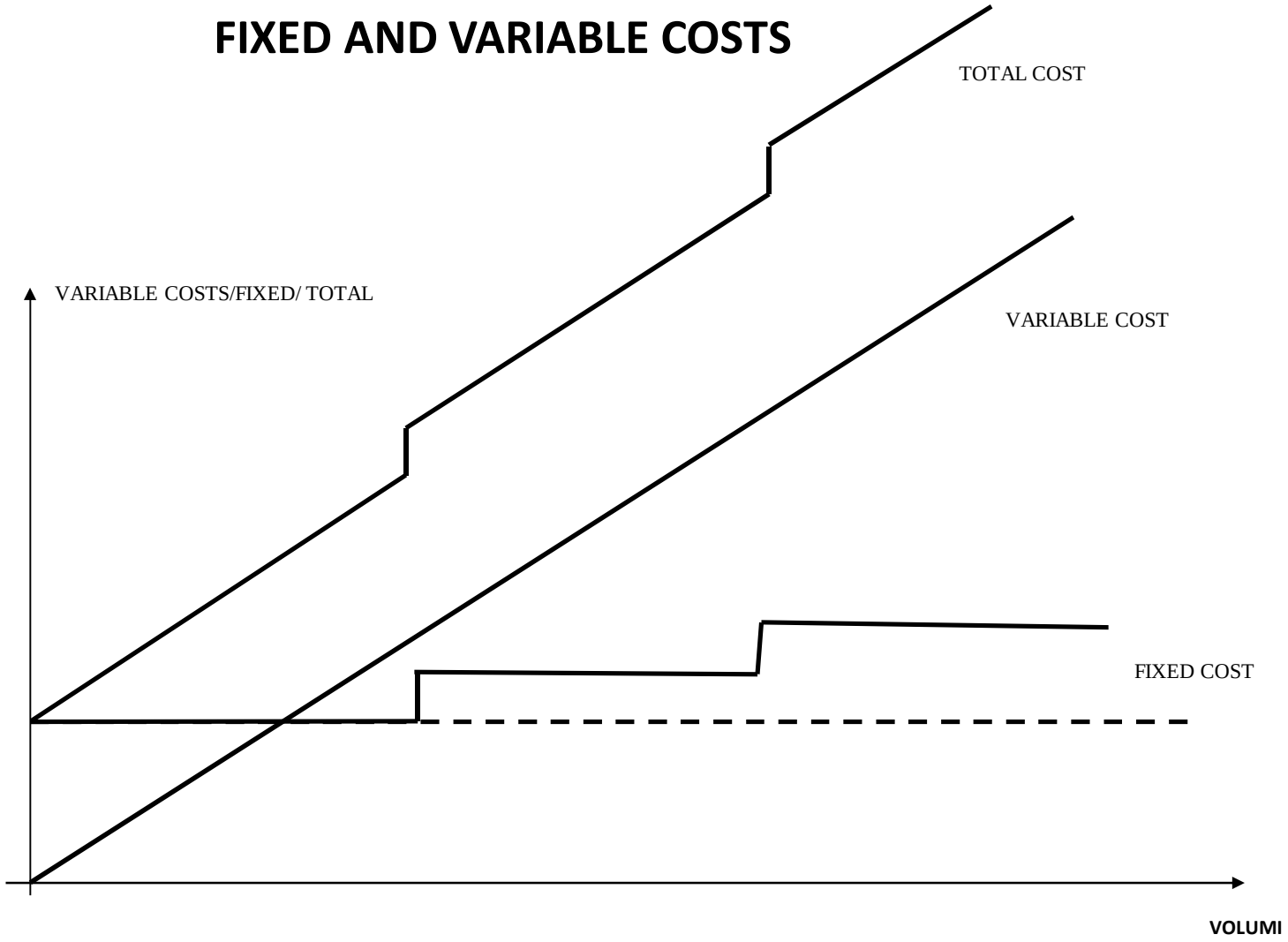
FIXED AND VARIABLE COSTS



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PRODUCTIVE FACTORS COSTS

(CLASSIFICATION ACCORDING TO ACTUAL EXPENDITURE)

ACTUAL COSTS

Costs actually spent in the period by the production centers in order to transform raw materials into finished products

FIGURATIVE COSTS

Costs that are not actually spent in the period by the production centers but equally considered in order to stimulate organizational behavior aimed at reducing costs and accelerating the return of the initiative

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PRODUCTIVE FACTORS COSTS

(CLASSIFICATION ACCORDING TO ACTUAL TIME HAPPENING)

FINAL COSTS

Costs that were actually incurred in the period and were recognized in the final Profit and losses statement

PREVENTIVE COSTS

Costs not yet incurred actually in the period by the production centers but which should be incurred, under certain "standard" conditions. In other words, predetermined costs with a high degree of approximation and repeatable.

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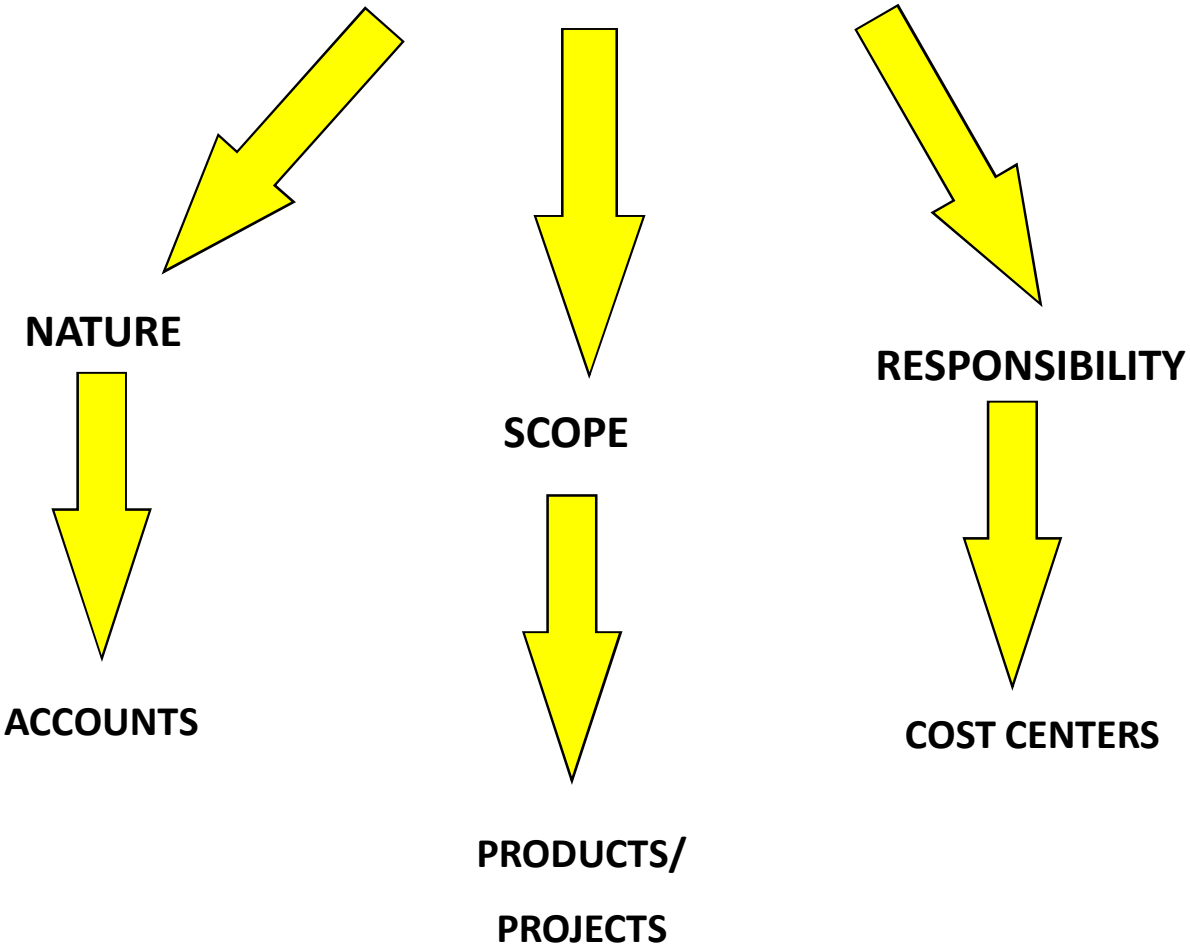
PRODUCTIVE FACTORS COSTS

(CLASSIFICATION ACCORDING TO GROUPINGS)



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PRODUCTIVE FACTORS COSTS

(CLASSIFICATION ACCORDING TO GROUPINGS)

ACCOUNTS:

- Scraps
- Auxiliary material
- Energies
    - Water
    - Electric Energy
    - Heating
    - Compressed Air
- Internal Maintenance
- External Maintenance
- Cleaning
- Phones
- Travels
- .....

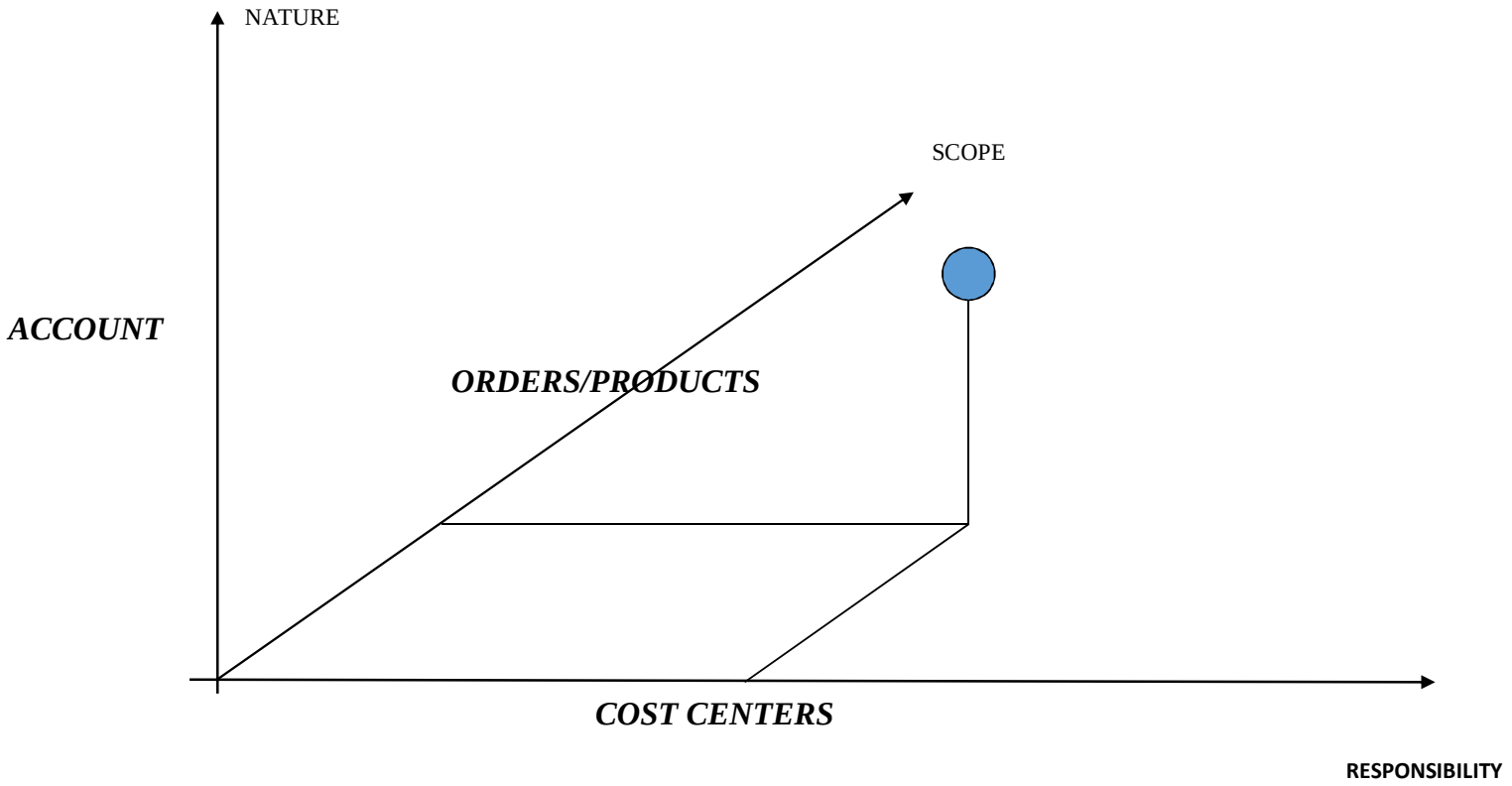
ORDERS /PRODUCTS:

- Order 1
- Order 2
-.....
- Order n

- Products A
- Products B
- .....
- Products N

COST CENTERS

- Plant Director
- Cost Control
- Quality Assurance
- Material management
- Engineering
- Product Development
- Laboratory
- Internal Maintenance
- Employees
    - general costs
    - Survellaince
    - Infirmery
    - Cars
    - Services.....
    - EDP
    - .....



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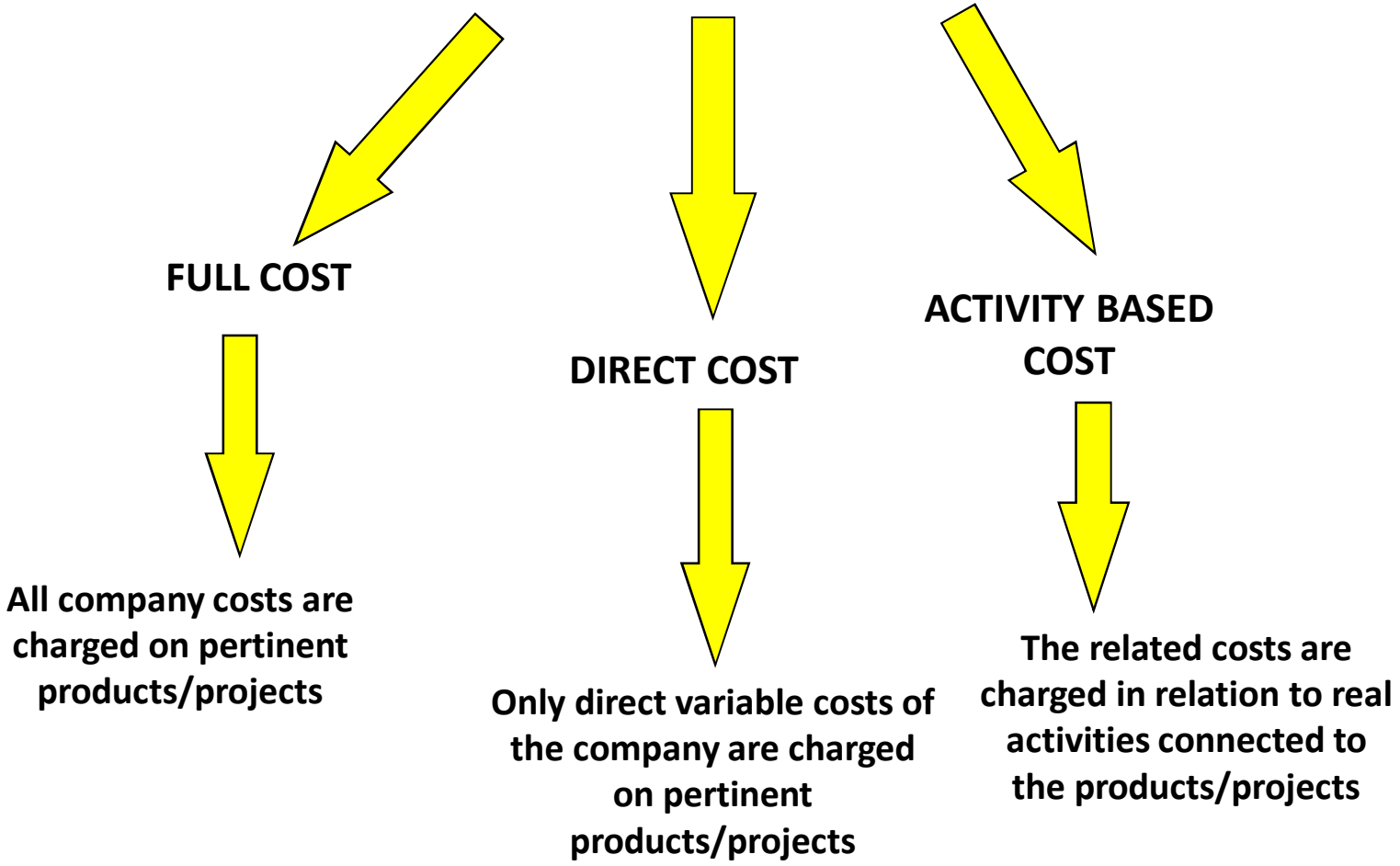
PRODUCTIVE FACTORS COSTS

(CLASSIFICATION ACCORDING TO POSSIBLE CONFIGURATIONS)



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FINAL COSTS AND ESTIMATED COSTS

A) FINAL COSTS

These are the costs actually incurred by the production centers in a certain period for the purpose of transforming raw materials into finished products and recorded in the final balance.

B) ESTIMATED COSTS

These are costs not actually incurred by the production centers but which should be incurred under certain "standard" conditions, that is, predetermined and repeatable costs.

Hence the concept of "standard" cost

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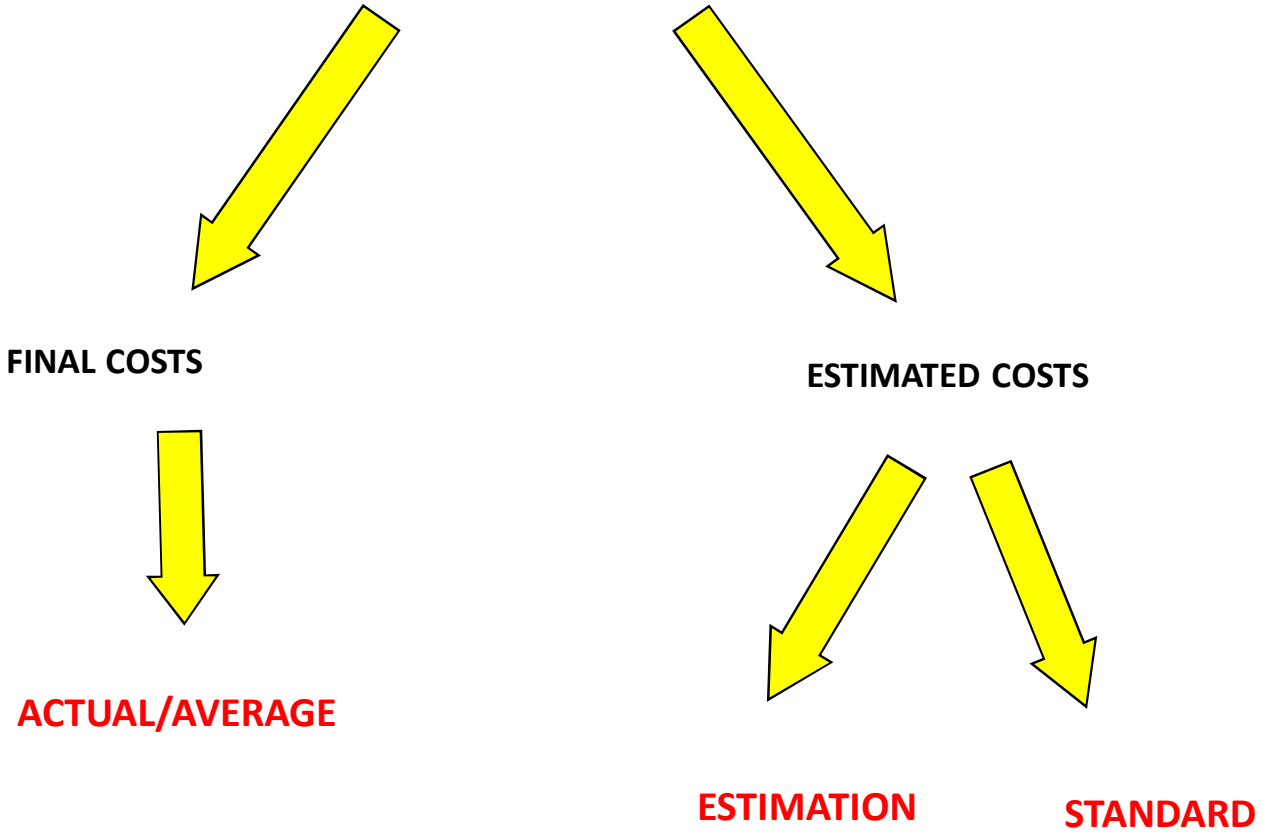
FINAL COSTS AND ESTIMATED COSTS



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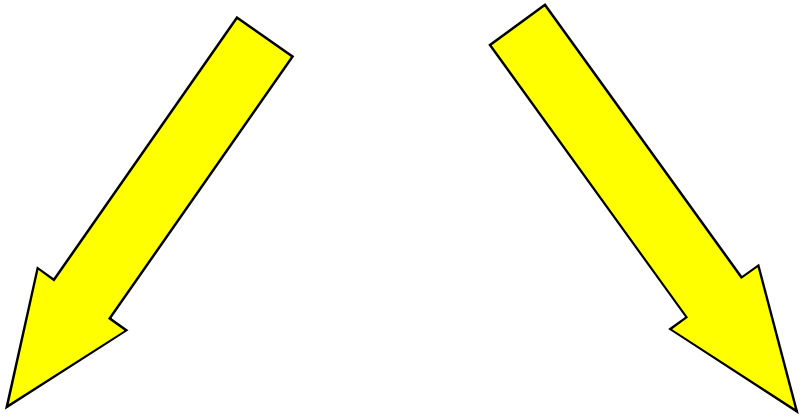
LIMITS ACTUAL COSTS



COSTS VARIABILITY

NO CONTROL OF THE PRODUCTION SYSTEM PERFORMANCES

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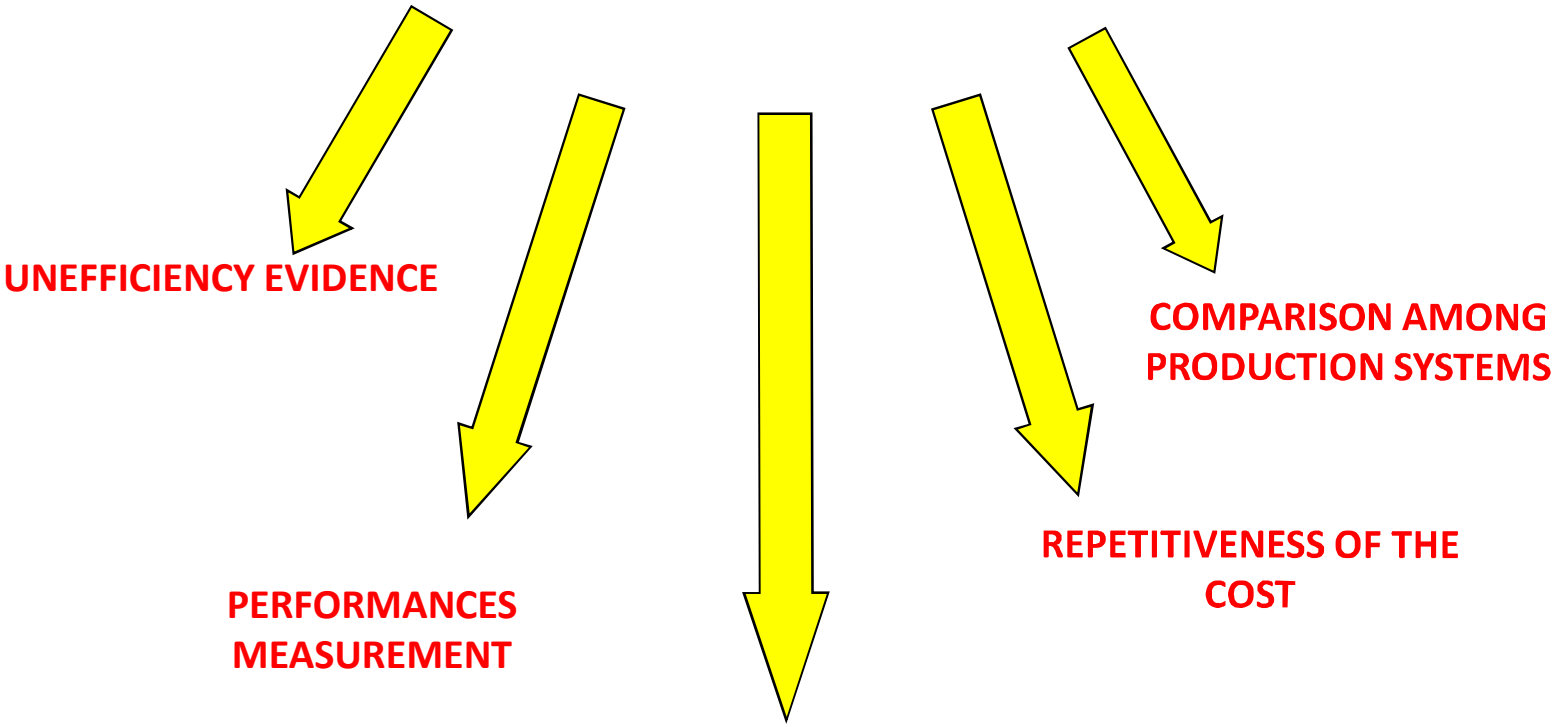
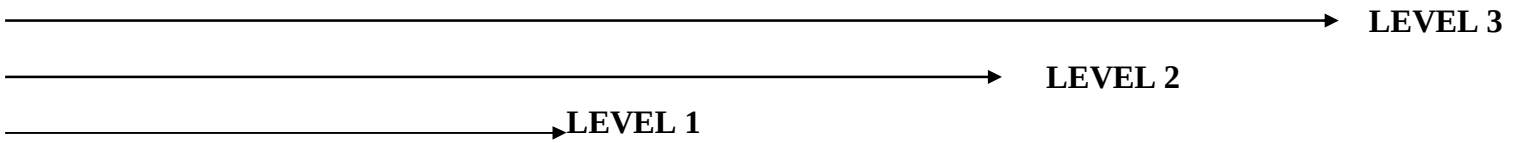
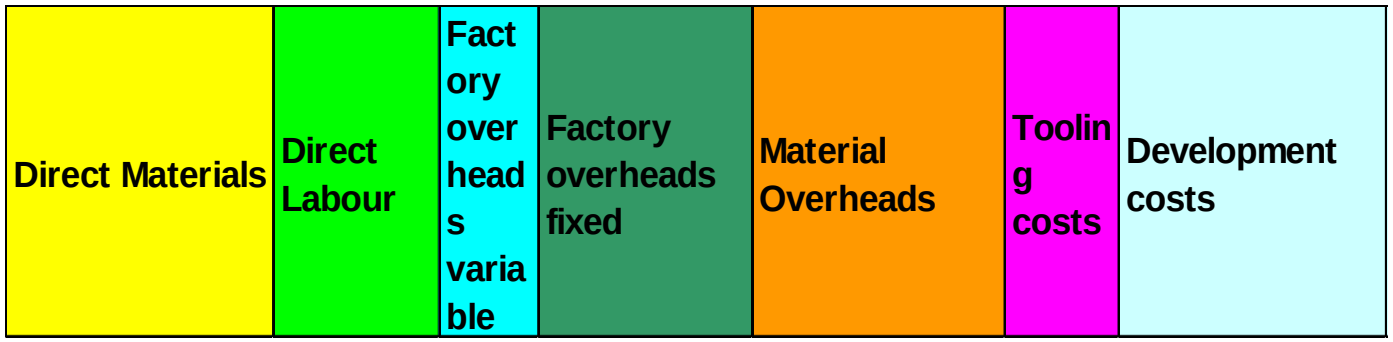
BENEFITS OF STANDARD COSTS



FULL STANDARD COSTS





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MATERIALS COSTS

It is the material that contributes to directly form the finished product

What's in it:

- **Theoretical standard quantity: (at the time of ñfreezingò the Bill of Material)**
  - **raw materials and components**
  - **work carried out outside (subcontracting)**
  - **standard surcharge: applied to theoretical quantities raw materials (eg. Scrap)**
  - **Small-value components (e.g. fasteners)**

- **standard cost of purchase:**
  - **Average price expected for the budget year**
  - **Additional costs charged, not included in the price (eg. Transp)**

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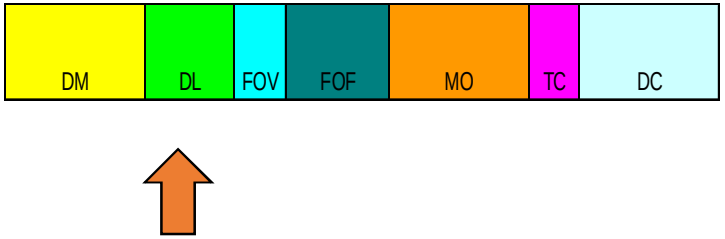
LABOUR COSTS



It is the cost of direct labour whose operations are directly linked to the product manufacturing

What's in it:

- **Std assigned time: Detectable from the processing cycles, at the time of ñfreezingò of the times; or detectable from the estimates made for products not yet launched.**
- **Direct efficiency: Given from the retio between the assigned time and the practical time of the direct workers, obviously without taking into account labor losses and waste**
- **calculation by cost center:**
  - **standard cost of the work**
  - **Direct salary (real money in employeesôpocket))**
  - **Indirect salary (holidays, extra salary, company seniorshipé)**
  - **Social security and welfare charges (health assistance, Injuries insurance...)**

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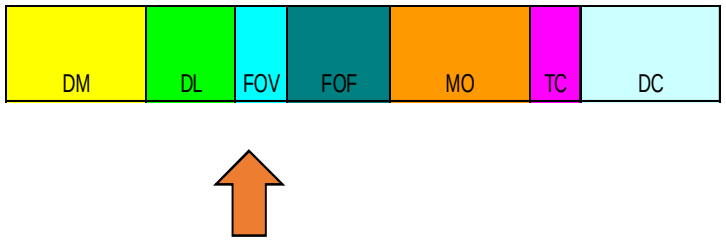
FACTORY OVERHEADS VARIABLE



These are the general manufacturing costs, variable or semi-variable, which are necessary for the functioning of the production departments

What's in it:

- **INDIRECT LABOR: It is the cost of labor whose activities are not strictly related to the single material or a single product. (set-up specialists, Waterspiders, forklift drivers ...)**
- **MAINTENANCE: It is the cost of labor and materials used to maintain the production departments assets, including the general cost of the maintenance cost center.**
- **GENERAL COSTS OF DEPARTMENTS: It is the cost of the management structure of the production departments (production manager, department manager, team manager ...) and includes the salaries of the people and the general costs of the departments (stationery, training courses, travel , telephone, various materials ...)**
- **WASTE It is the cost of direct scrap waste caused by the activities carried out in all production centers**
- **ENERGIES.: they are the energies costs used for production: (Electric energy, Water, Compressed air, Gas, Steam)**
- **AUXILIARY MATERIALS: It is the cost of materials that are not strictly related to the products. (Eg.: Rags, Drill bits, Small tools (under 1000 ú), Grease / lubricants / release agents, Gloves and other individual protection meansé)**

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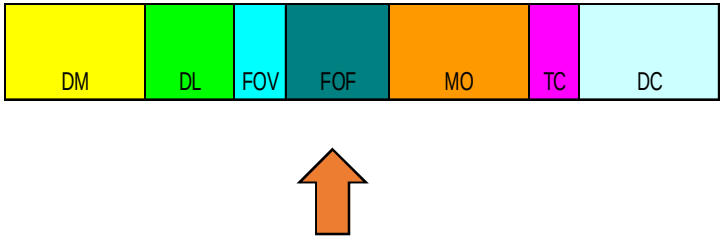
FACTORY COSTS FIXED



They are the overhead fixed manufacturing costs, which are necessary for the functioning of the production departments

They are the costs of the cost centers that provide the management of the Plant, of the Human Resources dept., of the Management Control and of the Process. Additionally these costs include also the allocations from other Central Staff:

- **PLANT**: - Plant Management, Human Resources dept., Costs Control Dept, Production Engineering
- **CENTRAL FUNCTIONS**: Technical Direction (Allocation), Central Human Resources Dept. (Allocation), EDP (Allocation), Central General Services (Allocation), Other Direction, é
- **CALCULATED DEPRECIATION / LEASING FEES** for Company Cars, Generic equipment, Vans, Other Assetsé
- **CALCULATED RENTALS / LEASING FEES**: for Property, Land, é é é .

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MATERIALS OVERHEADS

They are fixed general costs due to material management

They are the costs of the cost centers of the Materials Management, Production Planning and Scheduling, Plant Purchases, Incoming Materials, Warehouse Management and Material Handling, Quality Control. If there are Central Services concerning the Materials, this parts of the costs includes the Allocations from other Central Staff :

- **PLANT: Purchasing and scheduling, Incoming Material Dept., Warehouses (excluding Finished Products), Quality Control**
- **CENTRAL FUNCTIONS: Administration (supplier accounting) (Allocation), Central purchasing (Allocation), Logistics (part relating to Materials / Components) (Allocation), EDP (share for the Material Management Procedures) (Allocation), General Services (eg. Treasurer ...) (Allocation),**

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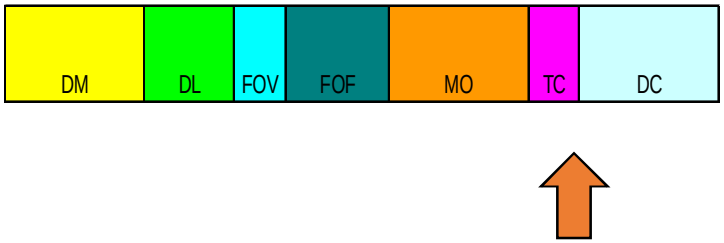
TOOLING COSTS



They are formed by the depreciation of specific tools that can be directly attribute to a specific product or to an homogeneous family of products

They are specific equipment, tools, jigs that are specific for manufacturing a certain product or a certain range of products.

The unit value or depreciation rate to be assigned to a finished product depends on the original value of the molds, their useful life and the expected production volume.

Normally the expected life span is three years.

The equipment must be owned, built internally or purchased and must be complete or replacement of important parts of it

Universal tools subject to rapid wear (eg pneumatic and electric tools, punches and dies for punching machinesé) which are instead considered in the FOV do not fall under this item.

Also not included in this item are test tools or tools required for prototyping that fall within the DC.

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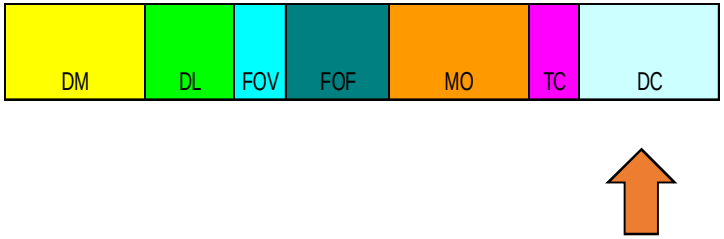
PRODUCT DEVELOPMENT COSTS



They are costs substained for the product development or the product design updating.

They include:

- Product Design

- Prototypes

- Tests and control

- Certifications

- Patents

- Technical documentation

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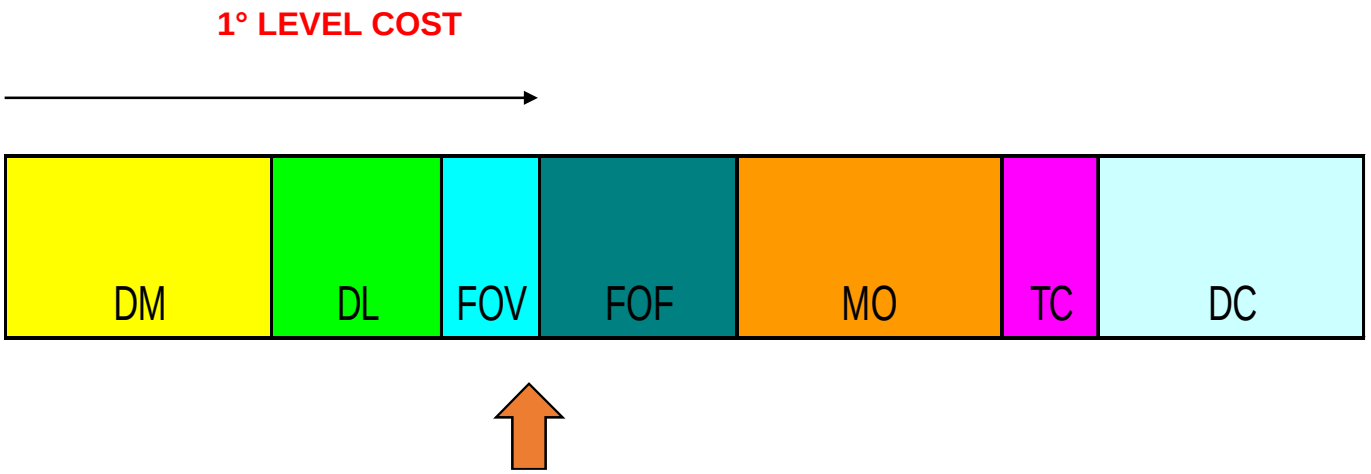
MEANING OF FIRST LEVEL COST



1° LEVEL COSTS = DM+DL+FOV

INDUSTRIAL FIRST LEVEL COST

VARIABLE/SEMIVARIABLE COSTS

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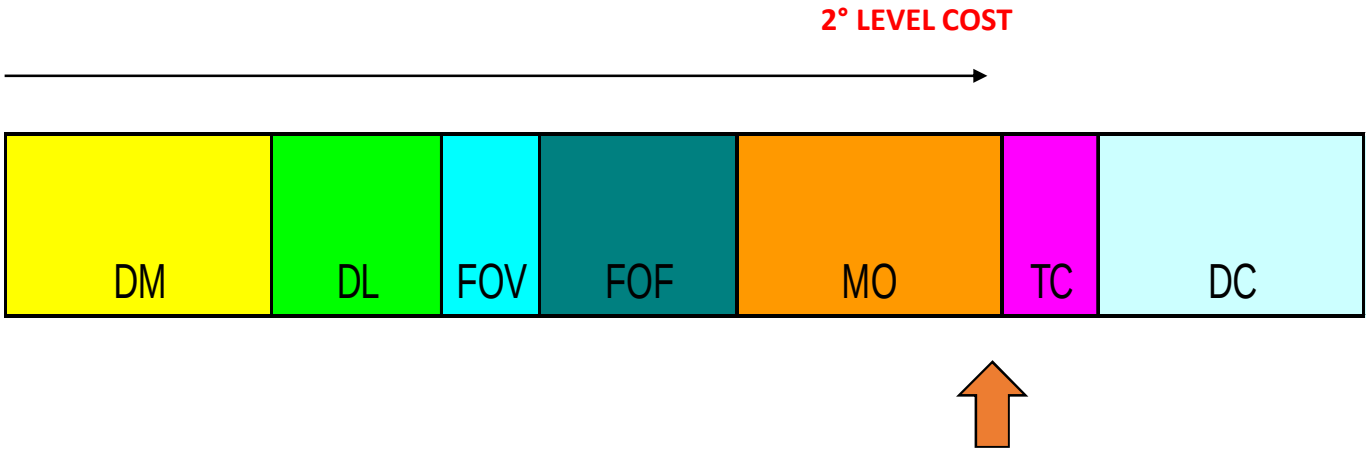
MEANING OF 2nd LEVEL COST



2° LEVEL COST = 1° LEVEL COST + FOF + MO

ENGINEERED COST

SUBCONTRACTOR COST

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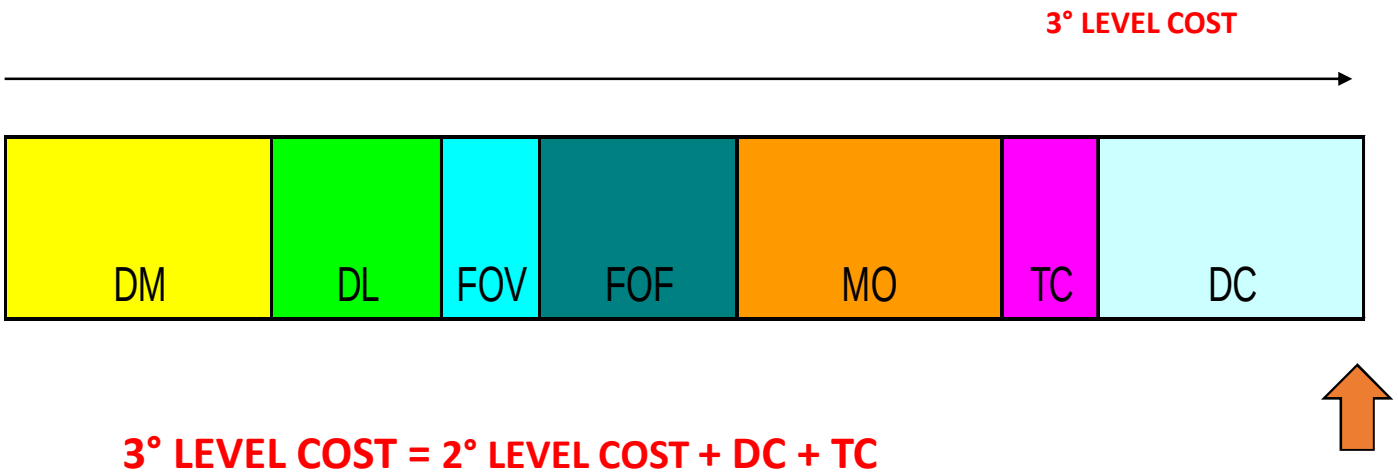
MEANING OF 3rd LEVEL COST



3° LEVEL COST = 2° LEVEL COST + DC + TC

COST OF DEVELOPED PRODUCT

INDUSTRIAL FULL COST

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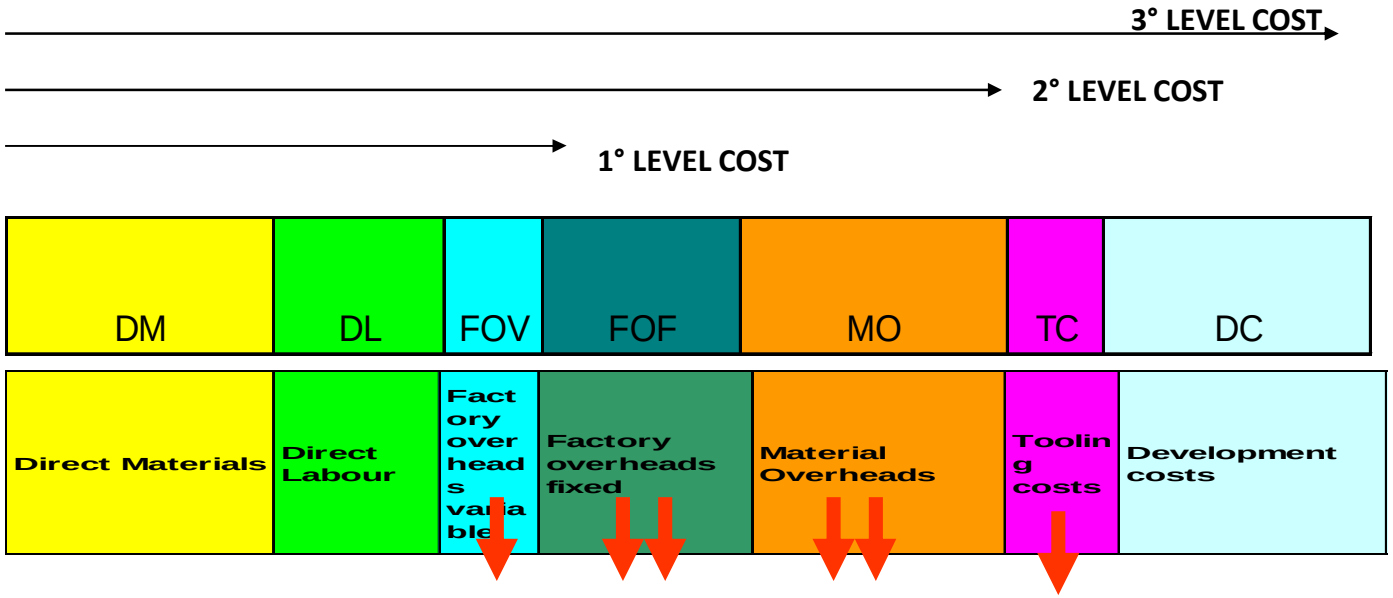
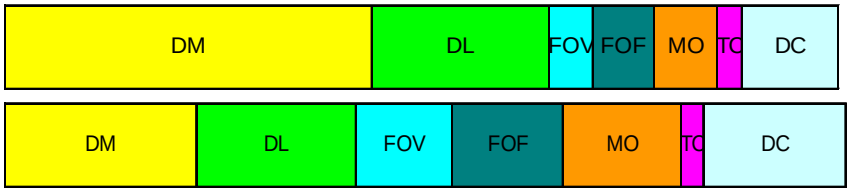
STANDARD COSTS

RELATIONSHIP AMONG 1°-2°-3° LEVEL COSTS





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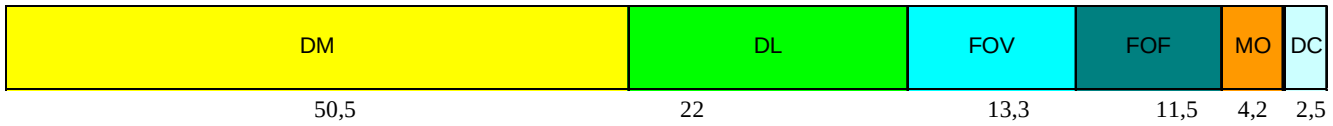
RELATIONSHIP AMONG 1°-2°-3° LEVEL COSTS

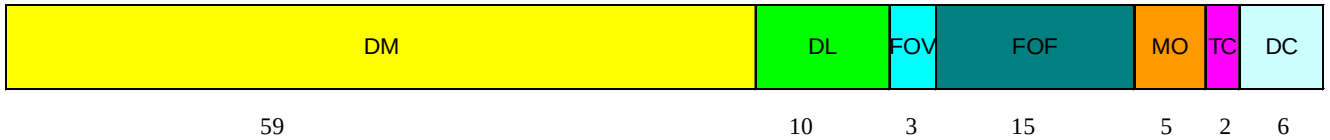
STAINLESS STEEL PRODUCTS



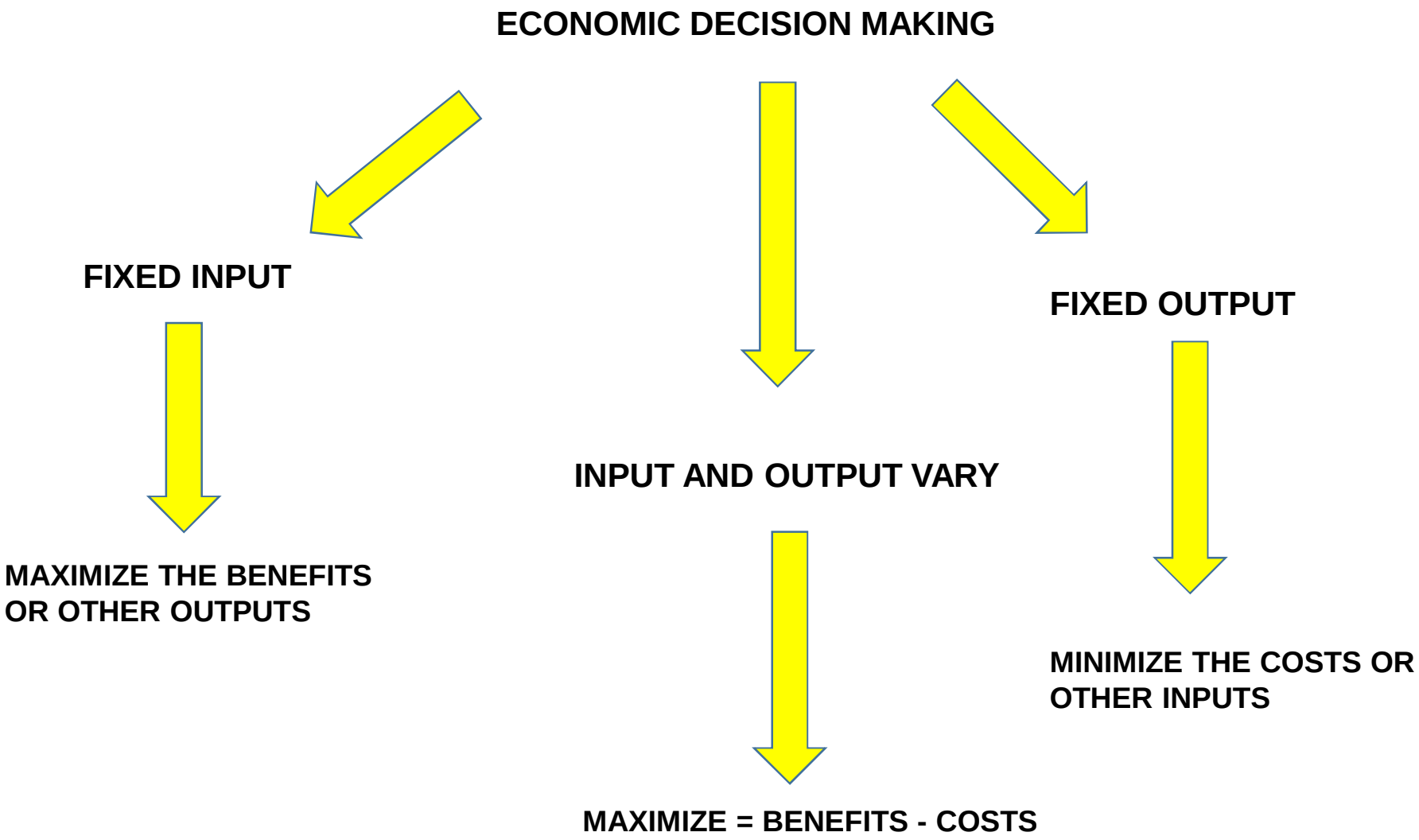
COMMERCIAL DW

1997

2002



ECONOMIC DECISION MAKING


ECONOMIC DECISION MAKING
FIXED INPUT
MAXIMIZE THE BENEFITS
OR OTHER OUTPUTS
INPUT AND OUTPUT VARY
MAXIMIZE = BENEFITS - COSTS
FIXED OUTPUT
MINIMIZE THE COSTS OR
OTHER INPUTS

ECONOMIC DECISION MAKING

	SITUATION	CRITERION
FIXED INPUT	AMOUNT OF CAPITAL AVAILABLE FIXED	MAXIMIZE PRESENT WORTH OF BENEFITS
FIXED OUTPUT	AMOUNT OF BENEFITS IS FIXED OR FIXED OUTCOME	MINIMIZE PRESENT WORTH OF COSTS
NEITHER FIXED	NEITHER CAPITAL NOR BENEFITS ARE FIXED	MAXIMIZE THE NET PRESENT WORTH (NPW)

Where: NPW (Net Present Worth) = NPB – NPC
B = Benefits
C = Costs

ECONOMIC DECISION MAKING

ALTERNATIVES	SITUATION	EXAMPLE	CRITERION
A	FIXED INPUT	150.000 ú budgeted for raw material	Purchese the most you can . Maximize the output
B	FIXED OUTPUT	20.000 sqm building are needed	Negotiate for minimum cost/sqm. Minimize the input
C	NEITHER FIXED	Purchasing rental property	Maximize the "profit". The bigger margin between benefit and cost. Maximize PWB - PWC

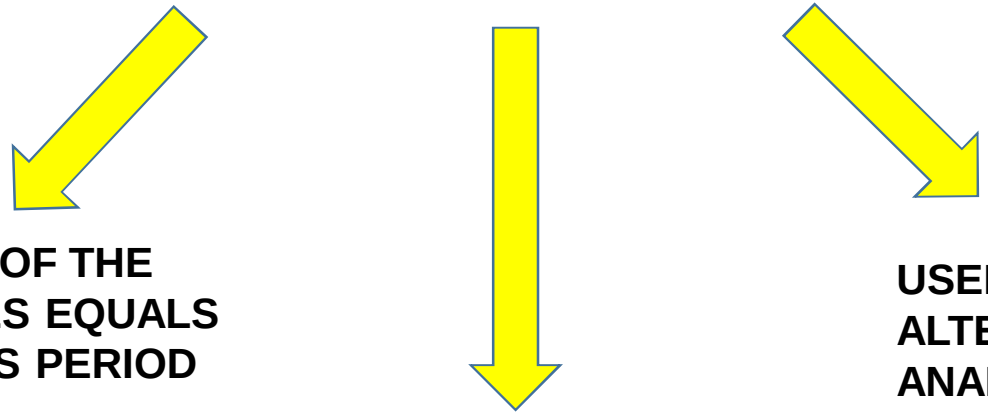
Where: NPW = NPB – NPC

B = Benefits

C = Costs

ECONOMIC DECISION MAKING
USEFUL LIFE

When we do economic analisys, the period of time is a major consideration



USEFUL LIFE OF THE ALTERNATIVES EQUALS THE ANALISYS PERIOD

THE ANALISYS PERIOD IS INFINITE OR LONG ENOUGH TO BE CONSIDERED INFINITE

USEFUL LIFE OF THE ALTERNATIVES DIFFERS FROM THE ANALISYS PERIOD

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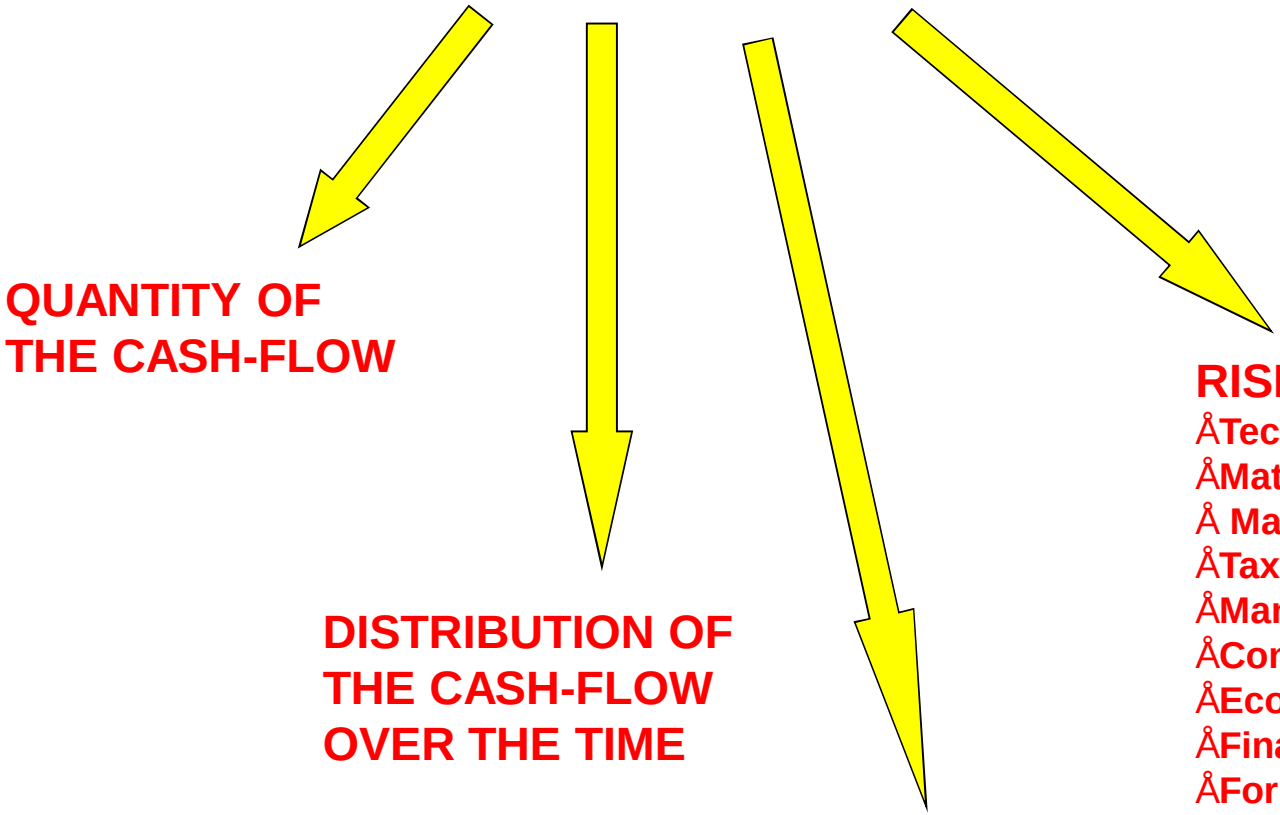
ELEMENTS FOR THE EVALUATION OF THE ASSET INVESTIMENT



QUANTITY OF THE CASH-FLOW

DISTRIBUTION OF THE CASH-FLOW OVER THE TIME

MONEY COST (i)

RISK DEGREE

- Technology
- Material purchasing
- Market
- Tax structure
- Management behaviour
- Contracts
- Economic-financial frame
- Financial resourses
- Form of funding

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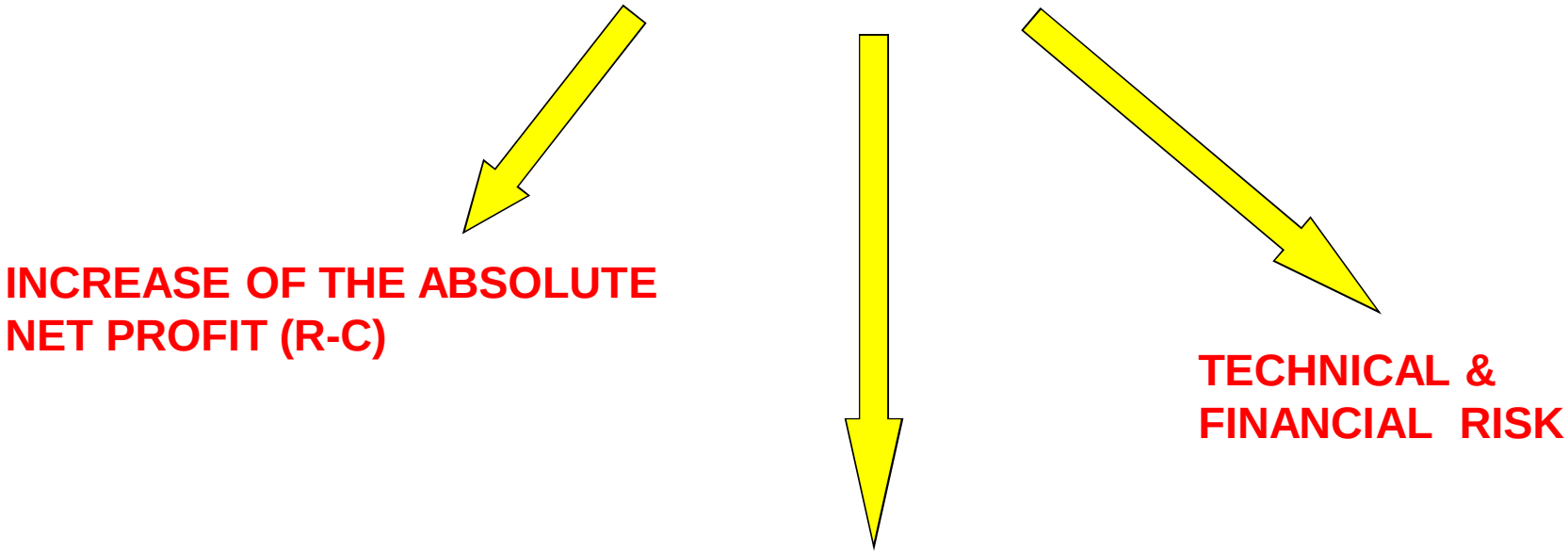
ELEMENTS FOR THE EVALUATION OF THE ASSET INVESTIMENT



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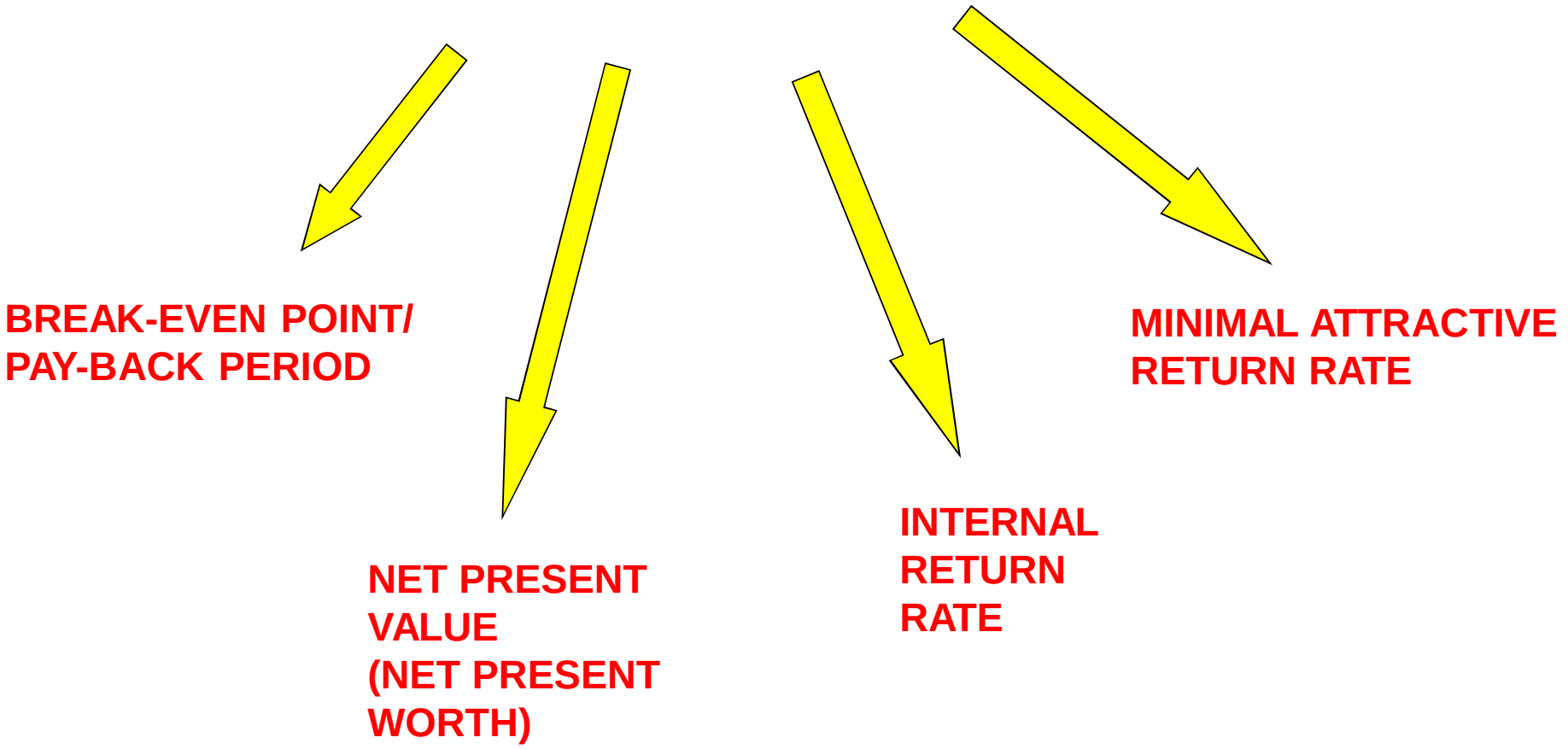
ELEMENTS FOR THE EVALUATION OF THE ASSET INVESTIMENT



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PAY-BACK PERIOD

The payback period is simply the number of periods required when the cumulative cash flow matches the initial investment.
Each firm sets a time limit (pay-back period) within which "the investment must be paid-offò.

$$\sum_{t=1}^{\pi} f_t = C_o$$

$$\text{ROI} = \frac{\text{BENEFITS}}{\text{COSTS}}$$

$$\text{PAYBACK PERIOD} = \frac{1}{\text{ROI}}$$

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PAYBACK PERIOD (PP)

- **Estimated initial expenditure: 212.500 ú**
- **Yearly savings : 50.000 ú**

$$ROI = \frac{50.000}{212.500} = 0,23 \qquad PP = \frac{1}{ROI} = \frac{1}{0,23} = 4,34$$

We assume that the investments are made at the beginning of the first year. The cash flows are recorded at the end of each year. Weighted average cost of capital (WACC) not considered

- Estimated initial expenditure		**cash flow**			
		1° year	**2° year**	**3° year**	
A	**ú 500.000**	**190.000**	**212.500**	**235.000**	**av. 212.500**
B	**ú 500.000**	**235.000**	**212.500**	**190.000**	**av. 212.500**

We assume that the investments are made at the beginning of the first year. The cash flows are recorded at the end of each year. Weighted average cost of capital (WACC) not considered

MONEY NOW IS BETTER THAN MONEY LATER!

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PAY-BACK PERIOD
RETURN OF INVESTMENT

Letôs suppose to have an asset where we want to perform and improvement program, to cut off failures:

C_R : Cost for reliability improvement program (50.000 ú)
N : 250 failures /year
C_{rep} : Cost for repair each failure (850 ú)
L: Useful life (years) (L = 8)
OH: general and administrative overheads (OH = 30%)
i: interest rate (%) (i = 10%)

$$ROI = \frac{B}{C}$$

$$ROI(\text{first year}) = \frac{N\,C_{rep}}{C_R\,(1 + OH)\,(1+i)} = \frac{250 \times 850}{50.000\,(1 + 0,3)\,(1+0,1)} = 2,97$$

$$PP = \frac{1}{ROI} = \frac{1}{2,97} = 0,336 \text{ years}$$

ROI(useful life) = 23,97 Sensitivity analysis

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NET PRESENT VALUE

Net Present Value is a method by which you define the up-dated value of a series of expected cash flows in a given period of time, not only adding them but updating them on the basis of the current interest rate (WACC)

$$\mathbf{NPV} = -C_o + \sum_{k=1}^{n} \frac{C_k}{(1 + r_w)^k}$$

where:

Åk: periods of time;

ÅC_k: cash flow (positive or negative) accounted at *k period*;

År_w: Weighted average cost of capital (WACC) rate of alternative interest

$1/ (1+ r_w)^k$: discount factor at *k period*

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NET PRESENT VALUE

NPV > 0	the investment would add value to the firm	the project may be accepted
NPV < 0	the investment would subtract value from the firm	the project should be rejected
NPV = 0	the investment would neither gain nor lose value for the firm	We should be indifferent in the decision whether to accept or reject the project. This project adds no monetary value. Decision should be based on other criteria, e.g. strategic positioning or other factors not explicitly included in the calculation.

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INTERNAL RETURN RATE

The Internal Rate of Return (IRR) is an index of an investment financial profitability. It is the compound annual real return rate that an investment generates.

Generally speaking, a project should be pursued when the IRR appears to be greater than the cost of capital for that investment project.

Mathematically the IRR is defined as the discount rate that makes the net present value of a series of cash flows equal to zero. It is obtained by iterative calculation until it reaches zero.

$$\text{NPV} = -CF_0 + \frac{CF_1}{1+i} + \frac{CF_2}{(1+i)^2} + \cdots + \frac{CF_n}{(1+i)^n} = 0$$

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INTERNAL RETURN RATE

Example: An investment allows to have the following cash flows:

Year (n)	Cash flow (C_n)
0	-4000
1	1200
2	1410
3	1875
4	1050

then the IRR (r) is given by

$$\mathrm{NPV} = -4000 + \frac{1200}{(1+r)^1} + \frac{1410}{(1+r)^2} + \frac{1875}{(1+r)^3} + \frac{1050}{(1+r)^4} = 0.$$

In this case, the answer is 14.3%.

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INTERNAL RETURN RATE

Companies and analysts may also look at the return on investment (ROI) when making capital budgeting decisions.
ROI tells an investor about the total growth, start to finish, of the investment. It is not an annual rate of return.
IRR tells the investor what the annual growth rate is.
The two numbers normally would be the same over the course of one year but wonôt be the same for longer periods of time.

Although IRR is sometimes referred to informally as a projectôs ñreturn on investment,ò it is different from the way most people use that phrase. Often, when people refer to ROI, they are simply referring to the percentage return generated from an investment in a given year or across a stretch of time. But that type of ROI does not capture the same nuances as IRR, and for that reason, IRR is generally preferred by investment professionals.

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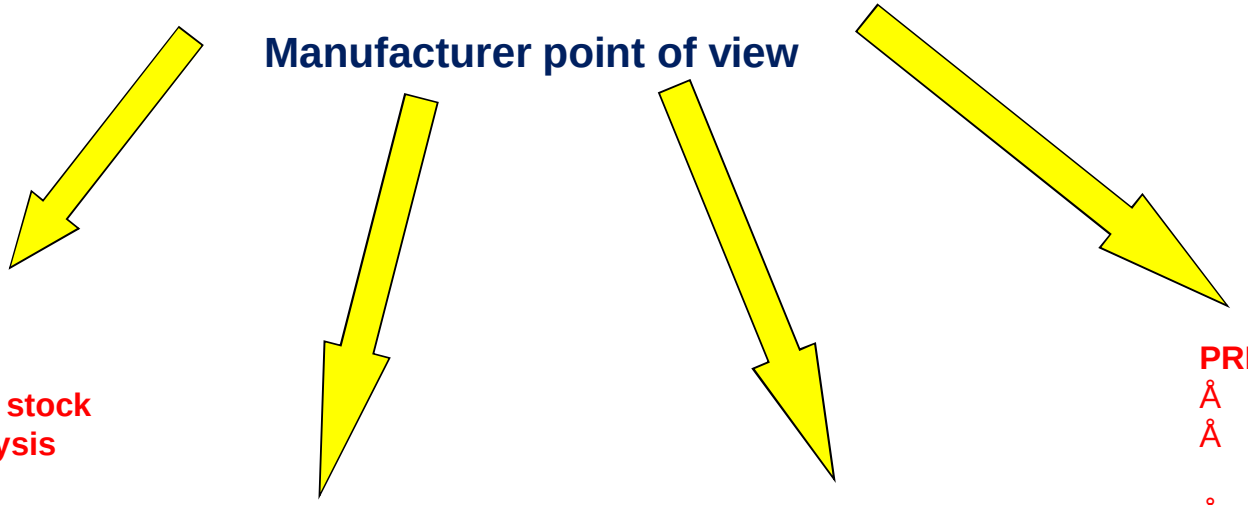
RELIABILITY AND COST

The Cost of Reliability is the total cost that a manufacturer incurs during the design, the production and the warranty period of a product of a given reliability. The most important classification areas are:



EXTERNAL FAILURES
- Costs of warranty
- Cost of spare parts stock
- Cost of failure analysis
- é

INTERNAL FAILURES
- Cost for reliability tests
- Costs for scraps
- Costs for failure caused by downtime
- Cost for redesign
- é .

RELIABILITY APPRAISAL
- Life tests
- Evaluation for environmental impact
- Stressed use test
- Failure data reporting and analysis
- Reliability modeling and simulation
- é

PREVENTION
- Design for reliability
- Reliability standard and guidelines development
- Design review
- Reliability training
- Fault-tree analysis
- FMEA
- é

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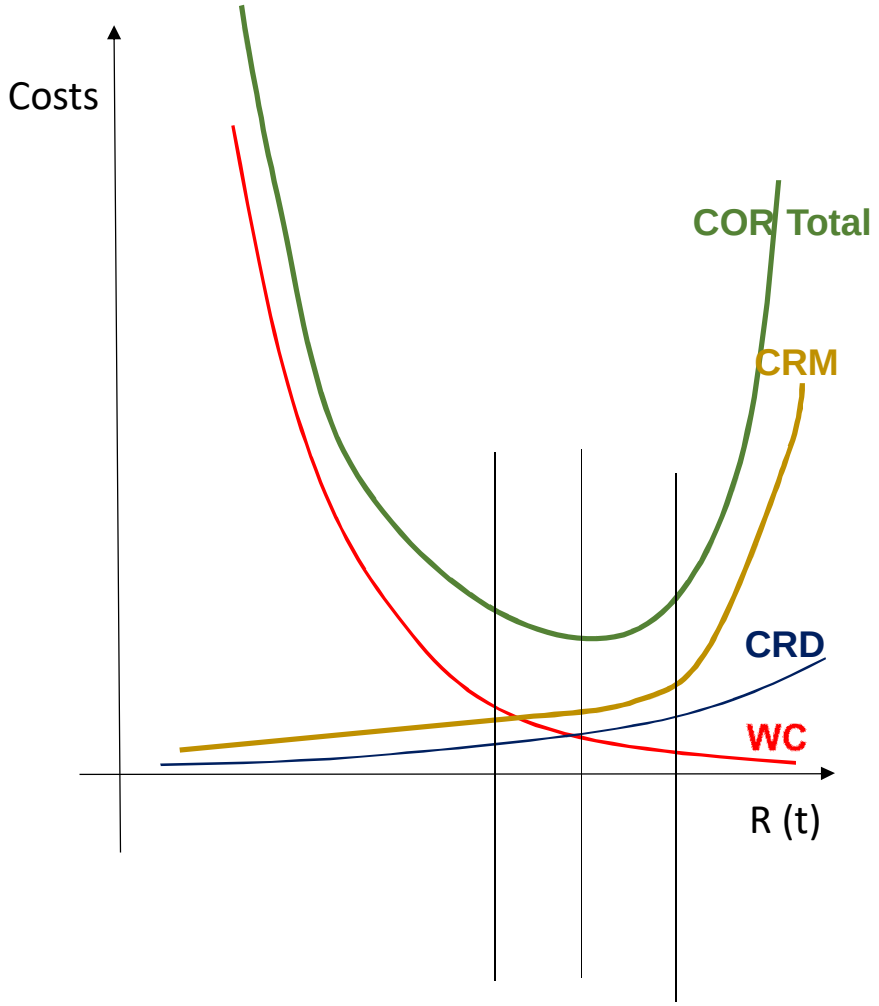
RELIABILITY AND COST

Manufacturer point of view

$$CoR_{total} = CRD + CRM + WC$$

Where:
CoRtotal: Total cost of reliability
CRD: Cost of reliability for Design = $f_1(Q)$
CRM: Cost of Reliability for Manufacturing = $f_2(Q)$
WC: Warranty Costs
Q: level of required quality
F(Q): cost related to the bathtub curve and repairs along the life cycle



$$CoR_{total} = f_1(Q) + f_2(Q) + WC$$

$$CoR_{total} = f_1(Q) + f_2(Q) + WC - F(Q)$$

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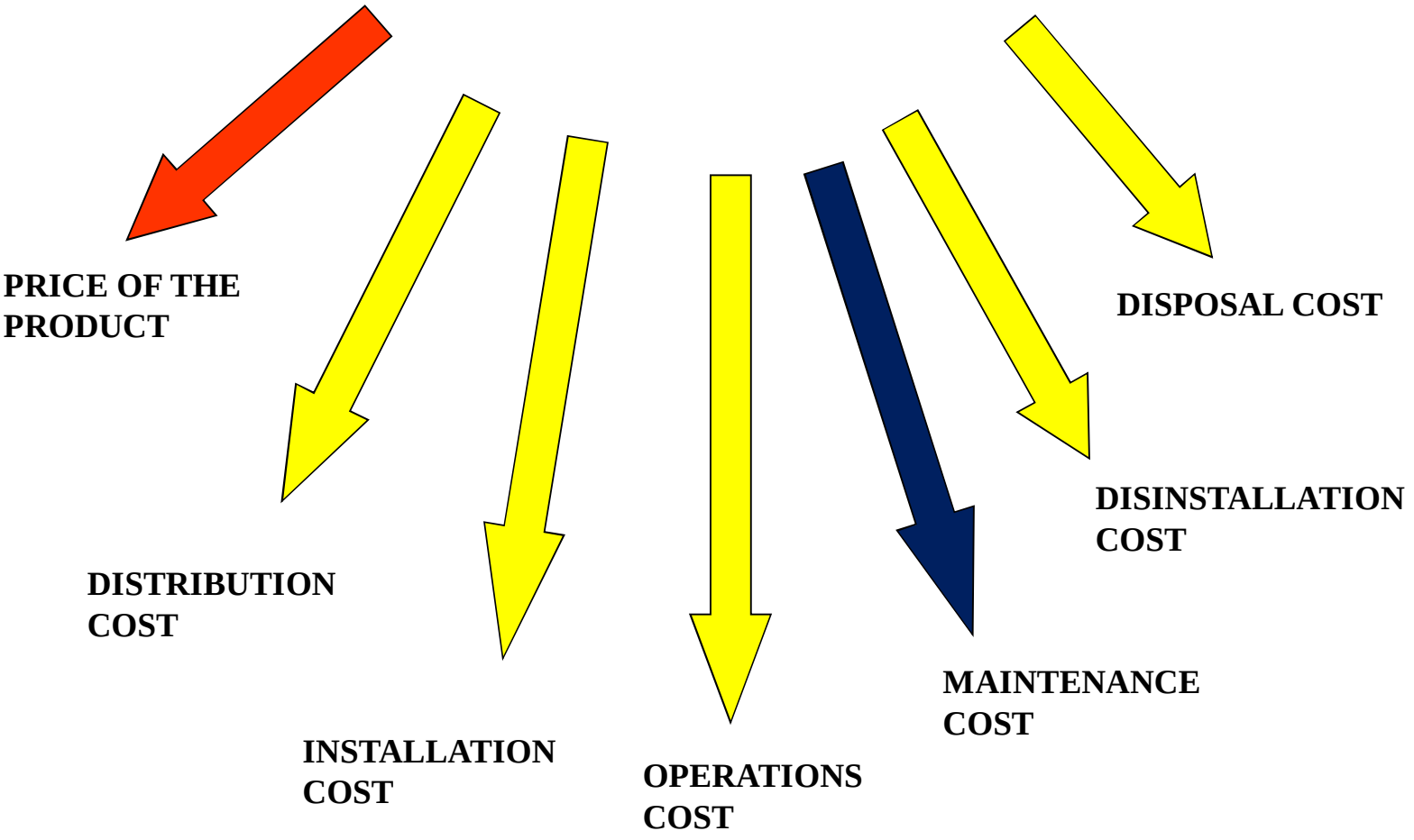
Customersô point of view

LIFE CYCLE COST



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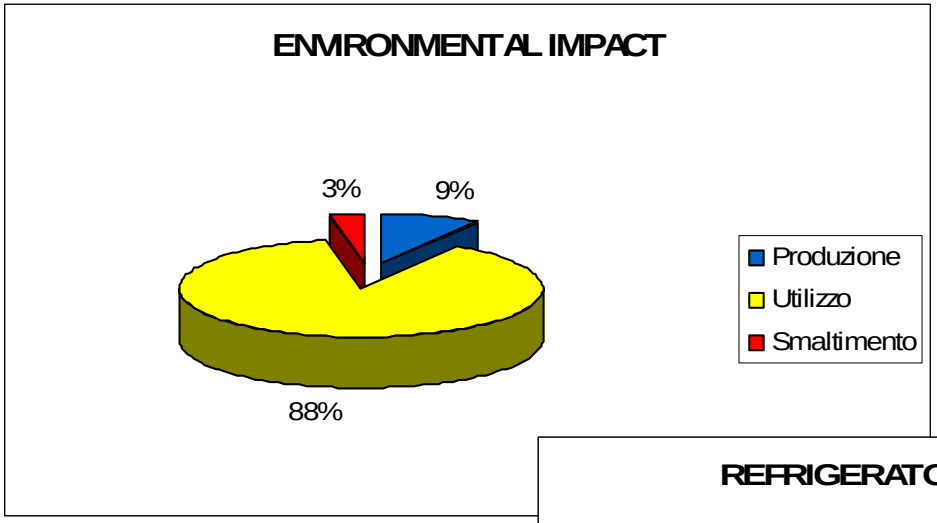
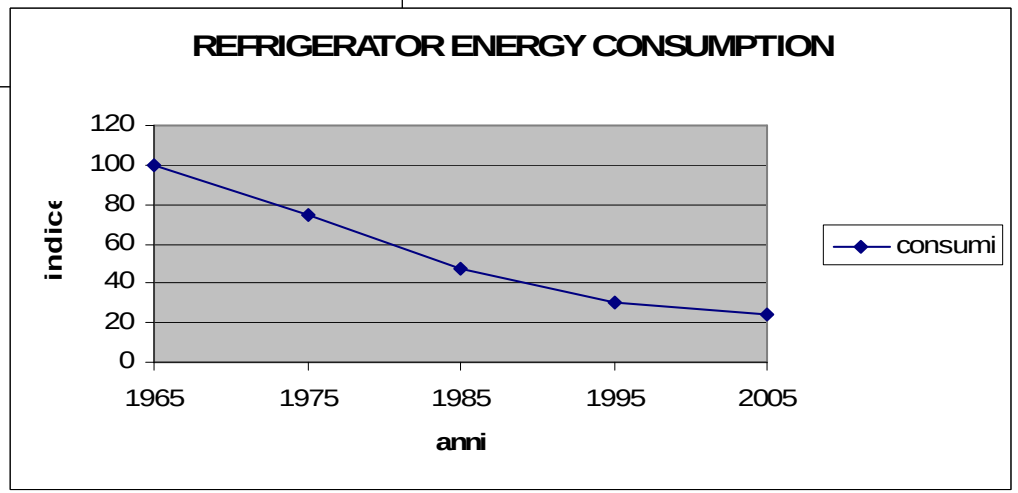
CONSUMPTION DURING THE PRODUCT LIFE CYCLE





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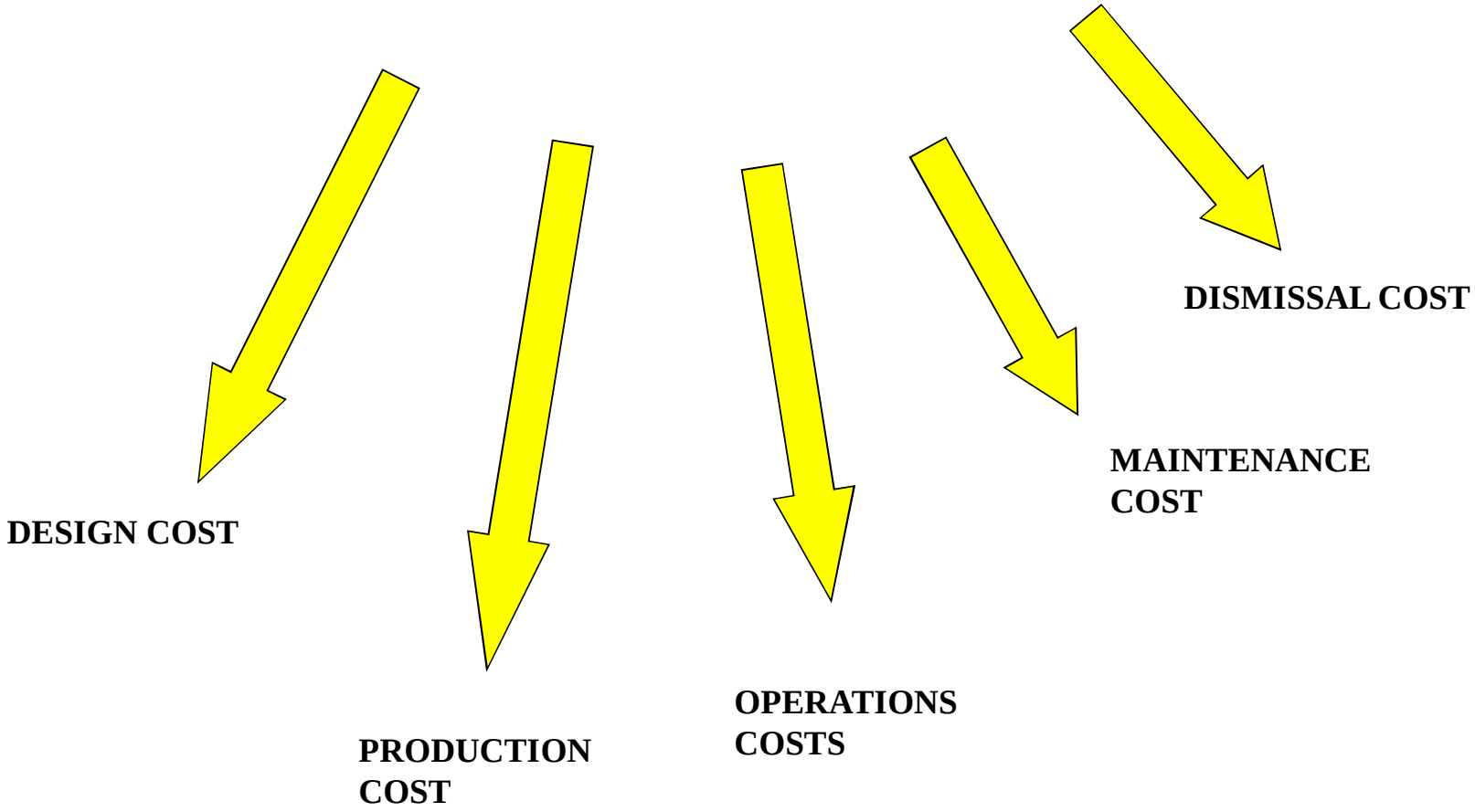
DESIGN TO LIFE CYCLE COST

ES. MILITARY SHIP



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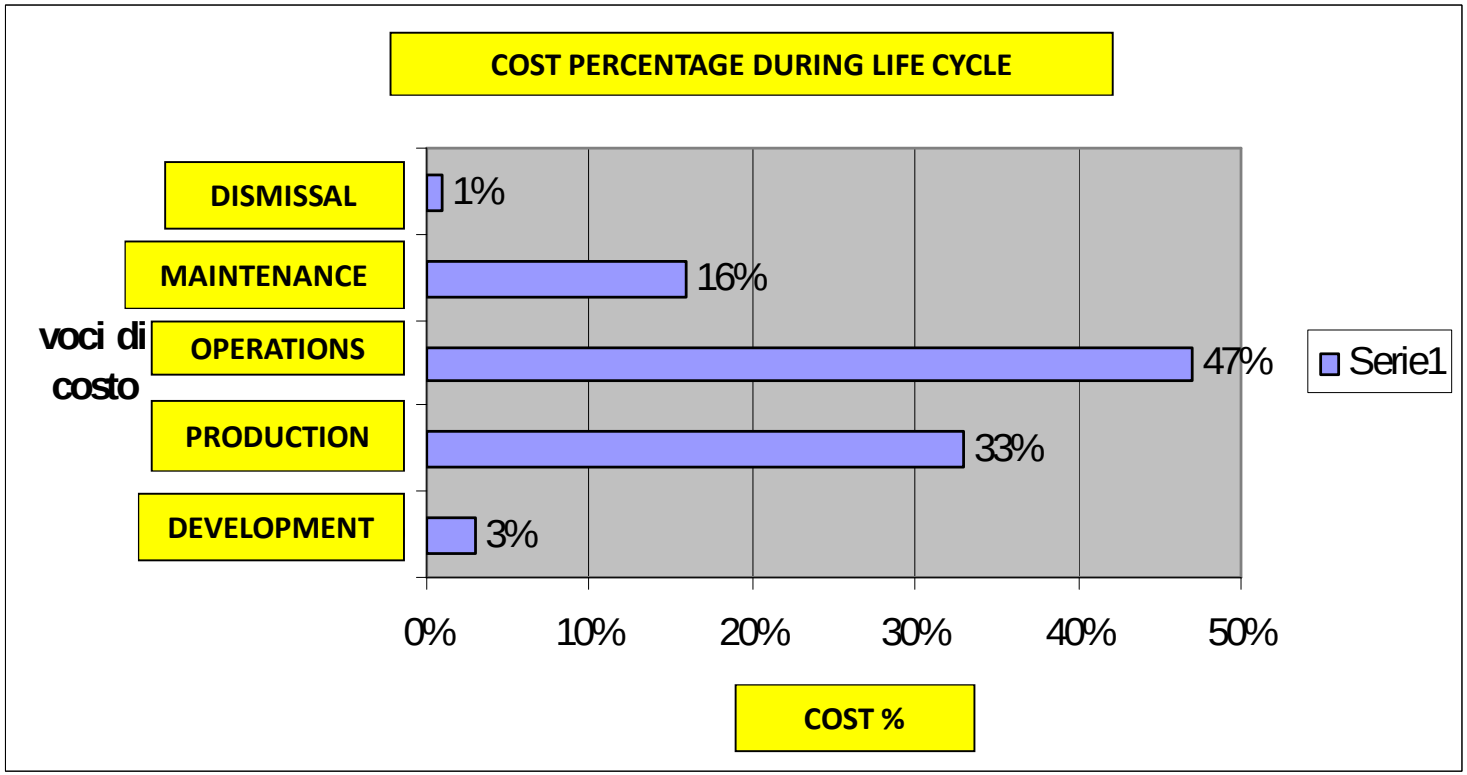
DESIGN TO LIFE CYCLE COST

ES. MILITARY SHIP



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DESIGN TO LIFE CYCLE COST

ES. MILITARY SHIP

		VARIATION		TOTAL	
DEVELOPMENT	30	10%	0,10	33,00	
PRODUCTION	330	10%	0,10	363,00	396,00
OPERATIONS	470	-10%	0,10	423,00	
MAINTENANCE	160	-10%	0,10	144,00	567,00
DISMISSAL	10	-10%	0,10	9,00	9,00
	1000			972,00	972,00

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LIFE CYCLE COSTS

Therefore, if we give for granted the purchasing price, and we consider only the maintenance costs, we could calculate them as follows:

$$C_m = C_{inv} + C_{pm} + C_{cm} = C_p * C_{ir} + \frac{t_{pm} + t_{tpm}}{T_{pm}} + \frac{t_{tcm}}{T_{bf}}$$

Where

- C_m: Maintenance costs
- C_{inv}: Cost of spare part inventory
- C_{pm} : Preventive maintenance cost
- C_{cm} : Corrective maintenance cost
- C_p : Manufacturing cost of spare parts at customerôs site
- C_{ir} : Inventory cost rate
- t : equipment in-use time (hours)
- t_{pm}: scheduled time for preventive maintenance
- t_{tpm}: expected travel time for preventive maintenance
- T_{pm}: scheduled preventive maintenance interval
- T_{tr}: mean time to repair
- T_{bf}: mean time before failure
- t_{tcm}: expected travel time for corrective maintenance

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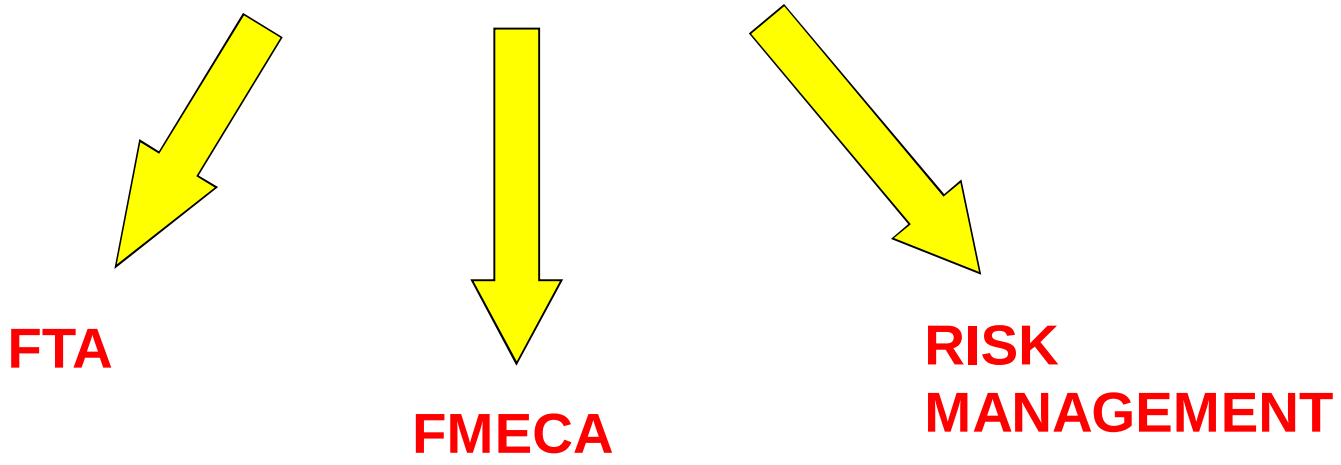
PARTICULAR ISSUES

ECONOMIC ASPECTS OF PRODUCT SAFETY

There is a close relationship between reliability and issues related to product safety. This is evident from the simple definition of risk:

Risk = probability of failure x exposure x consequence



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ECONOMIC ASPECTS OF PRODUCT SAFETY

RISK MANAGEMENT

The risk management process is a systematic application of management policies, procedures and practices to the tasks of communicating, establishing the context, assessing, monitoring and reviewing risks.

It comprises the following activities:

1) Communication and consultation;
2) Risk analysis:
   a. Hazard Identification
   b. Analysis and measurement of frequency and consequences
   c. Weighting
   d. Risk calculation
3) Risk Assessment
4) Risk Ranking
5) Sensitivity Analysis
6) Monitoring and review.

The process should also concern the risk based audit and information system support in all phases.

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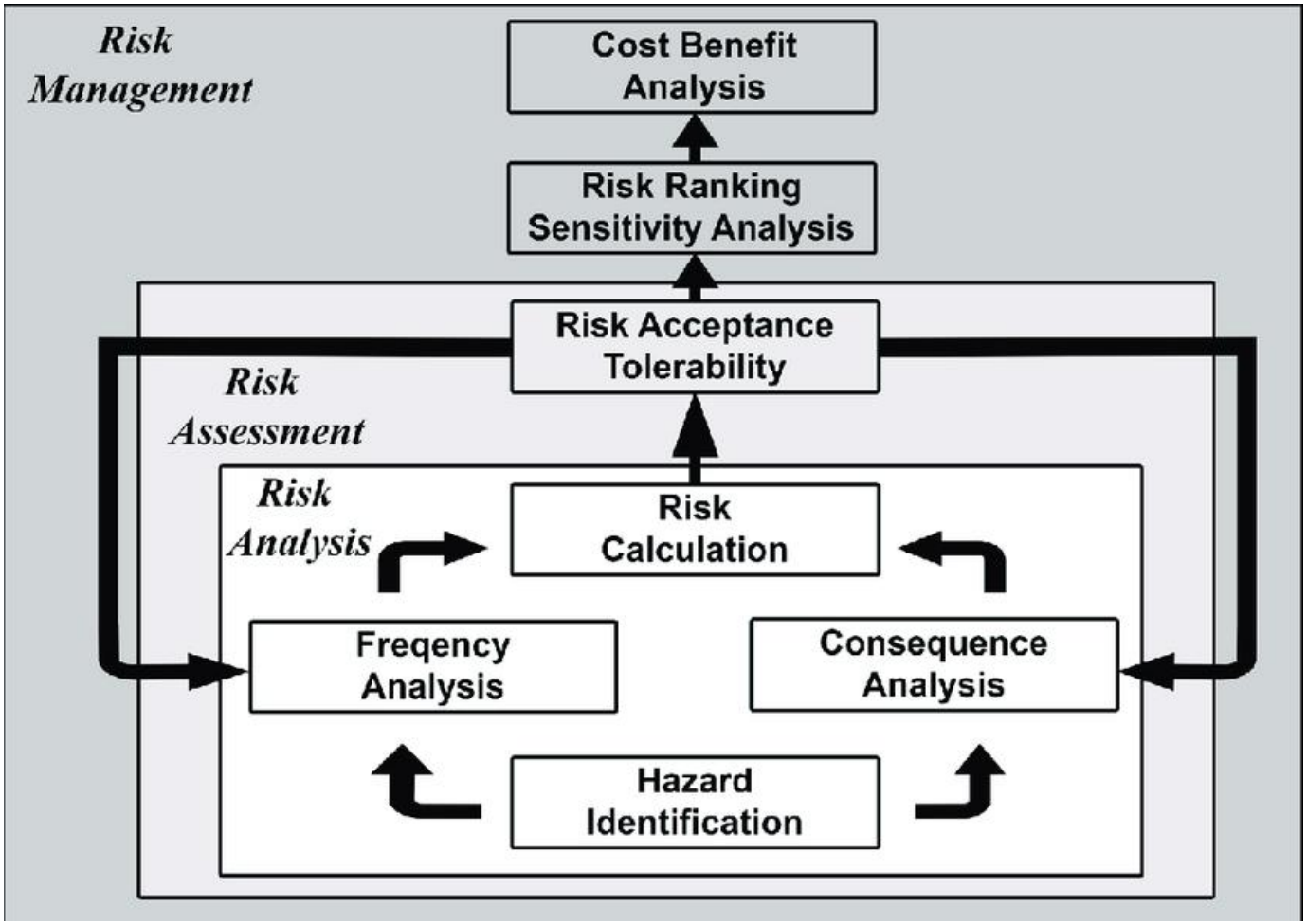
ECONOMIC ASPECTS OF PRODUCT SAFETY

RISK MANAGEMENT



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ECONOMIC ASPECTS OF PRODUCT SAFETY

RISK MANAGEMENT

		Consequence				
		Negligible 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Likelihood	5 Almost certain	Moderate 5	High 10	Extreme 15	Extreme 20	Extreme 25
	4 Likely	Moderate 4	High 8	High 12	Extreme 16	Extreme 20
	3 Possible	Low 3	Moderate 6	High 9	High 12	Extreme 15
	2 Unlikely	Low 2	Moderate 4	Moderate 6	High 8	High 10
	1 Rare	Low 1	Low 2	Low 3	Moderate 4	Moderate 5

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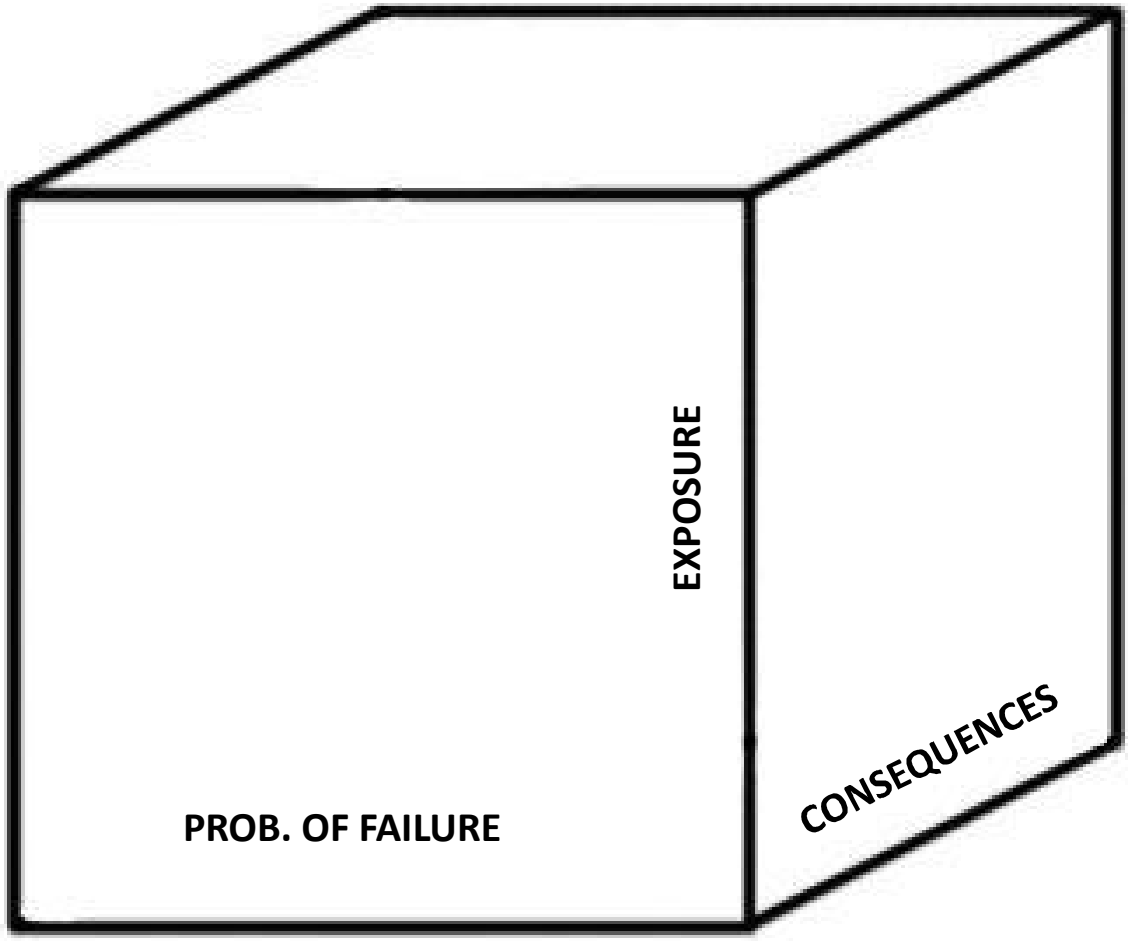
ECONOMIC ASPECTS OF PRODUCT SAFETY

RISK MANAGEMENT



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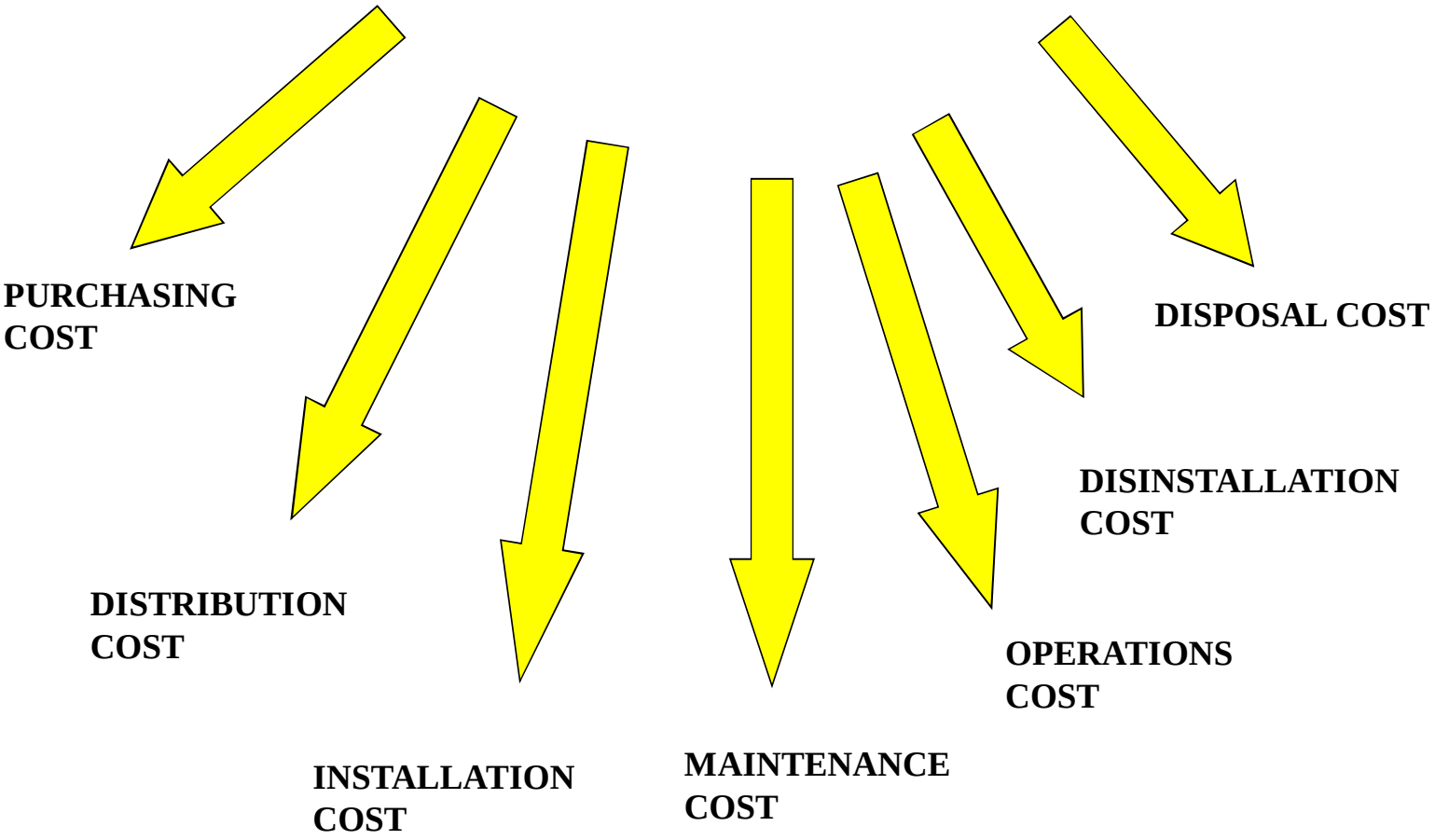
COST EVALUATION METHODS

LIFE CYCLE COST



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COST EVALUATION METHODS

Cost estimation of asset alternatives is essential for project planning and budgeting decisions by both equipment manufacturer and customer.
A good check list for cost estimation could be:

- **Establish the target time: medium term plan? Year budget project? Hence the accuracy.**
- **Ensure adequate resources to do the estimation**
- **Write down the reliability specs and document all the assumptions**
- **Explore all the possible details available that help accuracy**
- **Estimate using different methods to compare them**
  - **Modules or functions**
  - **Algorithmic models**
  - **Expertsô judgements and/or Group Consensus**
  - **Analogies based on experiences of past cases (do not forget to take into account inflation, new technologies, productivity growth and so on.**
- **Compare and iterate**
- **Eestimate the optimistic-pessimistic biases**
- **Evaluate the importance of estimate via Pareto analysis**
- **Follow up your estimates with regular comparison with actual cost collection during the project implementation**

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RELIABILITY COST CATEGORIES/INDICATORS

PREVENTION COSTS

- Hourly cost for reliability engineers, material engineers, technicians, test personnel
- Cost of preventive maintenance cost
- Cost of annual reliability training
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APPRAISAL COSTS

- Hourly cost and OH rates for reliability evaluation, qualification, demonstration, environmental testing, life testing
- Average cost per part of assembly testing, screening, inspection, auditing, calibration
- Vendor assurance cost for new component qualification, audit...
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RELIABILITY COST CATEGORIES

INTERNAL FAILURE COSTS

- Hourly cost for rate for troubleshooting and repair failure analysis
- Spare parts cost
- Stare parts inventory rotation
- Cost of production changes administration
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EXTERNAL FAILURE COSTS

- Cost to repair a failure
- Service engineering hourly rate and OH
- Spare parts cost
- Spare pats inventory rptation
- Cost of failure analysis
- Warranty administration and reposting cost
- Cost of liability insurance
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