Μηχανουργική Τεχνολογία Ι

"Συστήματα Παραγωγής"

Καθηγητής Γεώργιος Χρυσολούρης
Πολυτεχνική Σχολή
Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών

Manufacturing Processes I

"Manufacturing Systems"

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THE SYSTEM OF MANUFACTURING

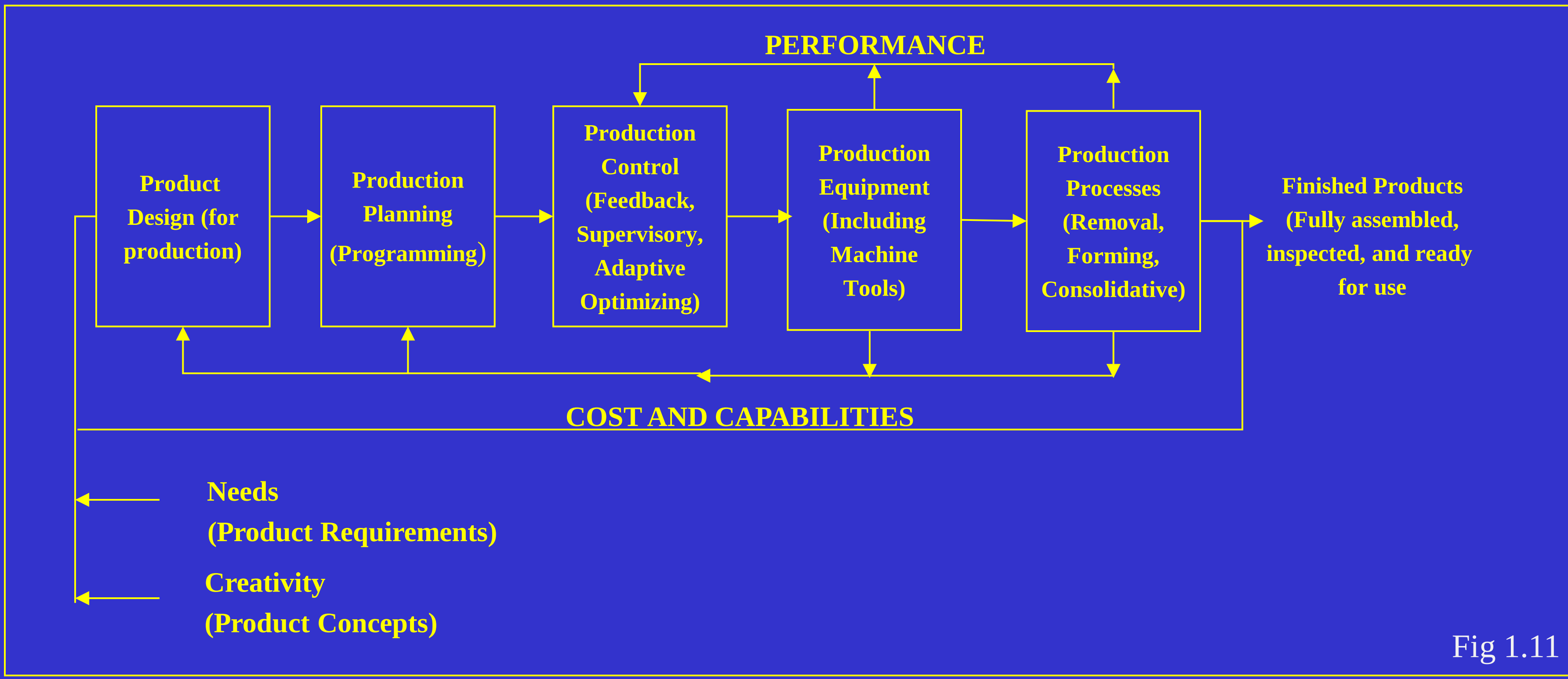


Fig 1.11

Product design

Design-manufacturing interfaces

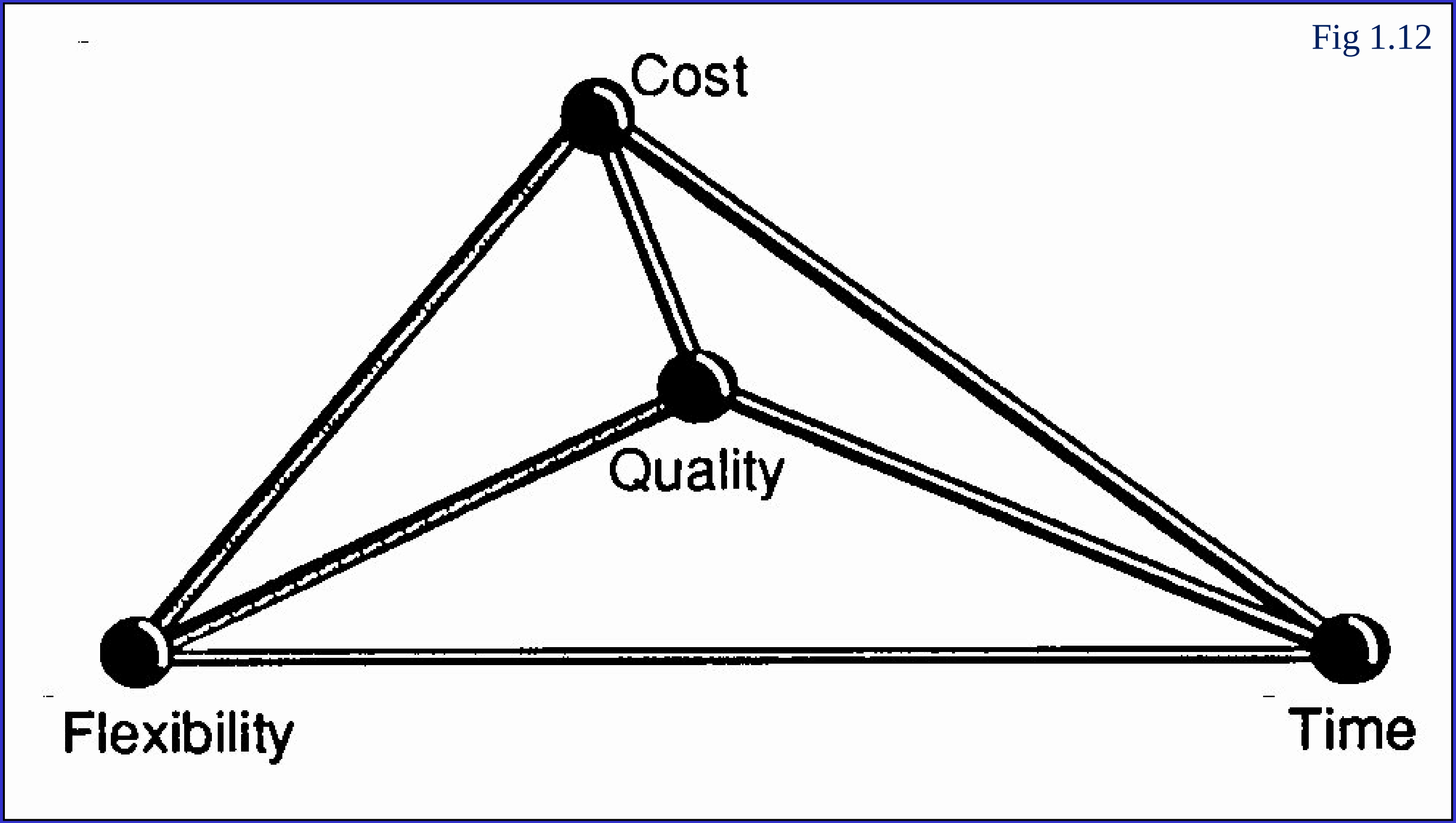
processes

equipment

systems

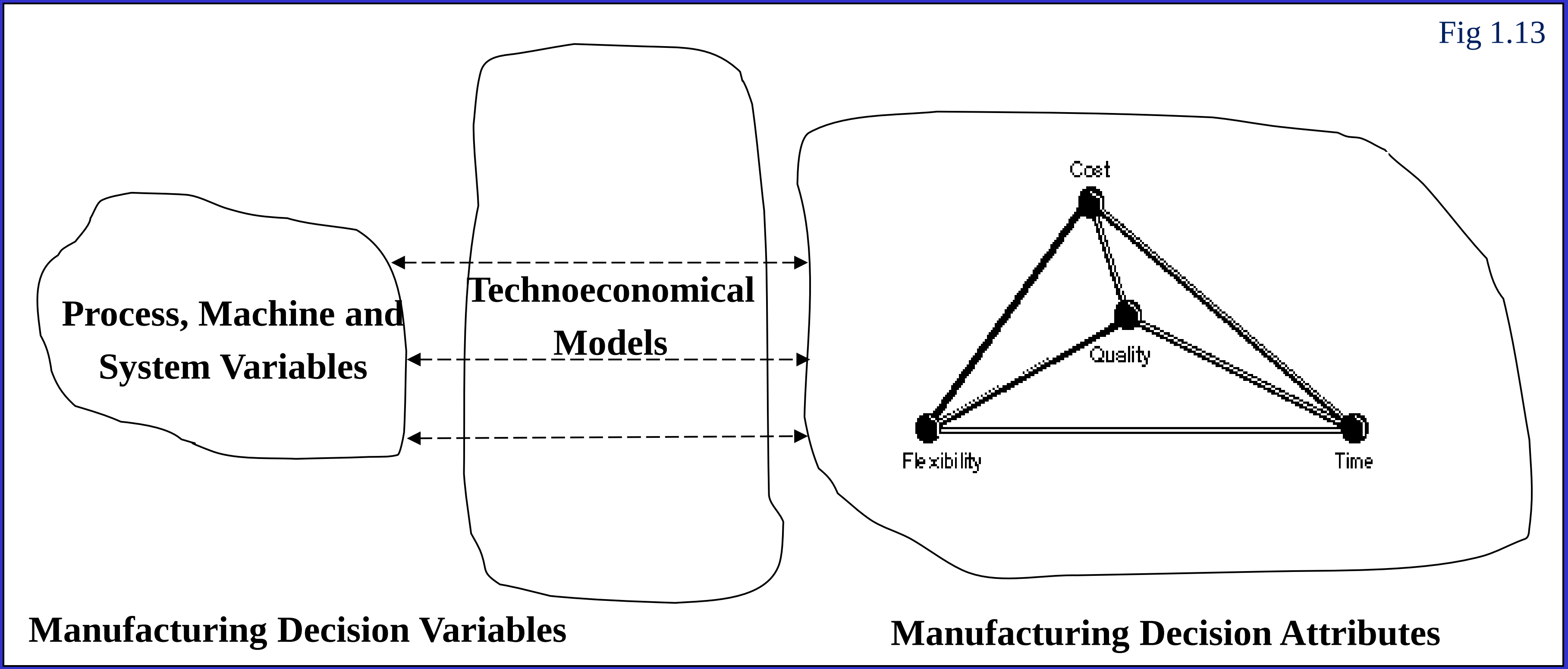
Chryssolouris, G. (2006). Manufacturing Systems: Theory and Practice, p10. © Springer, 2006

MANUFACTURING ATTRIBUTES



OBJECTIVES … GOALS … CRITERIA

A MANUFACTURING DECISION



Era of
Mass Production → Cost
Production Rate

Era of
Global Competition → Quality

Era of
Market Niches → Flexibility

MANUFACTURING DECISION MAKING

- Requires trade-offs between different types of attributes
- informed trade-offs require quantifiable attributes

- cost
- time/rate

Well quantified

- quality
- flexibility

Few quantitative definitions

COST

- Equipment and facilities
- Materials
- Labor
- Energy
- Maintenance
- Training
- Overhead
- Cost of capital

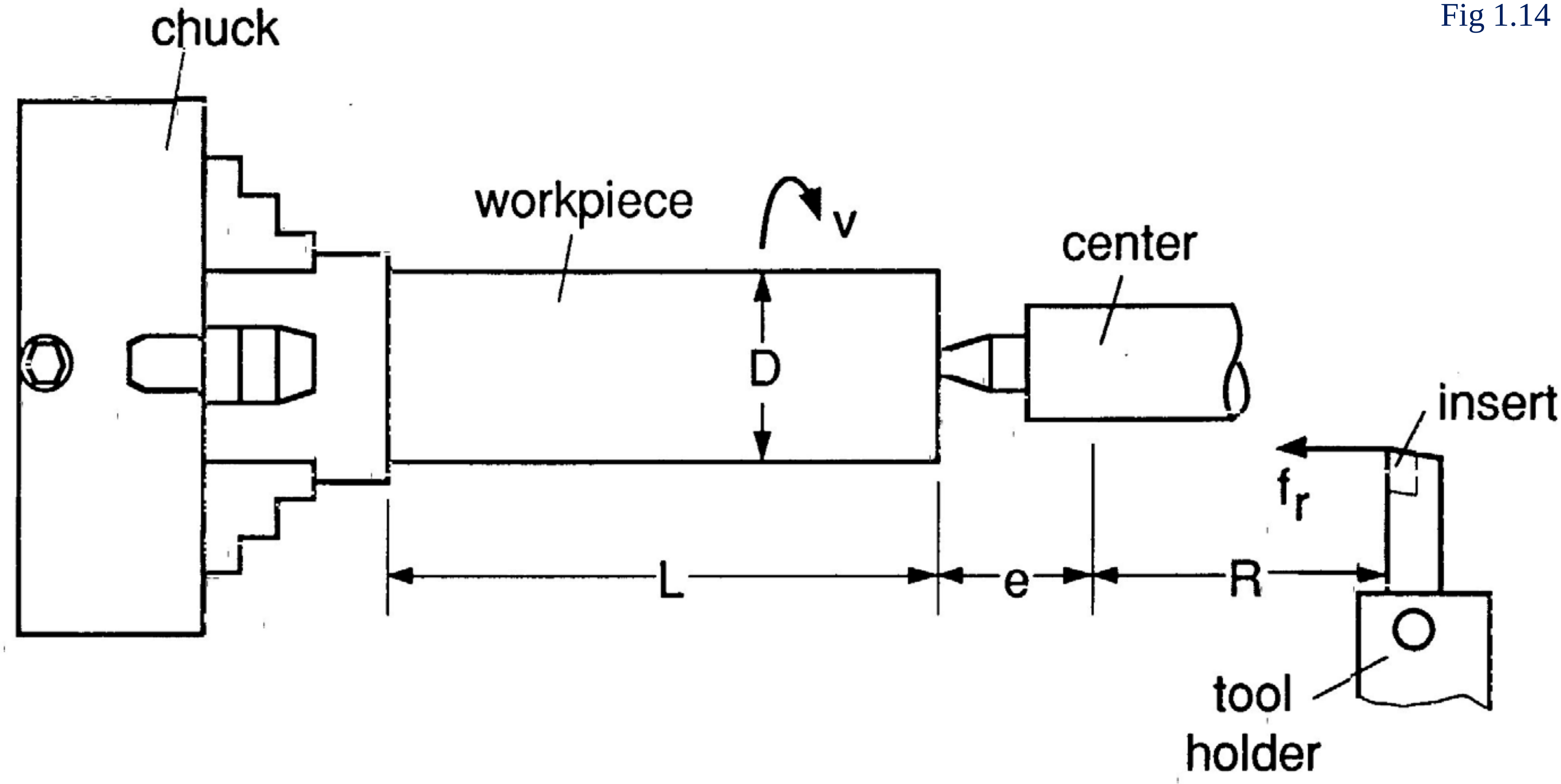
COST

Costs related to manufacturing encompass a number of different factors which can be broadly classified into the following categories:

- *Equipment and facility costs.* These include the costs of equipment necessary for the operation of manufacturing processes, the facilities used to house the equipment, the factory infrastructure, etc.
- *Materials.* This cost includes the raw materials for producing the product, and tools and auxiliary materials for the system, such as coolants and lubricants.
- *Labour.* The direct labour needed for operating the equipment and facilities.
- *Energy* required for the performance of the different processes. In some manufacturing industries, this cost may be negligible compared to other factors, while in others it contributes significantly to be financial burden of the manufacturing system.
- *Maintenance and training.* This includes the labour, spare parts, etc., that are needed to maintain the equipment, facilities and systems, as well as the training necessary to accommodate new equipment and technology.
- *Overhead.* This is the portion of cost that is not directly attributable to the operation of the manufacturing system, but supports its infrastructure
- *The cost of capital*, which may be not readily available within the manufacturing firm, and therefore must be borrowed under specific terms.

PROCESS GEOMETRY
(TURNING)

Fig 1.14



TECHNOECONOMICAL MODEL (TURNING)

$$\text{Cost Per Workpice} = \left[\text{Machining Rate} + \text{Labour Rate} + \text{Overhead Rate}\right] \times \left[\text{Feeding Time} + \text{Rapid Feeding Time} + \text{Portion of Tool Insert Replacement Time Per Workpiece}\right] + \frac{1}{\text{No. of Workpieces Bet. Tool Insert Changes}} \times \left[\text{Cost Per Tool insert}\right]$$

$$C = M \times \left[\frac{D(L+e)}{318 f_r v} + \frac{R}{r} + \frac{DLt_d}{318 f_r v T}\right] + \frac{DL}{318 f_r v T} \times \left[C_i\right]$$

C	Cost for turning one workpiece [$]	L	Length of workpiece [mm]
fr	Feed per revolution [mm]	e	Extra travel at feed rate f_r [mm]
v	Cutting speed [m/min]	R	Total rapid traverse distance for one part [mm]
M	Machining + labour + overhead rate [$/min]	r	Rapid traverse rate [mm/min]
N_{IR}	Number of workpieces between insert changes	t_d	Tool insert replacement time [min]
C_I	Cost per insert [$]	T	Tool life [min]
D	Workpiece diameter [mm]		

- Derived from process **physics** and **geometry.**

TECHNOECONOMICAL MODEL

MACHINING RELATIONSHIPS

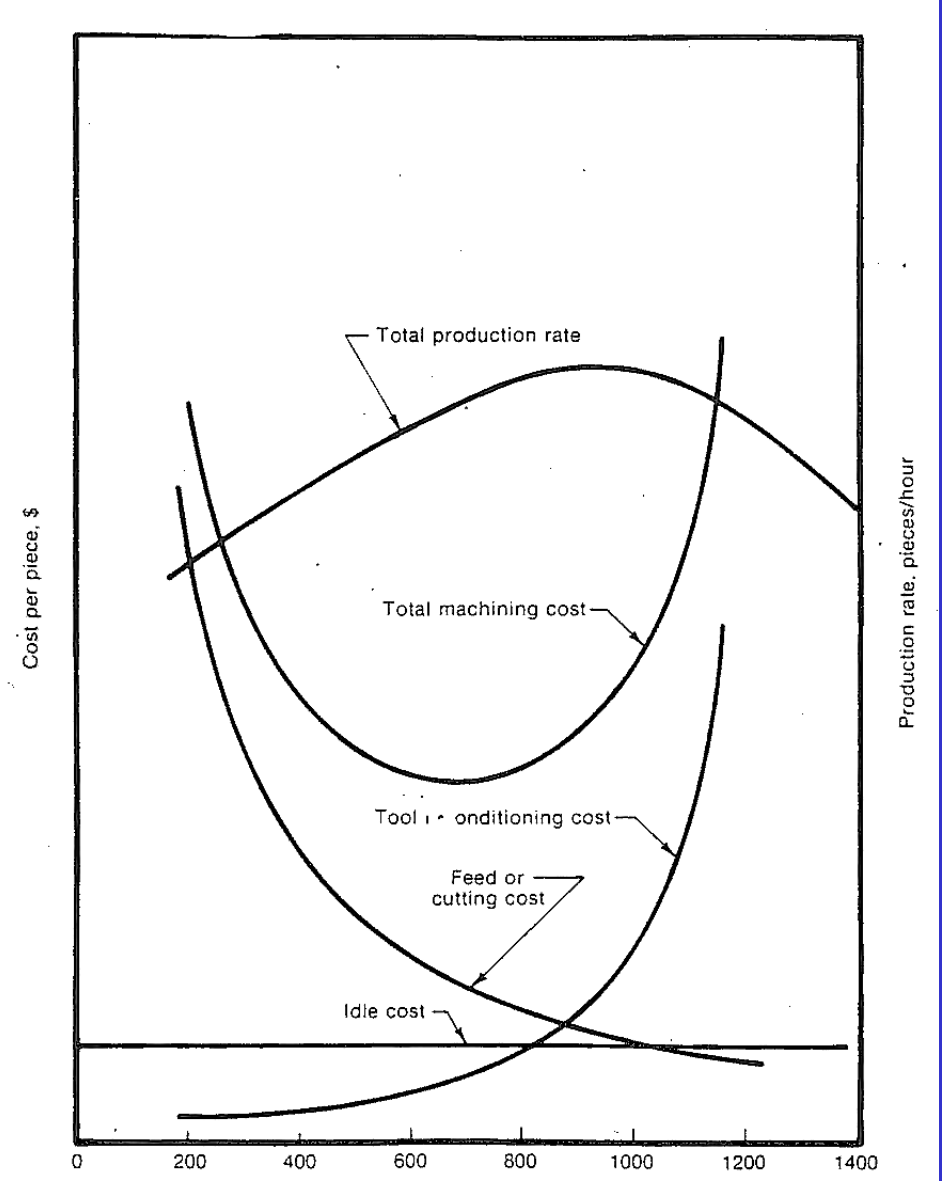


Fig 2.13

TECHNOECONOMICAL MODEL

MACHINING RATE RELATIONSHIPS

EQUATIONS FOR OPERATING TIME PER PIECE	
Turning	$t_{op} = \dfrac{D(L+e)}{3.82\, f_r\, v} + \dfrac{R}{r} + t_i + \dfrac{DL\, t_d}{3.82\, f_r\, vT}$
Milling	$t_{op} = \dfrac{D(L+e)}{3.82 Z\, f_r\, v} + \dfrac{R}{r} + t_i + \dfrac{L\, t_d}{Z\, T_F}$
Drilling and Reaming	$t_{op} = \dfrac{D(L+e)}{3.82\, f_r\, v} + \dfrac{R}{r} + t_i + \dfrac{L\, t_d}{T_F}$
Tapping	$t_{op} = \dfrac{mD(L+e)}{1.91 v} + \dfrac{R}{r} + t_i + \dfrac{L\, t_d}{T_F}$
Center drilling and Chamfering	$t_{op} = \dfrac{D(L+e)}{3.82\, f_r\, v} + \dfrac{R}{r} + t_i + \dfrac{u_c\, t_d}{T_h}$

EQUATIONS FOR PRODUCTION RATE

$$P = \frac{60}{\left(\sum t_{op} + t_i + \dfrac{t_d}{N_t}\right)}$$

PRODUCTION RATE AFFECTS OTHER ATTRIBUTES

e.g. transfer line

Fig 1.17

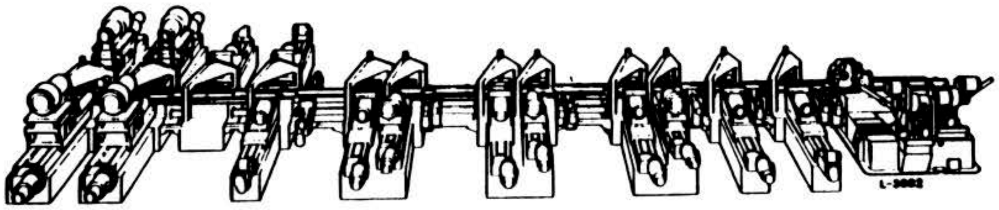
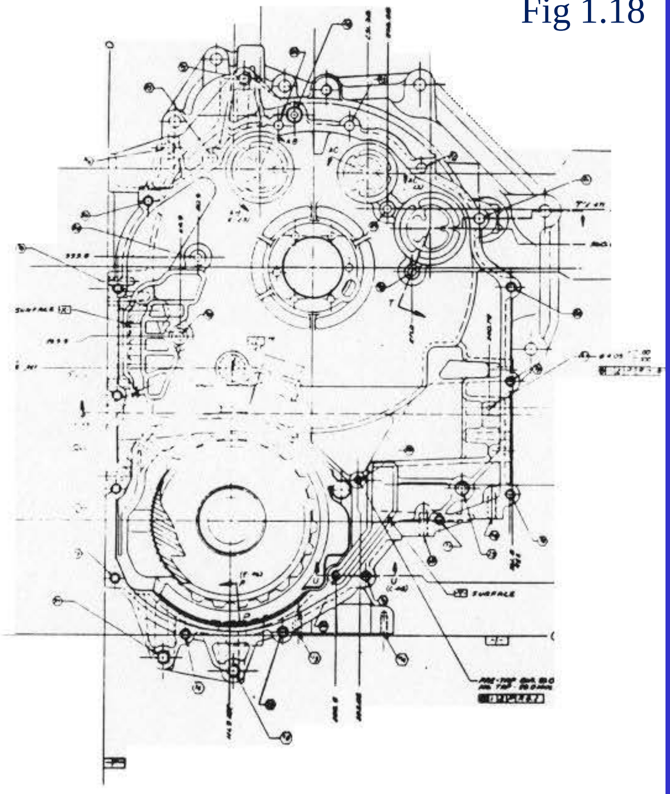


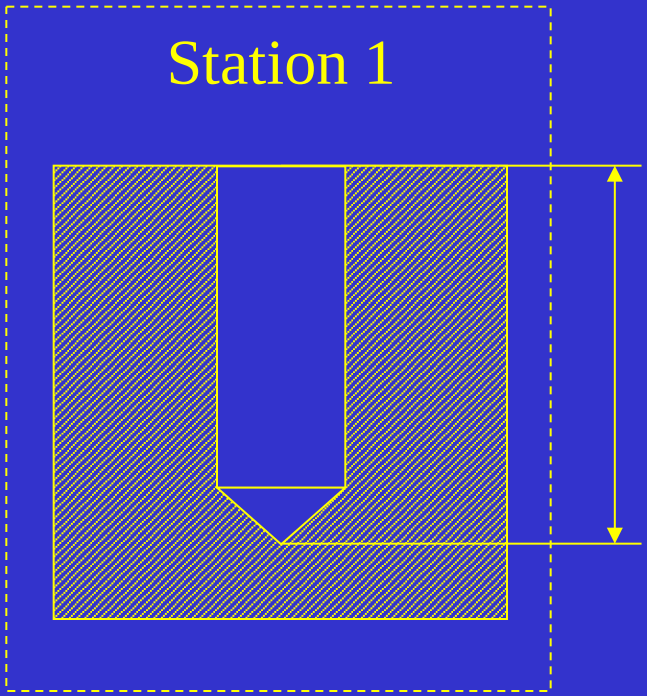
Fig 1.18



high production rate → **Low flexibility**

Hole Making

Process Speed: 10 mm/min, 1 station

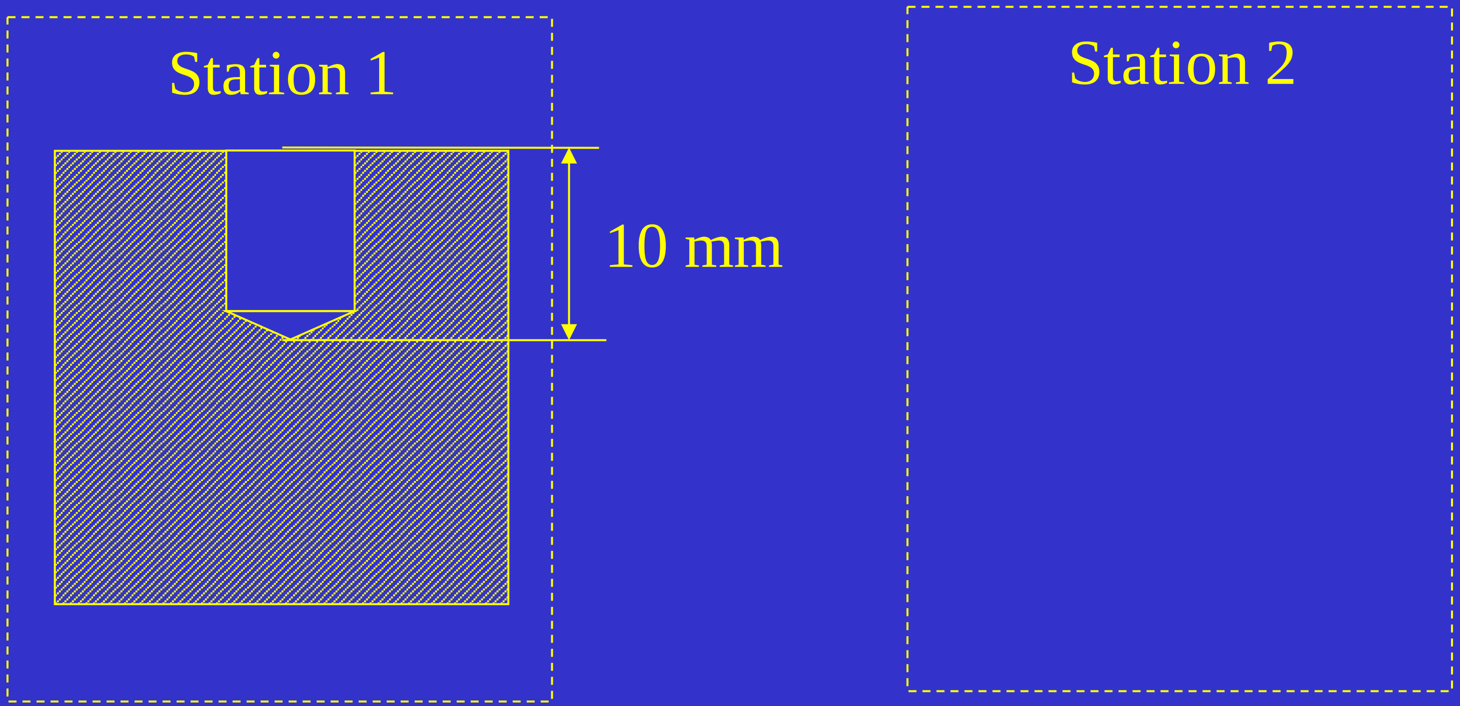


Total station time = 20mm / 10mm/min = 2min ⇒

⇒ Production Rate = 0.5 parts/min

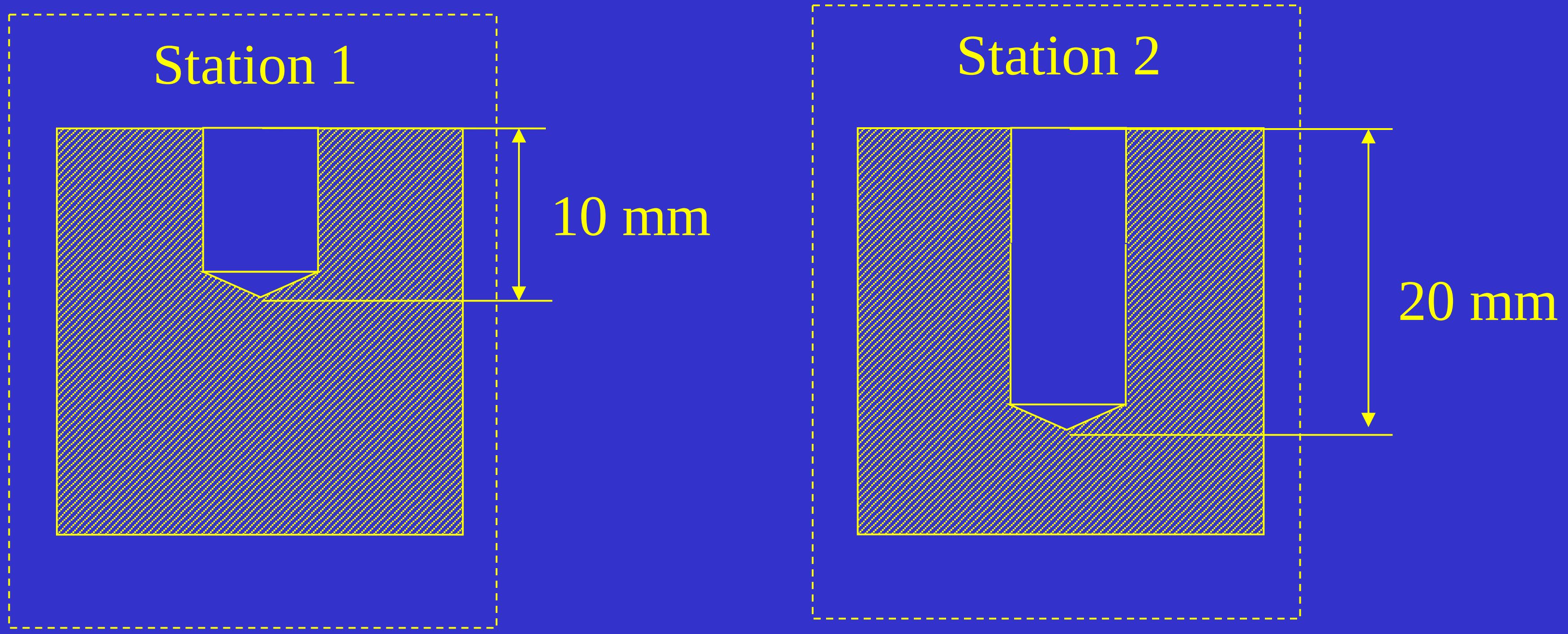
Hole Making

Process Speed: 10 mm/min, 2 stations



Hole Making

Process Speed: 10 mm/min, 2 stations



Total station time = 10mm / 10mm/min = 1min ⇒

⇒ Production Rate = 1 parts/min

RELIABILITY AND PRODUCTION RATE

Failure Rate (λ): number of failures over a time period

Mean Time Between Failure(MTBF): **1/λ**

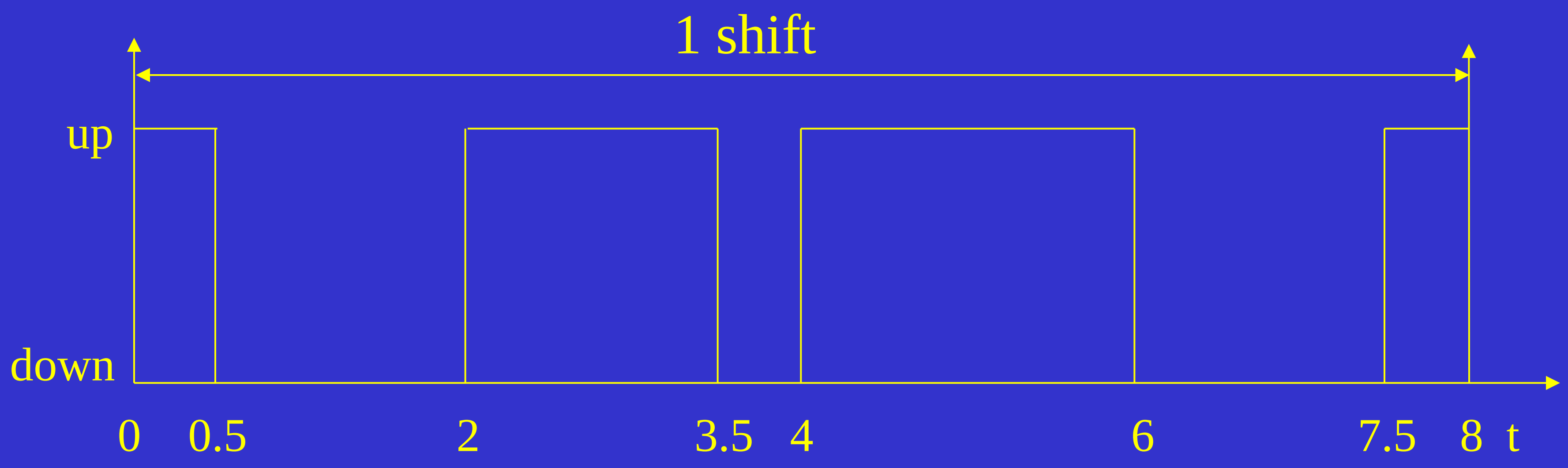
Reliability (R): The probability that a system or component will perform its required functions under stated conditions for a specified period of time.

$$R = e^{-\lambda T}$$

Availability (A): $$A = \frac{MTBF}{MTBF + MTTR}$$ MTTR:Mean time to repair.

ACTUAL PRODUCTION RATE = AVAILABILITY x MACHINE CYCLE

AVAILABILITY EXAMPLE 1



Failure rate $\lambda = 3/8$

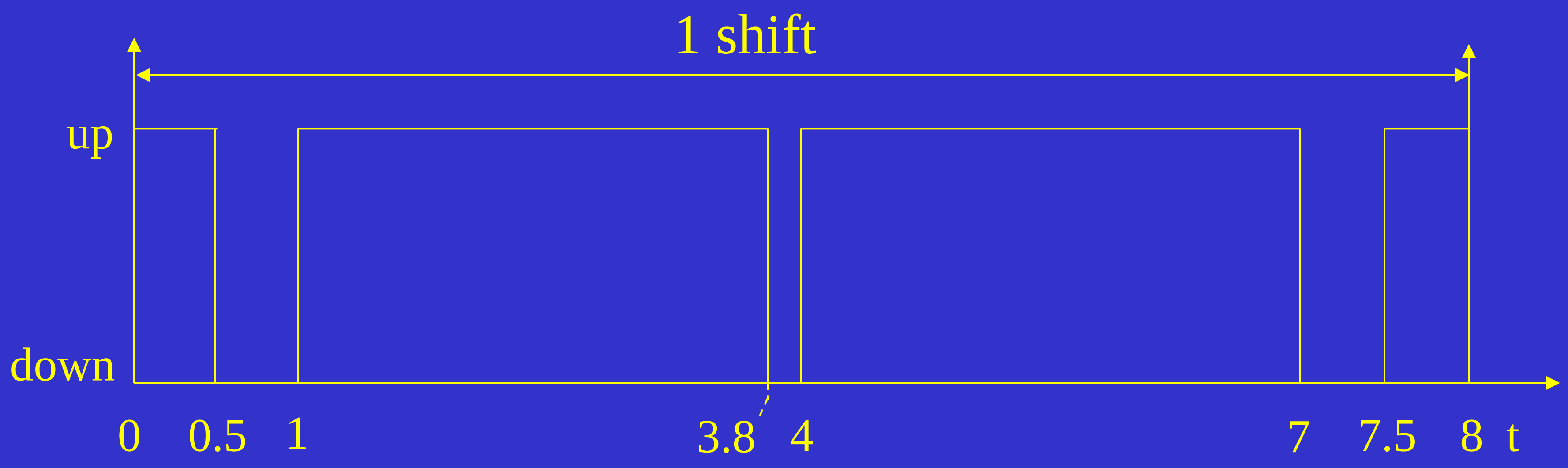
$MTBF = 1/\lambda = 8/3$

Reliability $= e^{-\lambda T} = e^{-3}$
$= 5\%$ for the 8 hrs period.

$$MTTR = \frac{(2 - 0.5) + (4 - 3.5) + (7.5 - 6)}{3} = 1.17$$

$$\text{Availability (A)} = \frac{MTBF}{MTBF + MTTR} = \frac{2.67}{2.67 + 1.17} = 0.7$$

AVAILABILITY EXAMPLE 2



Failure rate $\lambda = 3/8$

MTBF = $1/\lambda = 8/3$

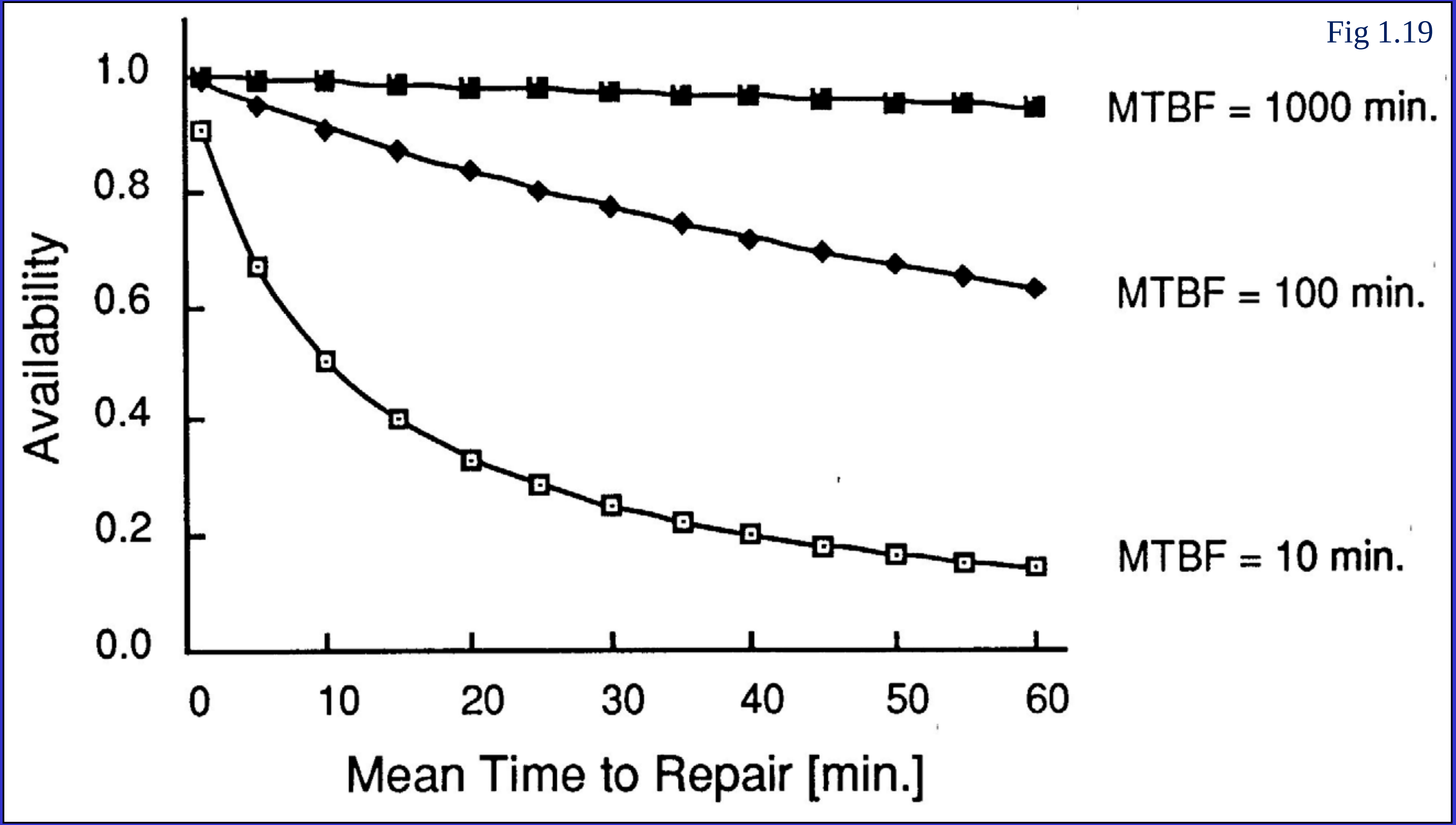
Reliability = $e^{-\lambda T} = e^{-3}$ = 5% for the 8 hrs period.

$$\text{MTTR} = \frac{(1 - 0.5) + (4 - 3.8) + (7.5 - 7)}{3} = 0.4$$

$$\text{Availability (A)} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}} = \frac{2.67}{2.67 + 0.4} = 0.87$$

AVAILABILITY

MTBF → AVAILABILITY ← MTTR



TRANSFER LINE RELIABILITY

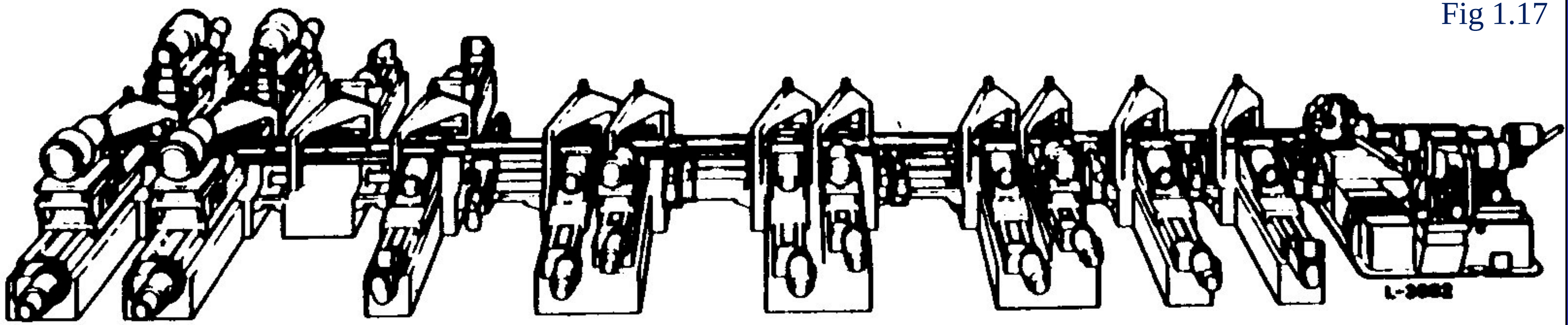


Fig 1.17

$$R = R_1 \times R_2 \times \cdots \times R_n$$

$$e^{\lambda t} = e^{\lambda_1 t} \times e^{\lambda_2 t} \times \cdots \times e^{\lambda_n t}$$

$$\lambda = \lambda_1 + \lambda_2 + \cdots + \lambda_n$$

TRANSFER LINE RELIABILITY

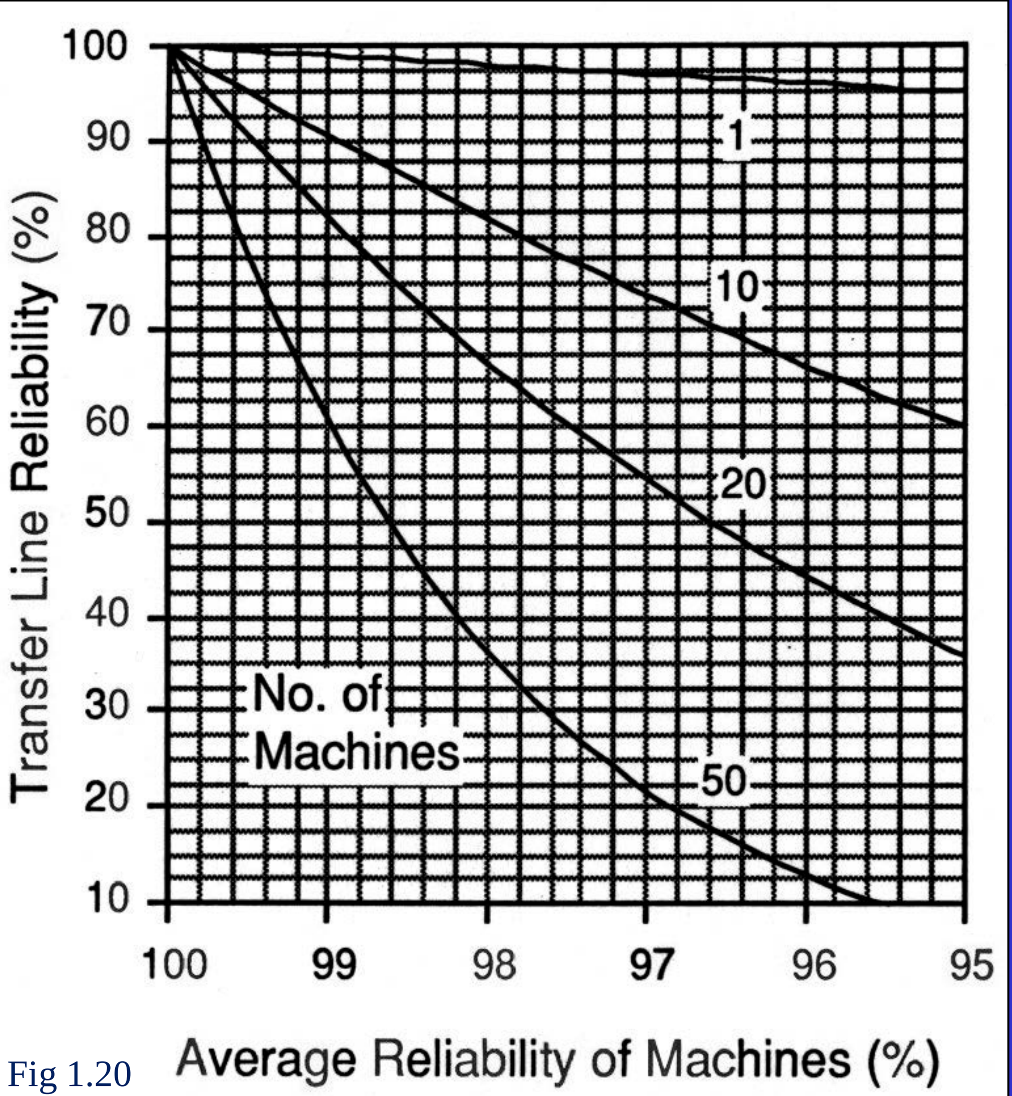
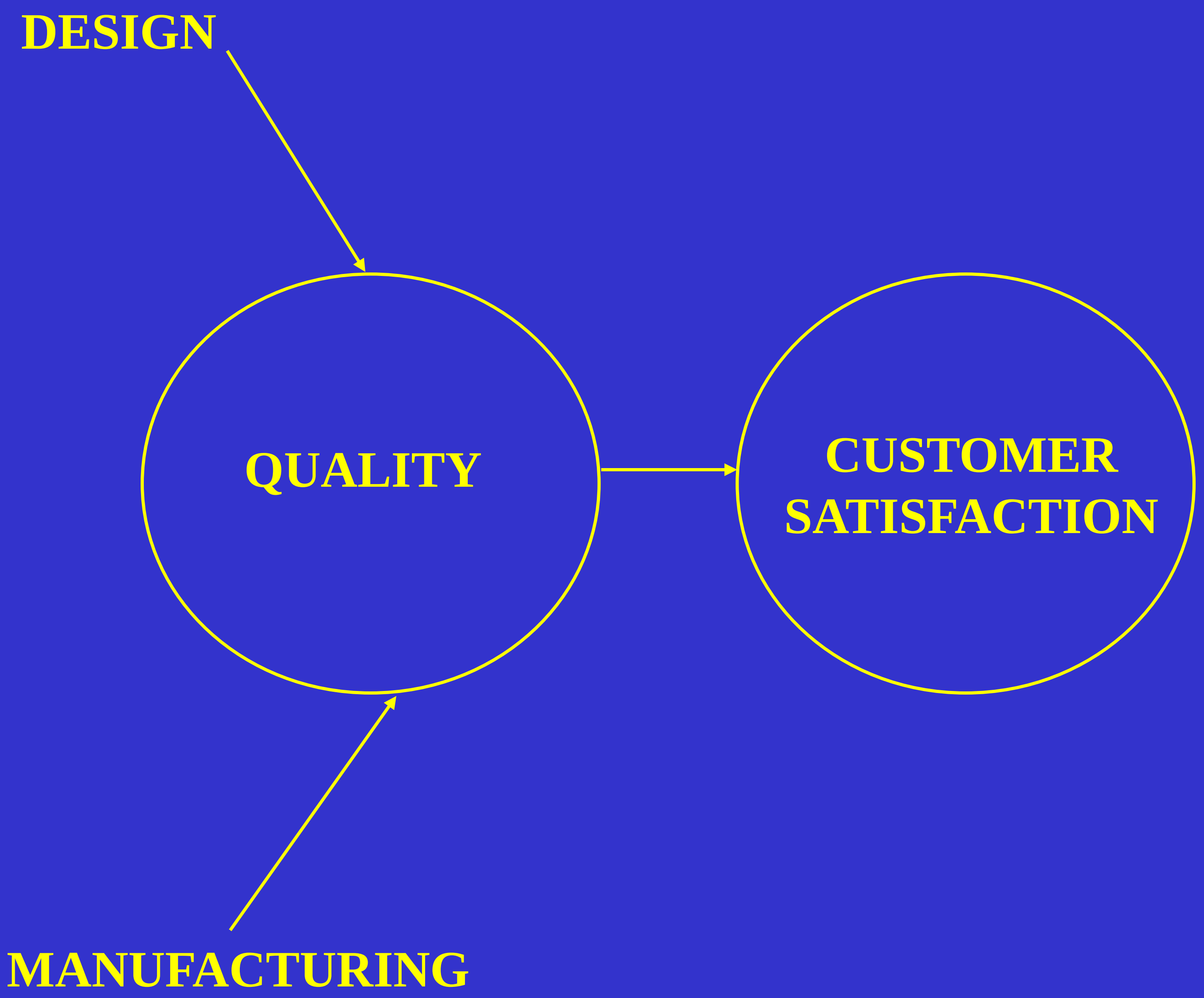


Fig 1.20


DESIGN
QUALITY
CUSTOMER SATISFACTION
MANUFACTURING

MANUFACTURING QUALITY

How well **production process** meets **design specifications**

- feature **geometries**
- material properties
    - **mechanical properties**
    - **chemical properties**

Issues:

- repeatability
- longevity/maintainability

Quality is traditionally measured by

- **percent defective:** the percent of parts produced that do not meet required specifications

- **warranty costs:** the costs that occur in the manufacturing organisation due to the failure of parts during operation

- **process capability index,** defined as the tolerance over six standard deviations,

$$Cp = \frac{\text{tolerance}}{6 \text{ x Standard Deviation}}$$

Where tolerance is defining the range of the specifications which are acceptable for a particular quality characteristic of a part or a product and the standard deviation is derived from the distribution of this quality characteristic.

QUALITY

Process Capability Index, C_p

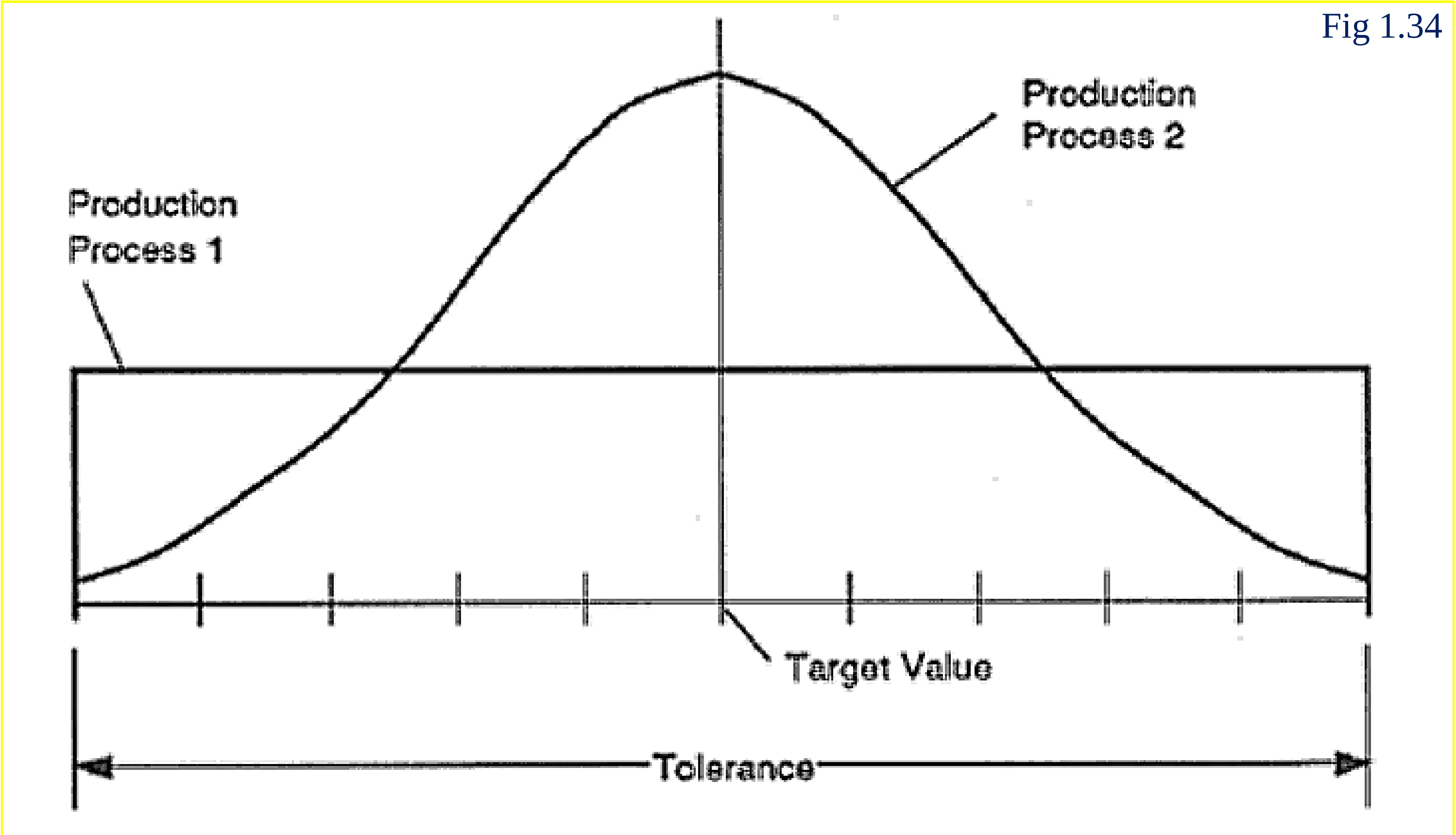
Process-oriented indicator of quality,

$$C_p = \frac{\text{tolerance}}{6 \times \text{standard deviation}}$$

QUALITY

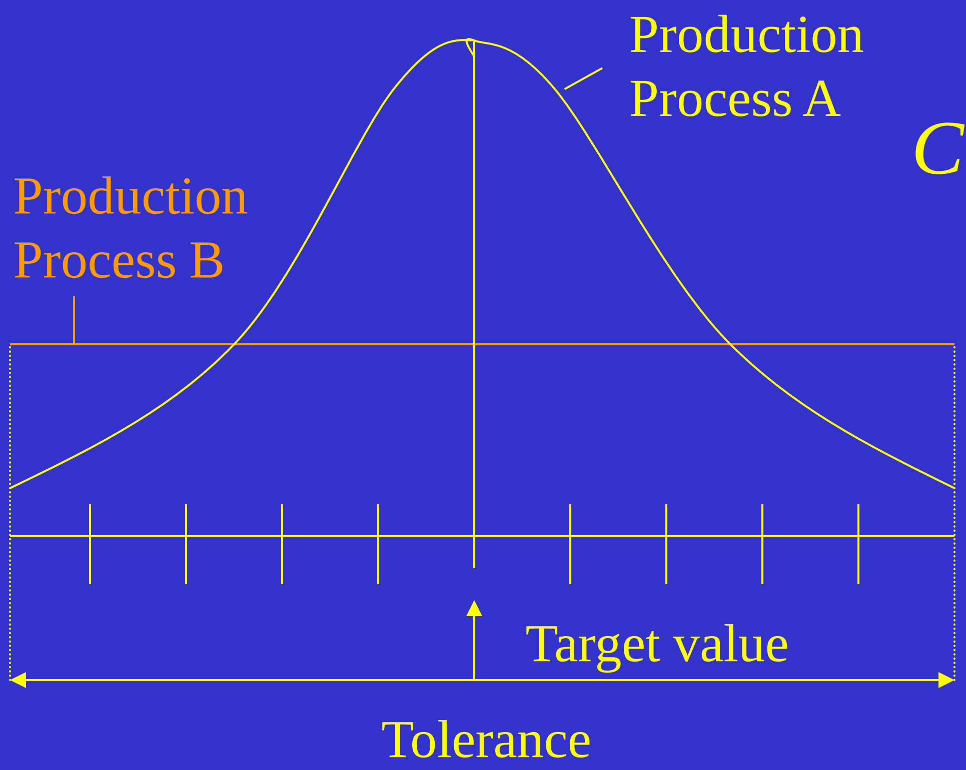
Quality Characteristic Distributions

(for two processes)



QUALITY

EXAMPLE: Process Capability Index, C_p



$$C_p = \frac{\text{tolerance}}{6 \times \text{standard deviation}}$$

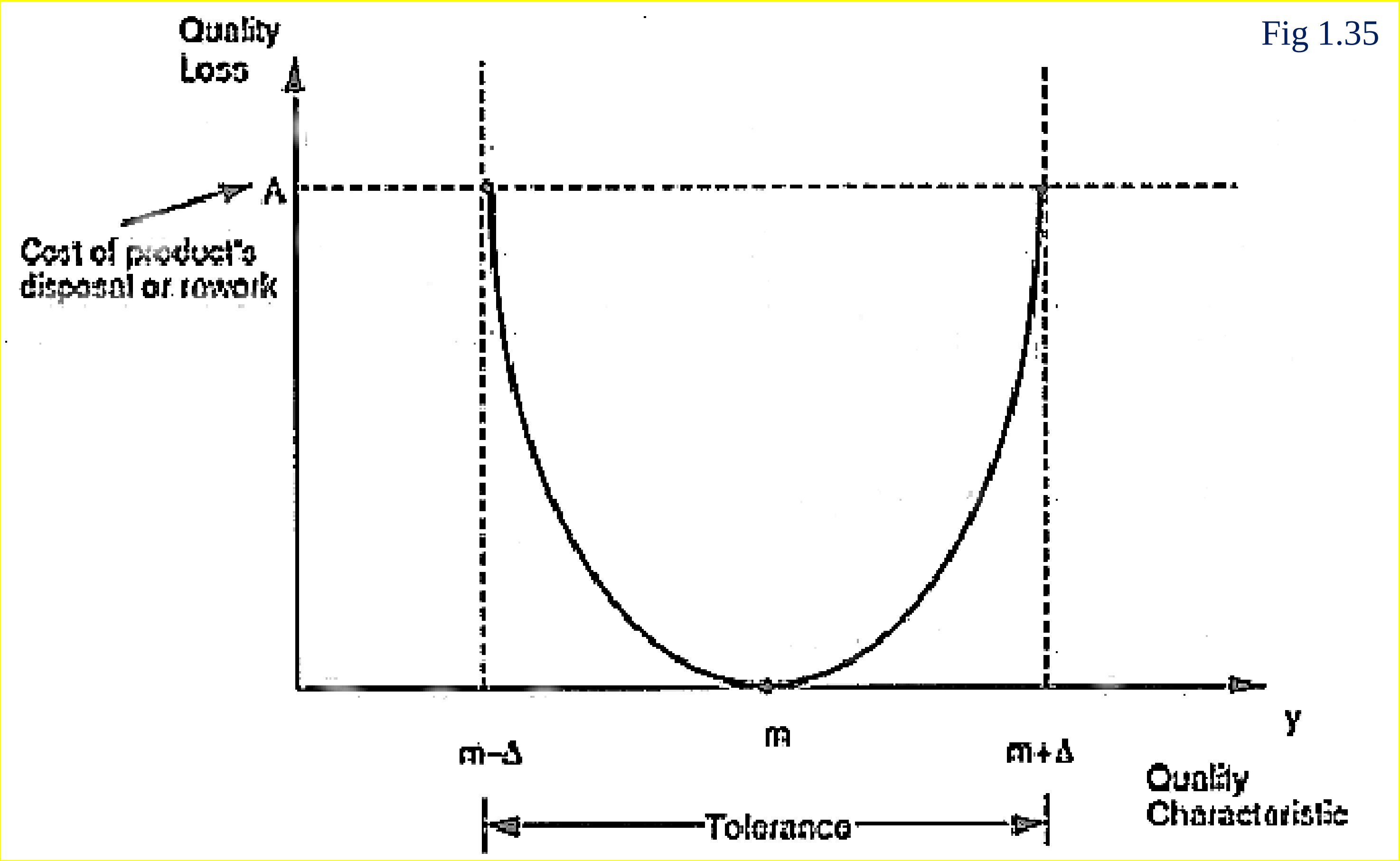
$$C_{PA} = \frac{10}{6 \times \frac{1}{6} \times 10} = 1$$

$$C_{PB} = \frac{10}{6 \times \frac{1}{\sqrt{12}} \times 10} = 0.577$$

Tolerance Range: 10 for both A and B

QUALITY

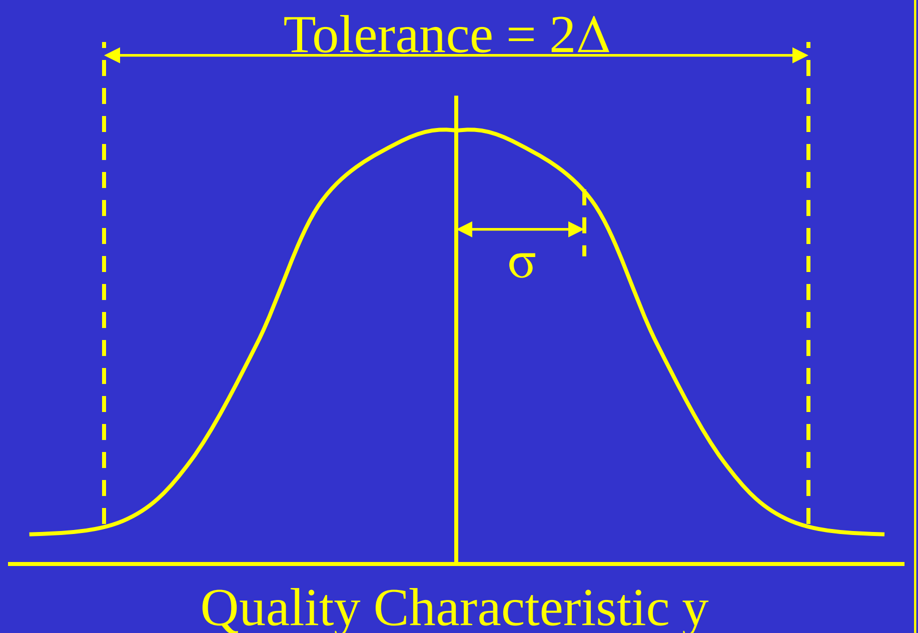
Quality Loss Function



MEASURES OF QUALITY

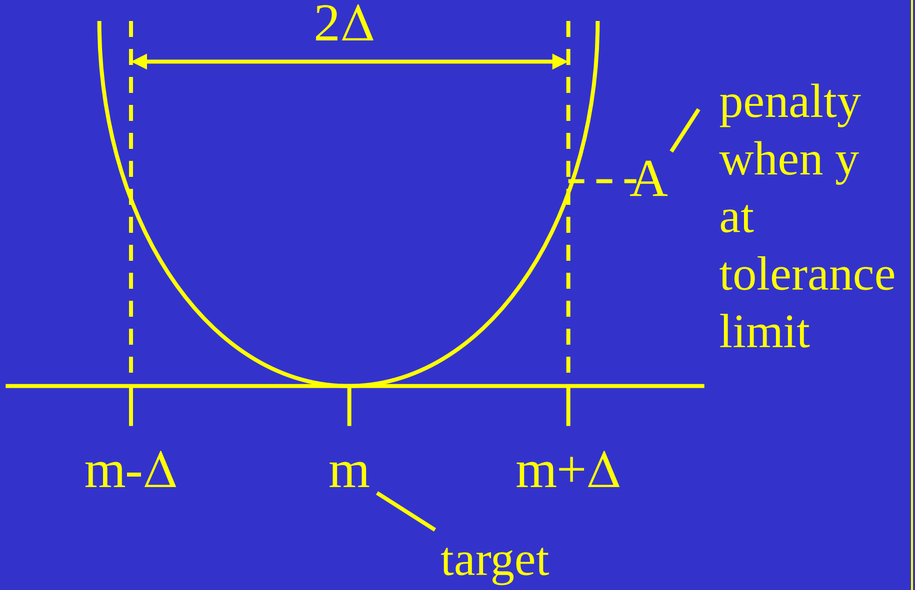
% DEFECTIVE	WARRANTY COST
PROCESS CAPABILITY INDEX	QUALITY LOSS FUNCTION

PROCESS CAPABILITY INDEX



$$Cp = \frac{\text{tolerance}}{6 \times \sigma}$$

QUALITY LOSS FUNCTION



$$L(y) = \frac{A}{\Delta^2}(y - m)^2$$

THE SIGNIFICANCE OF FLEXIBILITY

Flexibility will be the key predicator of manufacturing competitiveness in the 1990's.

Mass produced cars are a thing of the past because customers today demand more diversity.

-Knishi Yamamote, Mazda Chairman

It is not the volume of Japanese cars that western carmakers will come to fear most. It is their devastating variety.

-The Economist, July 21 1990

WHY MEASURE FLEXIBILITY?

Having flexibility can give a manufacturing system 3 important advantages.

1. *Investment efficiency.*
   The system can make more parts with less equipment.

2. *Breakdown tolerance.*
   The system is able to maintain production when machines break down.

3. *Large capacity range.*
   The system is easy to expand and to reduce in size.

Measuring flexibility provides a quantitative assessment of the extent to which a given manufacturing system possesses the above advantages.

FLEXIBILITY

Definition:

SENSITIVITY OF COST TO CHANGE

THREE TYPES OF FLEXIBILITY

Product flexibility enables a manufacturing system to make a variety of part types with the same equipment.

Advantages: • small lot sizes become economical
• investment efficiency.

Operation flexibility is the ability to produce a set of products using different machines, materials, operations, and sequences of operations.

Advantage: • breakdown tolerance

Capacity flexibility allows a manufacturing system to vary the production volumes of different products to accommodate changes in demand while remaining profitable.

Advantage: • insensitive to market variations

FLEXIBILITY

Product flexibility

- Enables a manufacturing system to make a variety of part types with the same equipment.
- Over the *short term*, the system can adapt to changing demands for various products.
- Over the *long term*, the system's equipment can be used across multiple product life cycles, increasing *investment efficiency*.

FLEXIBILITY

Operation flexibility

- The ability to produce a *set of products* using different machines, materials, operations, and sequences of operations.
- It provides *breakdown tolerance*.
- It affects *mass production* in particular, where the production *quantity* is often the most *significant indicator* of manufacturing success.

FLEXIBILITY

Capacity flexibility

- Allows a manufacturing system to vary the production volumes of different products to accommodate changes in demand while remaining profitable.
- Critical for make-to-order systems.
- Important in mass production of high-value products.

MEASUREMENT OF FLEXIBILITY

Flexibility: sensitivity of a manufacturing system to change

Measurement must account for:

- penalty for change
  - low penalty ⟶ high flexibility
  - high penalty ⟶ low flexibility
- demand for change
  - responsiveness to highly likely changes more important than responsiveness to unlikely changes

Penalty Of Change = Penalty x Probability

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European Union European Social Fund

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MINISTRY OF EDUCATION, LIFELONG LEARNING AND RELIGIOUS AFFAIRS

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