Production Concept and Mathematical Models

Production Quantity → Q
Product Variety → P
No. of parts per product → n_p
No. of operations to produce a part → n_o

(1) PRODUCTION RATE

(Work Units completed per hour (pc/hr))

Cycle Time (T_c) - Time that one work unit spends being processed or assembled

$$T_c = \underbrace{T_o}_{\text{Actual m/c'g operation time (min/pc)}} + \underbrace{T_h}_{\text{Work part Handling time (min/pc)}} + \underbrace{T_{th}}_{\text{(min/pc)}}$$

T_{th} → Tool handling time per workpiece

Batch & Job-shop Production

$$T_b = T_{su} + Q\,T_c$$

T_b → Batch processing Time (min)
T_{su} → set up time to prepare for batch (min)
Q → Batch Quantity (pc)
T_c → cycle time per ~~unit~~ work unit (min/cycle)

Average production time per work unit $(T_p) = \dfrac{T_b}{Q}$

Average production rate for machine is reciprocal of production time. (R_p)

R_p → hourly production Rate (pc/hour)

$$R_p = \frac{60}{T_p}$$

constant 60 converts minutes to hours

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Job-shop Production

Ex- $Q = 1$

$$T_p = T_{su} + T_c$$

when quantity is greater than one

Mass Production

Production Rate = Cycle Rate of m/c (Reciprocal of operation cycle time)

Q is very large, $(T_{su}/Q) \rightarrow 0$

$$R_p \rightarrow R_c = \frac{60}{T_c}$$

R_c → operation cycle rate of m/c (pc/hr)

T_c → Operation cycle time (min/pc)

$$T_c = T_R + \text{Max } T_o$$

T_c → cycle time of production line (min/cycle)

T_r = time to transfer work units b/w stations each cycle (min/cycle)

Max T_o = operation time at bottleneck station (max of operation time for all stations on the line, min/cycle)

Theoritically,

Production rate $\xrightarrow[\text{by}]{\text{determined}}$ Reciprocal of T_c

$$R_c = \frac{60}{T_c}$$

R_c = Theoritical or ideal production rate

T_c = ideal cycle time (min/cycle)

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② PRODUCTION CAPACITY

PC = Weekly production capacity of facility (Output units / wk)

n = no. of work centers working in $\parallel^{r}$ producing in the facility
or
No. of m/cs or work centers in facility

Work Centers :- Manufacturing system in the plant typically consisting of one worker and one m/c. It also be one automated m/c with no worker, or multiple workers working together on a production line.

S_w = no. of shifts per period (shift / wk)

H_{sh} = hr / shift (hr)

R_p = hourly production rate of each work center (output units / hr)

$$PC = n\, S_w\, H_{sh}\, R_p$$

n_o = no. of distinct operations through which work units are routed

$$PC = \frac{n\, S_w\, H_{sh}\, R_p}{n_o}$$

Changes:-

→ no. of shifts / week

Ex - Saturday shift authorized or temporarily

→ no. of hrs worked / shift

Ex - Overtime in each regular shift.

③ UTILIZATON AND AVAILABILITY

Utilization refers to the amount of output of a production facility relative to its capacity

$$\boxed{U = \frac{Q}{PC}}$$

Utilization of facility

Q → Actual quantity produced by facility during a given time period (pc / wk)

PC → Production capacity for the same period (pc/wk)

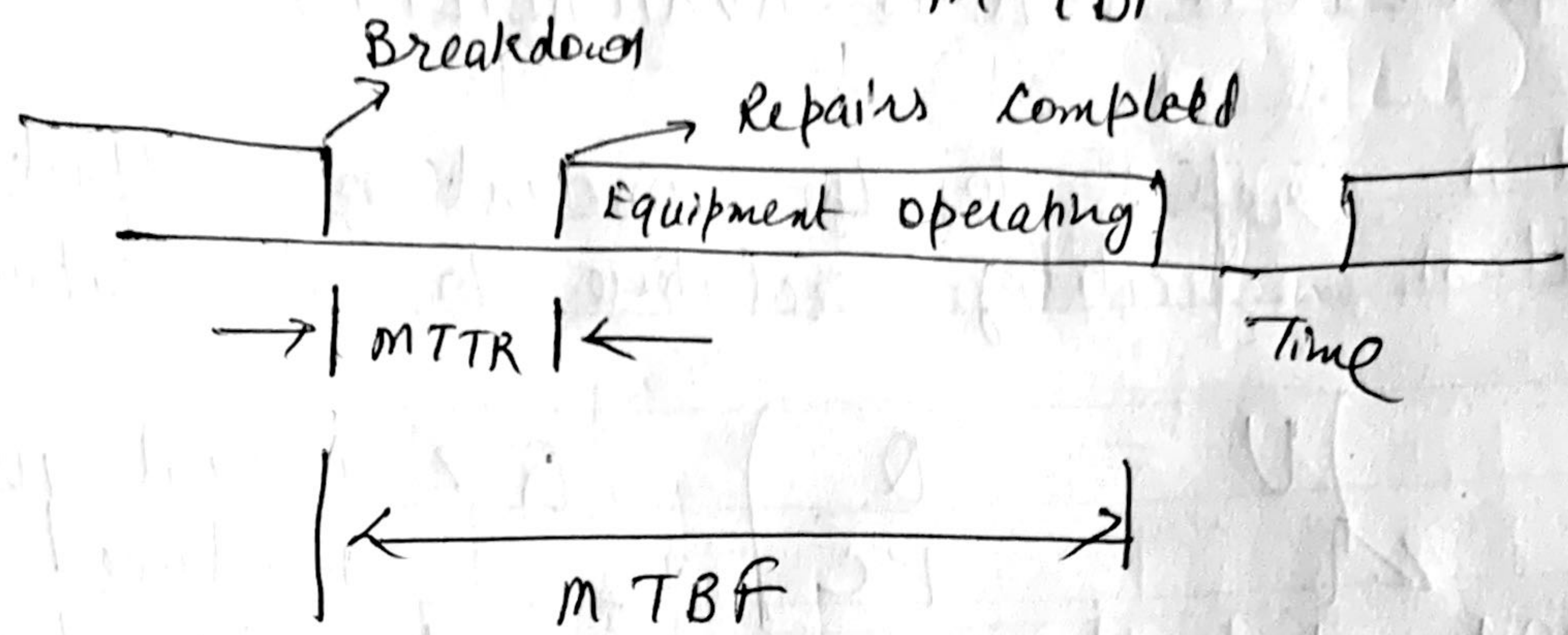
Utilization → • assessed for an entire plant
• a single m/c in plant or any other productive resource (ie labour)
• Expressed as a percentage

Availability :- → Common measure of reliability for equipment
→ Especially appropriate for automated production equipment.
→ 2 Reliability terms → MTBF → MTTR

MTBF (Mean time b/w Failure)
Average length of time the piece equipment runs b/w breakdowns

MTTR (Mean time to repair)
Average time reqd to service the equipment & put it back into operation when breakdown occur

$$A = \frac{MTBF - MTTR}{MTBF}$$



Time scale showing MTBF & MTTR to define Availability A.

A → Expressed as a percentage
When a piece of equipment is brand new (& being debugged), & later when it begins to age, its availability tends to be lower.

(4) MANUFACTURING LEAD TIME

It is the total time required to process a given part or product through the plant, including any lost time due to delays, time spent in storage, reliability problems & so-on.

$$MLT_j = \sum_{i=1}^{n_{oj}} \left(T_{suji} + Q_j T_{cji} + T_{noji} \right)$$

MLT_j → Manufacturing lead time for part or product j (min)

T_{suji} → Set up time for operation i (min)

Q_j → Quantity of part or product j in batch being processed (pc)

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T_{cji} ⇒ operation cycle time for operation i (min/pc)

T_{noji} ⇒ nonoperation time associated with operation i (min)

i → indicates the operation sequence in processing

$i = 1, 2 \ldots n_{oj}$.

MLT eq^n does not include time raw work-part spends in storage before it turns in the production schedule begins

$$MLT = n_o(T_{su} + QT_c + T_{no})$$

(For Job-shop & Batch size production)

$$MLT = n_o(T_{su} + T_c + T_{no})$$

(For job shop in which batch size is $Q = 1$)

$$MLT = n_o(T_r + \text{Max } T_o) = n_o T_c$$

(For flow line mass production)

T_c = cycle time of production line (min/pc)

$n = n_o$

no. of stns = no. of operations

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(5) Work in process

$$WIP = \frac{AU\,(PC)\,(MLT)}{S_w \quad H_{sh}}$$

→ Availabity

→ Utilizatam

(PC)

Product^n capacity of facility (pc/wk)