* Historical Background.

The Scientific Management movement

→ Started in response to the need to plane and control the activities of growing numbers of production workers.

→ the principal approaches of The S.M were:-

1. motion study → find the best Method to perform a given task and eliminate delays.

2. time study → to establish work standards for a job.

3. extensive use of standards in industry

4. the piece rate system and similiar labor incentive plans.

5. use of data collection, record keeping and cost accounting in factory operations

→ Fredrick Taylor is the father of S.M

→ Shoveling experiment , pig iron handling (Stop watch)

→ Frank Gilbreth :- the father of Motion study

→ his theories 1. all work was composed of 17 basic Motion elements called "therbligs"

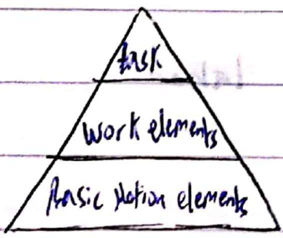
2. there is one best method to perform a given task.

→ bricklaying

→ Lillian Gilbreth :- First lady of engineering

* The Nature of Work

work :- an activity in which a person exerts physical and mental effort to accomplish a given task or perform a duty



- work consists of tasks
- task :- an amount of work that is assigned to a worker or for which he's responsible.

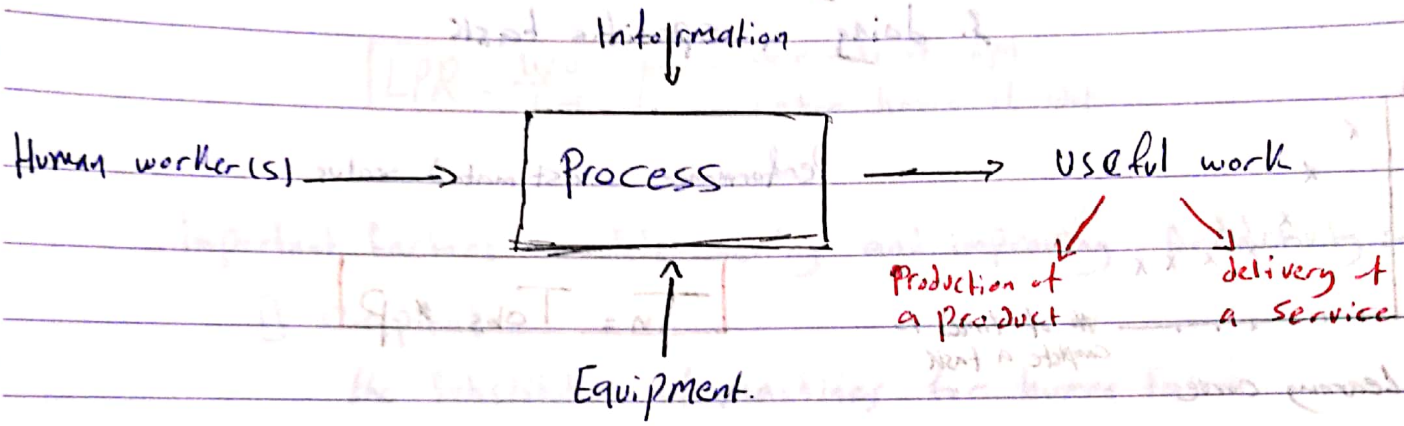
repetitive   nonrepetitive [performed periodically, infrequently, or only once]

- Basic Motion elements :- actuations of the limbs and other body parts while engaged in performing the task

- Work elements :- a series of work activities that are logically grouped together, because the have a unified function within the task

* Defining work system.

work system:- a system consists of humans, information, and equipment that is designed to perform useful work.



* Motion and Time

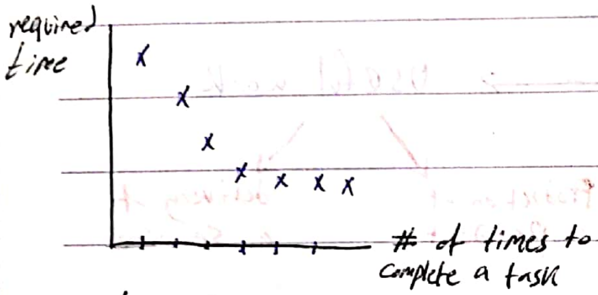
- **Motion Study**: The analysis of motion, constituting an operation to improve the motion pattern by eliminating ineffective motions and shortening the effective motions.

- **Time Study**:- The process of determing the Standard time.

Observed (actual) time → Normal time 100% → Normal time + Allowance value

Standard time :- the time required to produce a product where the following three conditions:-

1. qulified, well trained operator.
2. working at a normal pace [100% performance]
3. doing a specific task



Learning curve

Performance → estimated value

$$\boxed{T_n = T_{obs} * P}$$

- Importance of standard time
  1] how many machines do we need ?
  2] how many operators should we hire ?
  3] how fast to move conveyors ?
  4] how much will the product cost ?

$$\boxed{T_{std} = T_n(1 + A_{PFD})}$$

- examples for time study:-
  1. predetermined time standard study (PTSS)
  2. Stopwatch technique (Direct time study)
  3. work sampling technique

* Productivety

the level of output of a given process relative to the level of input.

the most common productivity measure is Labor Productivety ratio

$$\boxed{LPR = \frac{WU}{LH}}$$

WU → work units of output
LH → Labor hours of input

- Important factors in determening and improving productivity :-

1) Capital

the substitution of machines for human labor

2) Technology

a fundmental change in the way some activity or function is accomplished.

another productivity measure is Labor productivity index

$$\boxed{LPI = \frac{LPR_t}{LPR_b}}$$

base → 1, 2, ..., 8

Ex-1.1

during the base year $Q_b = 326.000$ tons $LH = 203.000$ hours

$Q_t = 341\,000$ tons $LH = 246000$ hours

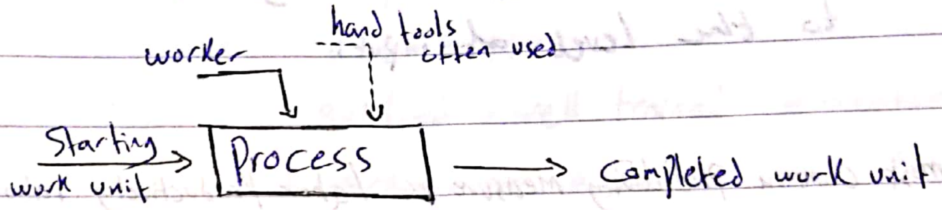
a) $LPR_b = \frac{Q_b}{LH_b} = \frac{326\,000}{203000} = 1.606$ tons per Labor hour

b) $LPR_t = \frac{Q_t}{LH_t} = \frac{341000}{246000} = 1.386$ tons per Labor hours

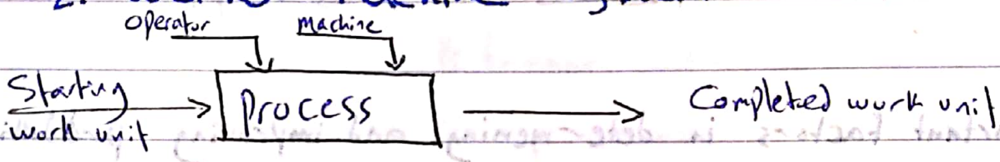
c) $LPI_t = \frac{LPI_t}{LPI_b} = \frac{1.386}{1.606} = 0.863$

* Three Types of work systems :-

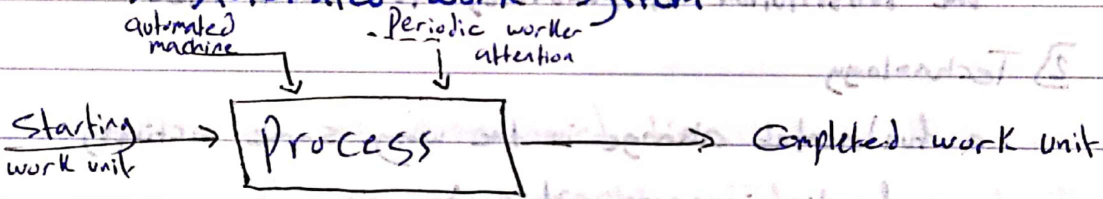
1. manual work system



2. Worker - machine system



3. Automated work System



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* Types of Manual work

1) Pure manual work
2) manual work using hand tools

* Cycle time analysis of Manual system

repetitive/ regular elements	get part A	0.1
	get part B	0.07
	assembly	0.31
	move aside	0.05
		0.53
non-repetitive irregular elements	move full contain & bring empty one	13 Min

freq $\left(\frac{1}{100}\right)$

$$\boxed{T_c = \sum T_{ei}}$$

x Cycle time = actual time

$$T_c = T_{e1} + T_{e2} + T_{e3} + T_{e4} + \frac{1}{100} T_{e5}$$

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* Performance :- the pace or relative speed with which the worker does the task

Normal time

$$\boxed{T_n = T_c * P}$$

مرتبطة بال task بغض النظر عن ال operator

Standard time

$$\boxed{T_{std} = T_n(1 + A_{PFD})}$$

Types of allowance :-

1. Personal time
2. Fatigue time
3. Delay time

Ex. 2.3

$T_n = 3.23$ min ; regular + irregular → 1.25 min every 5 cycles

$A_{PFD} = 15\%$

a) $T_{std} = T_n(1 + A_{PFD}) = (3.23 + 0.25)(1 + 0.15) = 4.00$ Min

b) $Q_{std} = \frac{8 \text{ hr} \times 60 \text{ min/hr}}{4 \text{ min/unit}} = 120$ work unit

Ex. 2.4

$8 \text{ hrs} = T_{actual}(1 + 0.15) \rightarrow T_{actual} = 6.956$ hr

Time lost $= 8 - 6.956 = 1.044$ hrs

Ex. 2.5

$T_c = \frac{T_n}{P} = \frac{3.48}{1.25} = 2.78$

$Q_p = \frac{6.956 \text{ hrs} \times 60 \text{ min/hr}}{2.78} = 150$ work units

* Standards Hours

the amount of work actually accomplished by the worker during a given period, expressed in terms of time.

$$\boxed{H_{std} = Q\,T_{std}}$$

* Worker efficiency

the amount of work accomplished during the shift expressed as a proportion of the shift hours.

$$\boxed{E_w = \frac{H_{std}}{H_{sh}}}$$

Ex. 2.6

a) $H_{std} = Q\,T_{std} = 150 * 4\ min = 600\ min = 10.0\ hr$

b) $E_w = H_{std}/H_{sh} = 10\ hrs / 8\ hrs = 125\%$

Ex. 2.7 $P = 125\%$ $T_{actual} = 7.42\ hr$

a) $Q = \frac{7.42 \times 60}{2.78} = 160$ units

b) $H_{std} = Q\,T_{std} = 160 \times 4\ min = 640\ min = 10.67\ hr$

c) $E_w = H_{std}/H_{shift} = 10.67\ hr / 8\ hr = 133.3\%$

$= T_{std}/T_{shift}$

Worker-machine system.

Classification

1- Types of power machinery used in the system.

2- Numbers of workers and machines in the system.

3- Level of operator attension required to run the machinery.

- Powered machinery
  - (1) Portable power tools
  - (2) Mobile powered equipment
    - a Transportation equip
    - b Transportable and mobile
    - c Transportable and stationary
  - (3) Stationary powered machines
    - a Machine tools.
    - b office equipment.
    - c other machinery.

(1) light enough in weight that can be carried by ~~hand~~ worker and manipolated by hand.

Ex. drills, rotary saws, chain saws, electric hedge trimmers

(2) heavy pieces of equipment

a) cars, taxicabs, buses, trucks, airplanes, boats, ships.

b) tractor, flatbed, buldozers, backhoes, forklift trucks

c) electric power generator, large power saws used in const sites.

(3) Stand on the floor or ground and can't be moved while they are operating; and they are not normally moved between operations

a) Stationary power-driven machines that shape or form parts

b) PCS, telephones, photocopiers

c) miscellaneous group: → furnaces, ovens, cash registers, sewing machines.

	One machine	Multiple machines
One worker	* truck driver * worker loading and unloading machine tool	* a worker tending several production machines
Multiple workers	* Several workers operating a rolling mill. * a crew on a ship or airplane	* an emergency repair crew

Levels of operator attension in worker - Machine system

1. Full-time attension

2. Part-time attension - during each work cycle

3. Periodic attension with regular servicing

4. Periodic attension with random servicing

Worker-Machine System

a   b   c   m → machining   d   a, b, c, d → external elements

$$\overline{T_n} = \overline{T_{nw}} + \overline{T_m}$$

$$T_{std} = T_{std-w} + T_{std-m}$$

$$T_{std} = T_{nw}(1+A_{PFD}) + T_m(1+A_m)$$

a   b   c   d   c → Internal element to the machine cycle.

m

c // m

$$\overline{T_n} = \overline{T_{nw}}_{a,b,d} + \max\{\overline{T_{n_c}}, \overline{T_m}\}$$

$$T_{std} = T_{std_{a,b,d}} + \max\{T_{std_c}, T_{std_m}\}$$

ex. 2.8

$T_{nw} = 1\,min$ ① $A_m = 0$ ② $A_m = 30\%$

$T_m = 2min$ $T_n = T_{nw} + T_m = 3$ $T_n = 3min$

$A_{PFD} = 15\%$ $T_{std} = 1(1+0.15) + 2(1+0) = 3.15\,min$ $T_{std} = 1(1+0.15) + 2(1+0.3) = 3.75$

ex. 2.9

Q: 150 units shift = 8 hrs

<u>Case 1</u>

$A_m = 0$ $H_{std} = 150 * 3.15 \text{ min}/60\text{min} = 7.87 \text{ hrs}$

efficiency = $H_{std}/H_{shift} = 7.87 \text{ hrs}/8 \text{ hrs} = 98.4\%$

<u>Case 2</u>

$A = 30\%$

$T_{std} = 3.75 \text{ min/unit}$

$H_{std} = 150 \text{ units} * 3.75 \text{ min/unit}/60 \text{ min/hr} = 9.37 \text{ hrs}$

$eff = H_{std}/H_{shift} = 9.37/8 = 117.2\%$

$w = \frac{WL}{AT}$ — w:- # of workers required

WL :- work load

$WL = Q * t_{std}$ — Q:- quanity

t_{std}:- standard time

$WL = \sum Q_i \, t_{std.i}$

$Q_{req} = Q^* (1-q)$ $\therefore Q^* = \frac{Q}{1-q}$

$WL = \frac{Q \; t_{std}}{(1-q) \, Eff}$

$AT = A * H_{shift}$ — A:- availability

Ex. 2.11

$T_{std} = 11.5 \text{ min/pc}$

$Q = 800$ Shaft

$AT = 40$ hrs/week

$w = \frac{WL}{AT} = \frac{153.3}{40} = 3.83$ workers

$WL = Q \times t_{std} = 800pc \times 11.5 \text{min/pc} / 60\text{min} = 153.3$

Ex. 2.11

$A = 95\%$ eff $= 110\%$

$q = 3\%$

$WL = \frac{Q \; t_{std}}{(1-q) \, eff} = \frac{800 \times 11.5 \text{min/unit}}{0.97 \, (1.10) \, 60} = 143.7$

$AT = H_{shift} * A = 40 \times 0.95 = 38$ hrs

$w = \frac{WL}{AT} = \frac{143.7}{38h} = 3.78$ worker on machine

Ex. 2.13

$Q = 800$ shaft

average batch size = 50 parts

Set up time = 3.5 hr / batch.

$T_c = 11.5$ min / shaft

$q = 3\%$ eff = 100%

$A_{setup} = 100\%$

$A_{production} = 95\%$

Setup w/ setup

$$WL = 16 \times 3.5 + \frac{800 \times 11.5}{(1-0.03) \times 60}$$

$$= 214.08$$

$$w = \frac{56}{40 \times 1} + \frac{158.076}{40 \times 0.95} = 1.4 + 4.16 = 5.56$$

Ex. 2.14

$$WL = 3.5 \times n + \frac{800 \times 11.5}{60 \times 0.97} = 3.5n + 158.076 \text{ hrs}$$

$AT = 40$ hrs

$$w = \frac{WL}{AT}$$

$$n = \frac{3.5n + 158.078}{40}$$

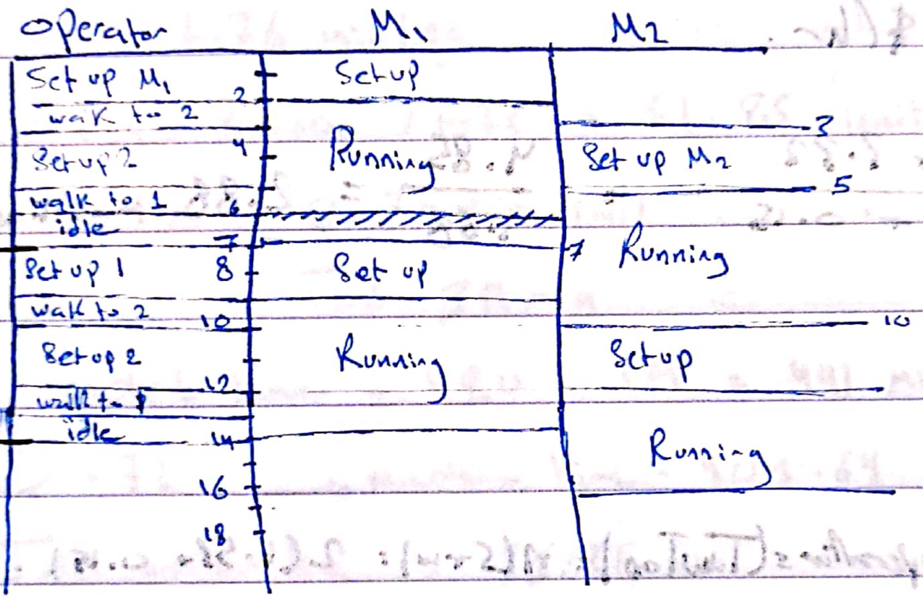
a system of two identical machines is assigned to one operator.

given :-

Loading / unloading time = 2 min (set up)

the walk time to the next machine = 1 min

the machine running time = 5 min



$n(S+w)$

$S+R$

$$n = \frac{S+R}{S+w}$$

$S = 2$ $w = 1$ $R = 7$

$$n = \frac{9}{3} = 3$$

ideal operator ← → ideal machine

If $n = 2.67$ ... 2 ↓ 3 4 5 ...

$n = 2.67$ machine

what is the optimal number of machines that would be assigned to one operator based on the minimum cost per unit of production given the, setup time = 1.53 min

machine running time = 3.32 min

the walk time to the next machine = 0.15 min

Labor cost/hr = 20 \$/hr

Machine cost = 15 \$/hr.

$$n = \frac{S+R}{S+W} = \frac{1.53 + 3.32}{1.53 + 0.15} = \frac{4.85}{1.68} = 2.88 \text{ machines}$$

Case 1

$n = 2$

Total working time for operator = (TWTop) : $n(S+w) = 2(1.53 + 0.15) = 3.36$

Total working time for the machine = (TWTm) = $R+S = 1.53 + 3.32 = 4.85$

$T_c = \text{Max}(TWTop, TWTm) = 4.85$ min/cycle

Production $\left(\frac{\text{units}}{\text{hr}}\right) = \frac{60 \text{ min/hr}}{4.85 \text{ min/cycle}} * \frac{2 \text{ units}}{\text{cycle}} = 24.74$ units

Cost/hr = $1 * \frac{20\$}{\text{hr/op}} + 2 * \frac{15\$}{\text{hr/mac}} = 50$ \$/hr

Cost/unit = $\frac{\text{Cost/hr}}{\text{Units/hr}} = \frac{50 \$/\text{hr}}{24.74 \text{ unit/hr}} = 2.02$ \$/unit

$n = 3$

TWT ope = $n(S+w) = 3(1.53 + 0.15) = 5.04$ Min/cycle

TWT = $S+R = S+R = 1.53 + 3.32 = 4.85$ Min

Tcycle = 5.04 min/cycle

Production = $\frac{60 \text{ min/hr}}{5.04 \text{ min/cycle}} * \frac{3 \text{ unit}}{\text{cycle}} = 35.71$ units/hr

$\frac{\text{Cost}}{\text{hr}} = 1 \text{ operator} * \frac{20\$}{\text{hr.op}} + 3 \text{ machine} \times \frac{15\$}{\text{hr.machine}} = \frac{\$65}{\text{hr}} \rightarrow \frac{\text{Cost}}{\text{Unit}} = \frac{\$65/\text{hr}}{35.71 \text{ unit/hr}} = \$\frac{1.82}{\text{Unit}}$

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2.11

$T_h = 6.27$ min $\quad T_{hw} = 5.92$

$A_{PFD} = 12\%$ $\quad$ ext = 0.65 min, int = 5.27 min.

$A_m = 25\%$

max{ }

T_{m}-ext = 0.65 $\quad T_m = 5.62$

a) $T_c(a) = T_{hw}(1 + A_{PFD}) + T_m(1 + A_m)$

= 7.76 min/pc

b) $Q = 8 \times 60 / 7.76 = 61.85$ unit / shift.

c) worker $Q = 72$ units / shift

$T_{lost} = 39$ min

actual time = 480 − 39 = 441 min

$Q = 72 \longrightarrow$ machine time = 404.64

Total worker time = 36.36 min

CHAPTER 9 Charting and diagraming Tech for Op Analysis

- Macro motion Techniques → operation chart, process chart, flow diagram
- Micro motion Techniques

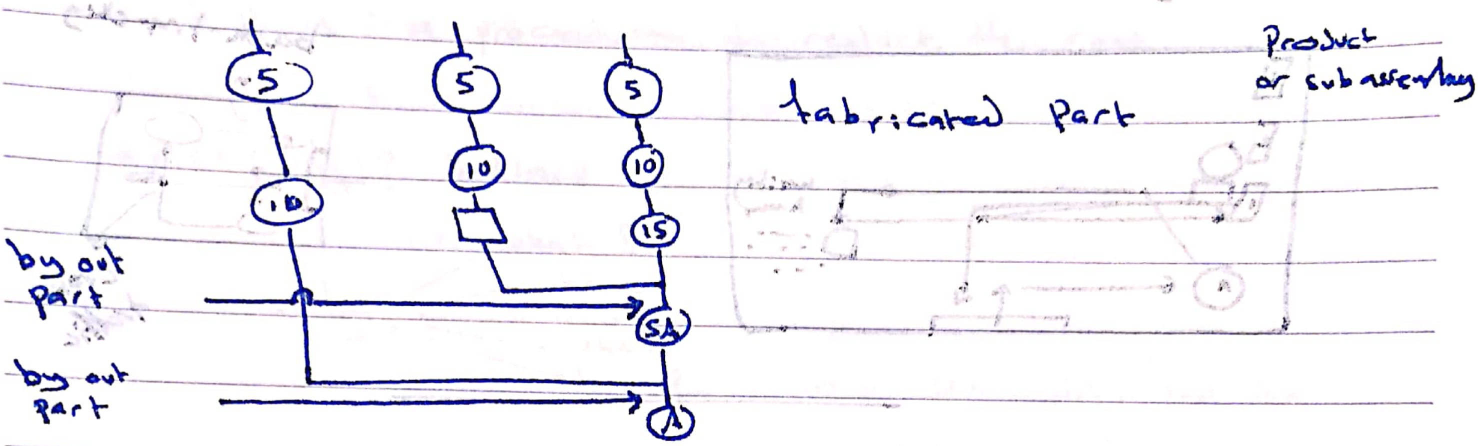
recieve
moving
X Storge
move to dep
drilling
move
assembly

Process activities :- (process operations)

C1:- process act	C2:- Symbol	C3:- letter	C4:- description
Operation	○	O	changing in prop of mat / assembly op
move (transport)	→	M	changing in location of Mat
Inspection	□	I	check for quality / quantity
Delay	D	D	waiting for the next operation
Storge	▽	S	

Operation chart → ○ , □
Process chart → ○ , → , □ , D , ▽
Flow diagram → ○ , → , □ , D , ▽

Operations Chart

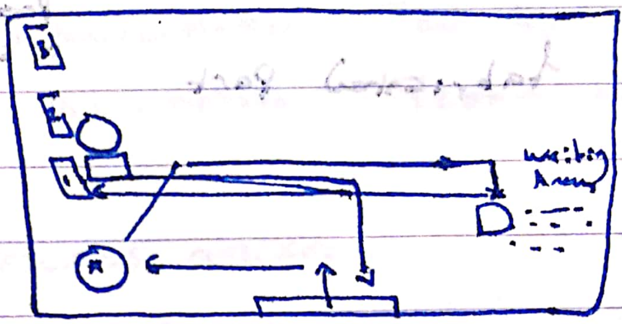


1. walking
2. receiving
3. walking
4. waiting
5. walk to window
6. fill the form
7. Check form
8. check Machine
9. leave

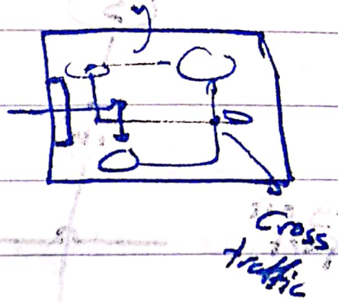
Process activity	Symbol	time	distance	notes
1.	→	0.5	✓	cost/time analysis
2.	○	0.3		
3.	→	0.2	✓	
4.	D	13		
5.	→	0.2	✓	
6.	○	0.4		
7.	▱	0.05		
8.	□	0.1		
9.	→	0.3	✓	

Process chart
1. flow process chart
2. form process chart
3. worker process chart

flow diagram — for every part



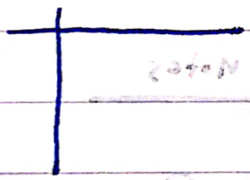
back-tracking

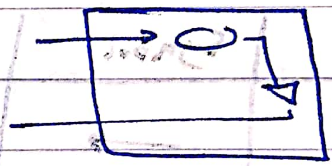


Process chart — Flow diagram

Part — Part

table (Text + Numbers) — Chart





Cost Reduction Formula

it is a procedure to reduce the cost

* ask (why)? 5 times

why? → what?
why? → where?
why? → who?
why? → when?
why? → How?

Can I eleminate this activity?

Yes → Cost reduction 100%

No

Can I combine this activity with another activity?

Yes → Cost reduction < 100%

No

Can I rearange or change the sequence of the activity?

Yes → Cost reduction

No

Can I simplify the activity?

Yes → Cost reduction

No

* activity charts

An activity chart is a listing of the work activities of one or more subjects (operator / machine) plotted against a time scale to indicate graphically how much time is spent on each activity.

1 Left hand / Right hand activity chart

Left hand	Right hand
idle	get part A
get part b	holding A
assembly	assembly

2 The worker machine activity chart.

Operator	Machine
Unloading	Unloading
loading	loading
idle	Running

$\left.\begin{array}{l}\text{Unloading time} = 0.5\text{ Min.} \\ \text{loading time} = 1.5\text{ Min.}\end{array}\right\}$ Set up time

Running time = 7 Min

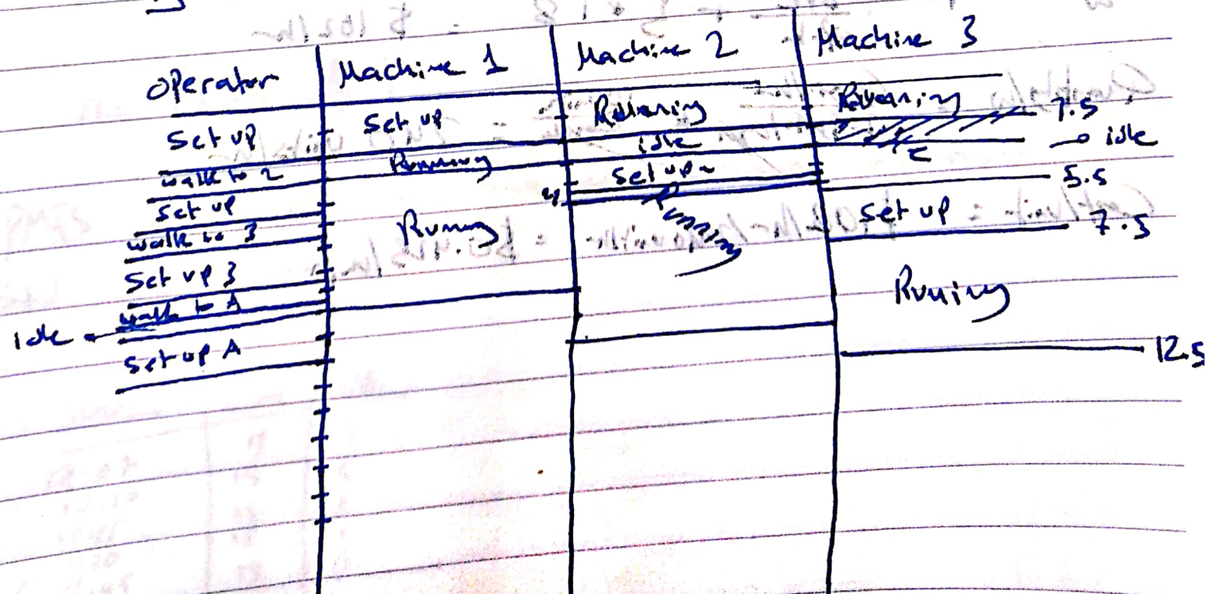
3 Worker Multi-machine activity chart. → sys of identical. → different machines.

Ex. a system of 3 different machines is assigned to one operator. the time values for Set up and Running are listed in the following table

	A	B	C
Set up	2	1.5	2
Running	7	6.5	5

the walk time between any two machines = 1 Min.

1) Draw the worker multi-machine activity chart.
2) calculate the TWT for each subject.
3) calculate the cycle time.



TWT (op): $S_A + W_{AB} + S_B + W_{BC} + S_C + W_{CA} = 8.5$ min

TWT (A) = 9 min   TWT (B) = 8 min   TWT (C) = 7 min

** Start from TWT >>>

2.24

$T_{setup} = 0.35$ min

$T_w = 0.15$ min

$T_m = 1.9$ min

L.R = 12 \$/hr

M.R = \$18/hr

$n = \frac{S+R}{S+W} = \frac{0.35+1.9}{0.35+0.15} = 4.5$

Case 1 n=4

$T_c = S+R = 2.25$ min/cycle

Cost per hr = 12\$/h + 4×18 = 84\$/hr

Production rate = 60 min / 2.25 min/cycle × 4 machines × 2 = 213.3

Cost/unit = $\frac{Cost/hr}{Units/hr}$ = \$0.3938/unit

Case 2 n=5

$T_c = 5(0.35 + 0.15) = 2.5$ min/cycle

$\frac{Cost}{w}$ = 1 operator × $\frac{\$12}{op \cdot hr}$ + 5 × 18 = \$102/hr

Quantity/w = $\frac{60 min/hr}{2.5 min/cycle} \times \frac{10 units}{cycle}$ = 240 units/hr

Cost/unit = \$102/hr / 240 units/hr = \$0.425/unit