Chapter 9

CHARTING AND DIAGRAMMING TECHNIQUES FOR OPERATIONS ANALYSIS

Reference:
Work Systems and the Methods, Measurement, and Management of Work
by Mikell P. Groover, ISBN 0-13-140650-7.

Objectives of Charts and Diagrams

1. To permit work processes to be communicated and comprehended more readily
2. To use algorithms specifically designed for the particular diagramming technique
3. To divide a give work process into its constituent elements for analysis purposes
4. To provide a structure in the search for improvements
5. To represent a proposed new work process or method

How to Create the Chart or Diagram

- Analyst is intimately familiar with the process and develops a graphic to represent it
- Analyst observes and records information about the process
- One-on-one interviews with those familiar with the process
  - A graphic model of the process is developed based on the interviews
- Group meetings with personnel familiar with process
  - A graphic model of the process is developed based on the group meetings

How to Analyze the Chart or Diagram

- Algorithmic analysis (e.g., line balancing, critical path methods)
- Checklists – general questions applied to the particular process
- Brainstorming – team activity in which participants contribute recommendations
- Separating value-added and non-value-added operations
  - Value added steps:
    1. Important to customer
    2. Physically change the product or service

Categories of Charts and Diagrams

1. Network diagrams
2. Traditional industrial engineering charts and diagrams
3. Block diagrams and process maps

3. Industrial charting and diagram techniques

- Charts and diagrams techniques intended to graphically displays relationships among the various entities included in the graphic.

- To analyze an existing operations, sequence of operation or other work activities for the purpose of making improvement.

Industrial charting and diagram techniques

Improvements includes:

- Reducing cycle time and cost.
- Eliminating unnecessary steps
- Mitigating safety hazards.
- Improving product quality.

Industrial charting and diagram techniques

Types and categories of charting and diagrams:

- Operation charts.
- Process chart.
- Flow diagram.
- Activity chart.

Industrial charting and diagram techniques

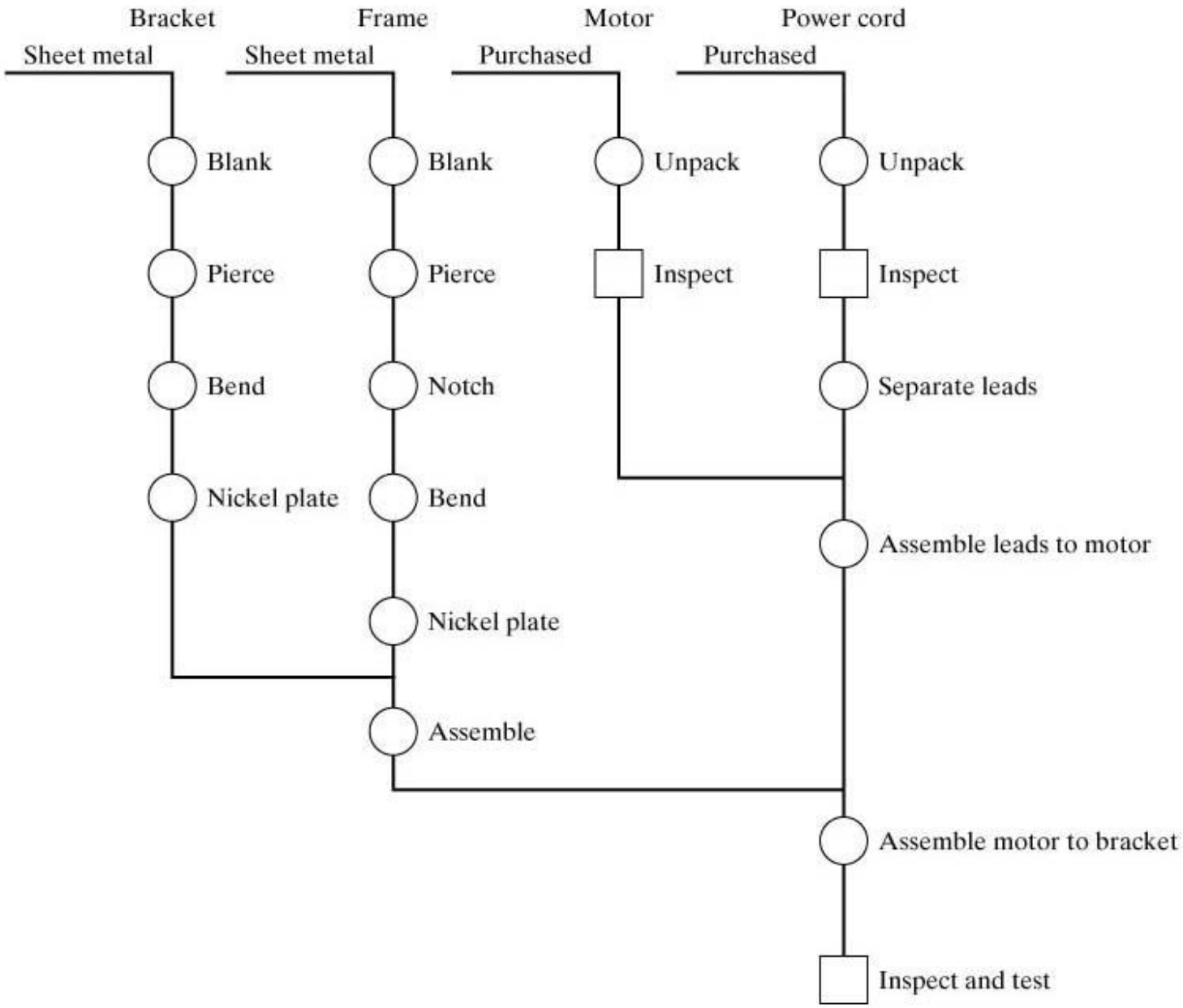
- Symbols used in operation, process, and flow diagrams .(table 3,page232)

symbol	letter	description
	O	Operation
	I	Inspection
	M	Move
	D	Delay
	S	storage

Operational chart:

Graphical and symbolic representation of the operations used to produce a product

- Two types of operations:
  1. Processing and assembly operations
     - Changing the shape, properties or surface of a material or workpart
     - Joining two or more parts to form an assembly
  2. Inspection operations
     - Checking the material, workpart, or assembly for quality or quantity


Bracket
Sheet metal
Frame
Sheet metal
Motor
Purchased
Power cord
Purchased
Blank
Pierce
Bend
Nickel plate
Blank
Pierce
Notch
Bend
Nickel plate
Unpack
Inspect
Unpack
Inspect
Separate leads
Assemble leads to motor
Assemble
Assemble motor to bracket
Inspect and test

Checklist of Questions

- What alternative starting material could be used?
- Make or buy decision: should the part be produced in our factory or purchased?
- Is this processing operation necessary?
- Can this operation be eliminated, combined, or simplified?
- Could a different joining method be used?
- Is this inspection necessary?
- Could the inspection task be automated?

Process chart

- Process chart: is a graphical and symbolic representation of the processing activities performed on something or by somebody.

- Vertical list of steps performed on or by the work entity using symbols: process operation, inspections, moves ,delays, other activities.
- Process chart is used to study a single material or work parts rather than the multiple component of an assembly.

- **Example (page 233)**

Process chart

Principal types of process chart:

- **Flow process chart** :analyze material and work piece being process(flow of the activities done on material or work piece).
- **Worker process chart**: analyze worker performing process(worker movement around the facility).
- **Form process chart**: analyze the processing of paperwork forms(processing on documents). (two additional activities used: creation C: ◎ , disposal x :X

Process chart

Uses five symbols to detail the work performed on a material or workpart as it is processed through a sequence of operations and activities:

- Operation – processing of a material
- Inspection – check for quality or quantity
- Move – transport of material to new location
- Delay – material waiting to be processed or moved
- Storage – material kept in protected location

Flow Process Chart					
Part No. 459011	Material: Steel C1045 forging		Description: Forgings processed in batches of 20		
Seq.	Activity Description	Symbol	Time	Distance	Analysis Notes
1	Forgings transported from forge shop	→		300 m	Forklift truck
2	Inspection of incoming forgings	□	1 hr		
3	Forgings moved and placed in storage	→		75 m	Hand truck
4	Storage	∇	7 days		Factory warehouse
5	Forgings retrieved from storage	→		75 m	Hand truck
6	Transport to machine shop	→		180 m	Forklift truck
7	Move to milling machine	→		20 m	Hand truck
8	Delay in queue for milling machine	D	5 hr		
9	Milling operation (roughing and finishing)	○	8 min/pc		Milling Machine No. 573
10	Move to drill press	→		20 m	Hand truck
11	Delay in queue for drill press	D	2 hr		
12	Drilling and tapping operations (6 holes)	○	3 min/pc		CNC Drill Press No. 226
13	Delay waiting for inspection	D	4 hr		
14	Inspection for machining operations	□	0.2 hr		
15	Delay waiting for transport to cleaning	D	3 hr		
16	Transport to finishing department	→		75 m	Forklift truck
17	Move to cleaning operation	→		10 m	Hand truck
18	Delay in queue for cleaning operation	D	30 min		
19	Cleaning operation (all parts in batch)	○	10 min		Solvent clean tank
20	Move to nickel plate operation	→		15 m	Hand truck
21	Delay in queue for nickel plate operation	D	45 min		
22	Nickel plate operation (all parts in batch)	○	20 min		Electroplating tank
23	Delay waiting for transport to storage	D	30 min		
24	Transport to storage	→		200 m	Forklift truck
25	Storage awaiting assembly	∇			Factory warehouse

Date:	Flow Process Chart		Page ___ of ____
Analyst:	Approval:	Summary of Activities	
Job:	Part No:	Activity (symbols)	Count	Time	Distances
Material:		Operations (○, O)			
Description:		Inspections (□ , I)			
		Moves (→, M)			
		Delays (D, D)			
		Storages (∇, S)			

Seq.	Activity Description	Symbol	Time	Distance	Analysis Notes
1					
2					
3					
4					
5					
6					

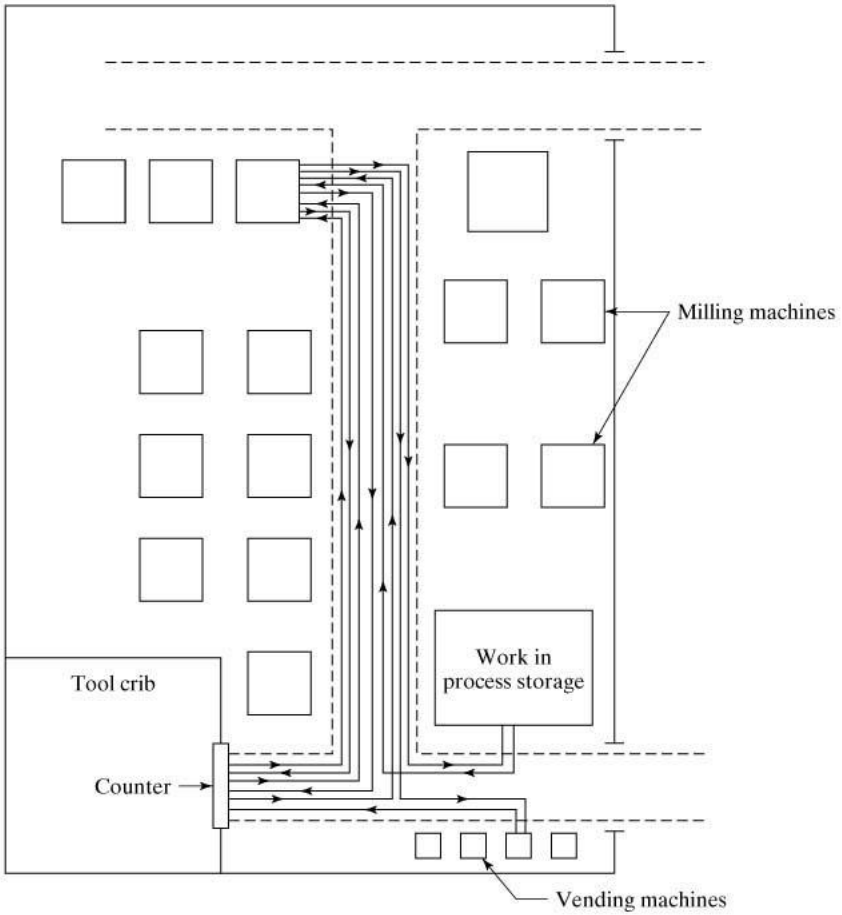
Flow diagram

- Flow diagram: a drawing of a facility layout with the addition of lines representing movement of material or worker to a specific locations in the facility.
- Arrows are used in flow diagram to indicate the direction of movement.
- Its used in conjunction with the process chart when the movement of materials, worker, and forms is a major factor in the analysis.
- Can be used to detect excessive backtracking, which might be missed in a process chart
- **Example(page237)**

Flow Diagram

Flow diagram for worker setting up a milling machine

Note the large number of trips back and forth between the milling machine and the tool crib



Activity Charts

A listing of the activities of one or more subjects (e.g., workers, machines) plotted against a time scale to indicate graphically how much time is spent on each activity

- Types of activity charts:
  - Right-hand/left-hand activity chart (a.k.a. workplace activity chart)
  - Worker-machine activity chart
  - Worker-multimachine activity chart
  - Gang activity chart (a.k.a. multiworker activity chart)

Activity Chart

Activity chart for a worker performing a repetitive task

Activity Description	Chart	Activity Time (min)	Cumulative time (min)
Pick up plate from tote pan.		0.05	0.05
Carry plate to drill press and load.		0.07	0.10
Activate press.		0.03	0.15
Semiautomatic machine cycle.		0.20	0.20
			0.25
			0.30
			0.35
Remove plate.		0.03	
Carry to pallet container.		0.05	0.40
Place in pallet container.		0.02	0.45
Walk to tote pan.		0.05	0.50

Shading Formats for Activity Charts

Shading	Color	Activity
Black	Blue	***Operation***: Performing an operation. Worker operating on or handling material at workplace. Machine performing an operation on automatic or mechanized cycle.
Gray	Yellow	***Inspection***: Worker performing an inspection, to check for either quantity or quality.
White (blank)	White (blank)	***Idle time***: Worker or machine is idle, waiting, or stopped.
Diagonal lines	Green	***Moving***: Worker walking outside immediate workplace (e.g., to fetch tools or materials).
Horizontal lines	Red	***Holding***: Worker holding an object in fixed position without performing any work on it.

Right-Hand/Left-Hand Activity Chart

Task involves placing pegs into a peg board

Note that left hand is used as a workholder

Left Hand	Time (min)	Right Hand	Cumulative time (min)
Pick up board	0.08		0.08
Hold board	0.06	Pick up peg and insert	0.14
Hold board	0.06	Pick up peg and insert	0.20
Hold board	0.06	Pick up peg and insert	0.26
Hold board	0.06	Pick up peg and insert	0.32
Hold board	0.06	Pick up peg and insert	0.38
Hold board	0.06	Pick up peg and insert	0.44
Hold board	0.06	Pick up peg and insert	0.50
Hold board	0.06	Pick up peg and insert	0.56
Put assembly in tote pan	0.06		0.62

Worker-Multimachine Activity Chart

Can be used to indicate *machine interference* (when a machine must wait for service because worker is currently servicing another machine)

Worker	Time (min)	Machine 1	Time	Machine 2	Time	Cumulative time (min)
Walks to machine 1	0.2					
Services machine 1	0.3	Idle	0.3			0.5
Walks to machine 2	0.2	Automatic cycle				
Services machine 2	0.3			Idle	0.3	1.0
				Automatic cycle		
	0.5					1.5
Walks to machine 1	0.2		1.2			
Services machine 1	0.3	Idle	0.3			2.0
Walks to machine 2	0.2	Automatic cycle			1.2	
Services machine 2	0.3			Idle	0.3	2.5
Idle				Automatic cycle		
	0.5					3.0
Walks to machine 1	0.2		1.2			
Services machine 1	0.3	Idle	0.3			3.5
Walks to machine 2	0.2	Automatic cycle			1.2	
Services machine 2	0.3			Idle	0.3	4.0

Improvement on operation charts:

- Step 1: developing the detailed listing of operations for the components and their assembly in to the final entity(operation chart) .

- Step2: examination of the chart to discover possible improvement by questioning procedure aimed at the material and operations.

- Step3:developing proposal for improvement on the operation chart for an existing work situation based on the results of the questioning procedure.

Improvement on operation charts:

Questioning used to analyze operation chart:

- Questions related to the materials.
- Questions related to processing or assembly operations.
- Questions related to inspection operations.

5 WHY's questions:- what? Where? When? Who? How?.

Improvement on operation charts:

- Examples:
  - Why is the activity necessary?
  - Why is this activity assigned to this type of operation?
  - Why is this activity performed at this time?
  - Why is this activity performed in this location?
  - ……ext

Improvement on flow process charts:

- According to the more detailed in the flow process chart beyond the operation chart that includes more types of activities ;the examining improvement procedure is expanded to include more questions related to the move, delay and storage process.

- A flow diagram with a modified and improved system should be submitted with the actual one.

- Table2,page231.table4,page 235.

Improvement on operation charts and process chart:

Cost reduction:

- Can I eliminate this process or activity?
- If YES eliminate
- If NO

Can I combine this process activity with another activity?

- If yes → combine
- If NO

Can I rearrange or change the sequence of this activity?

- If yes → rearrange
- If NO

Can I simplify this activity?

- If yes → simplify
- If NO → No improvement activity is possible.

A case study: Jordan university press

THE OBJECTIVES

APPLY THE MACRO MOTION STUDY TECHNIQUES ON A PART OF A PRODUCT WHICH IS THE PAPER.

THINK OF A NEW –MORE EFFICIENT– METHOD THAN THE PRESENT METHOD.

Why we choose the Jordan university press?

It produces a lot of books, lab manuals, researches done by faculty members and university magazines.

Its closeness.

The Binding Paper

Its Size is (50X70) cm containing 32 pages of the size P5 (17 X 24 cm).

Process Description

- Entering the printing hall.

- Print 500 copy of one binding paper in the offset printing machine.

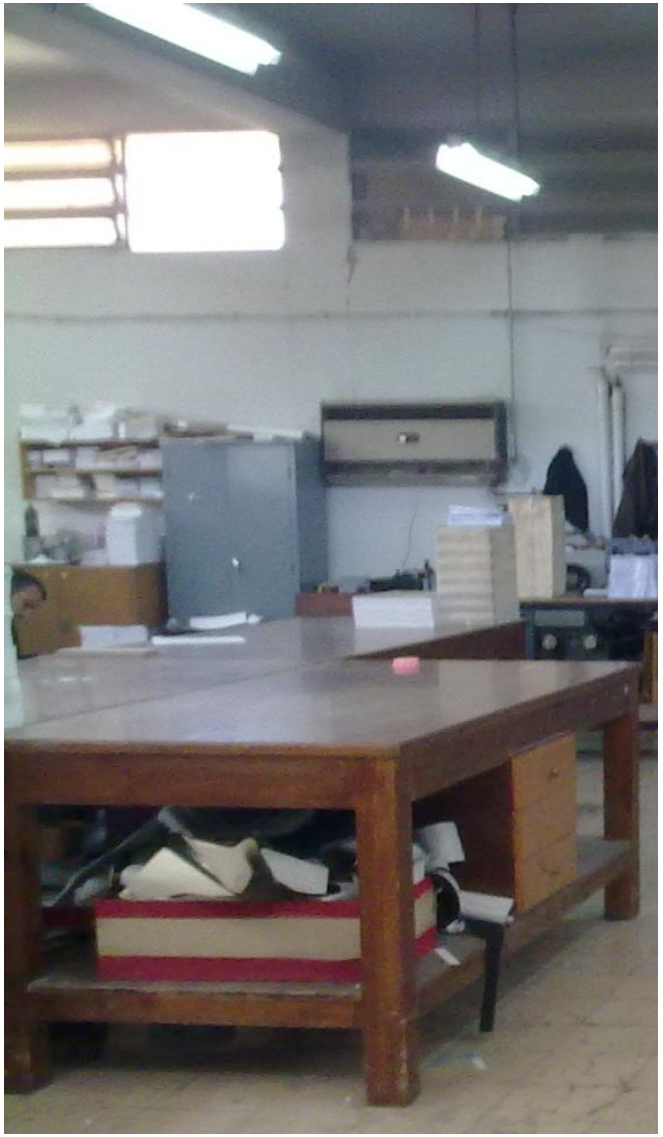
- Sent to a table by jack.

- Inspection and individualization.

- Send it to the folding machine by hand.
- Fold.

- Moved manually to floor.
- Delay.

- Move to table by hand.
- Organize



- Move to the assembly machine by a jack.
- Assemble with cover page by glue.

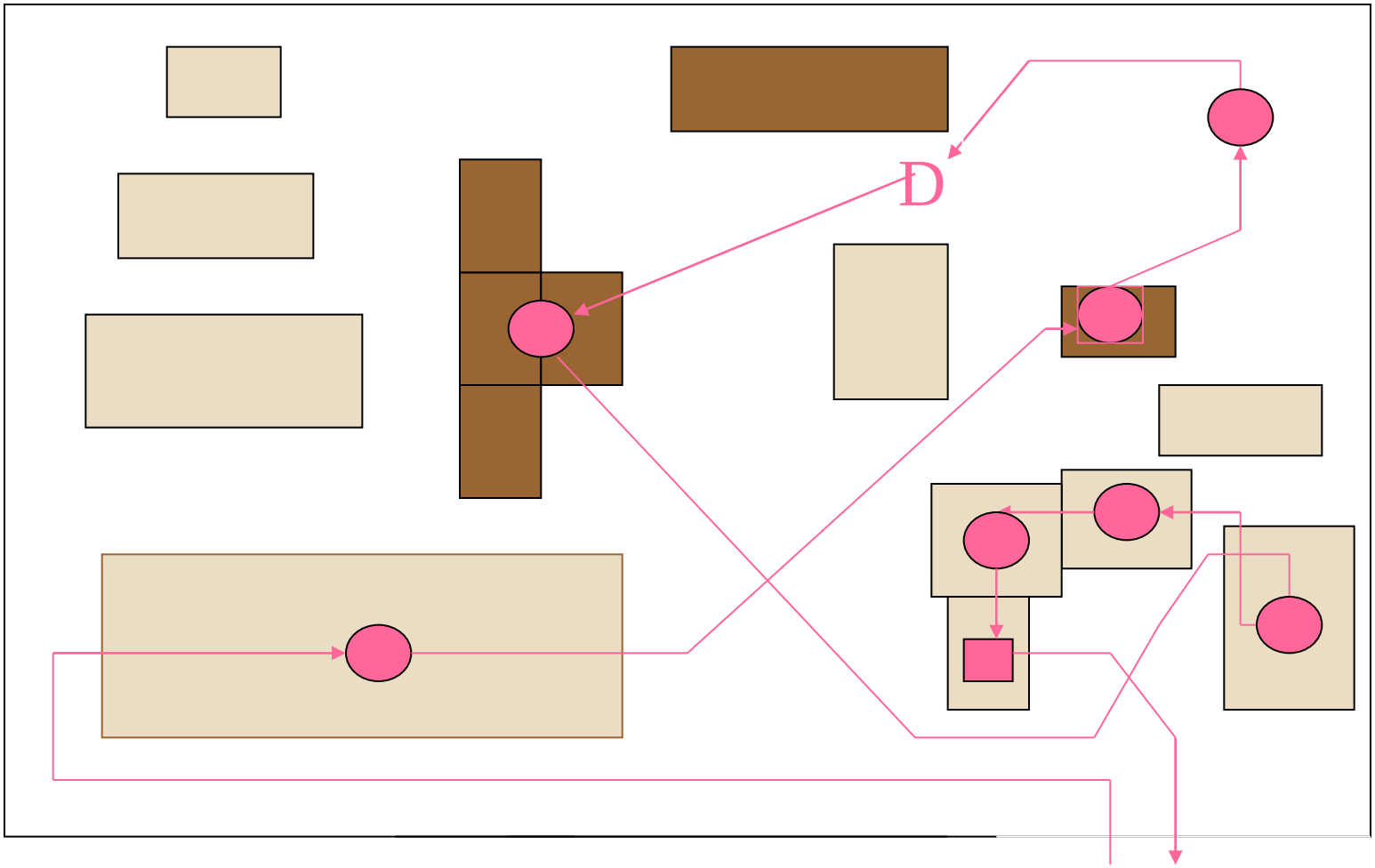
- move to the cooling machine by a conveyor

- Cooling.

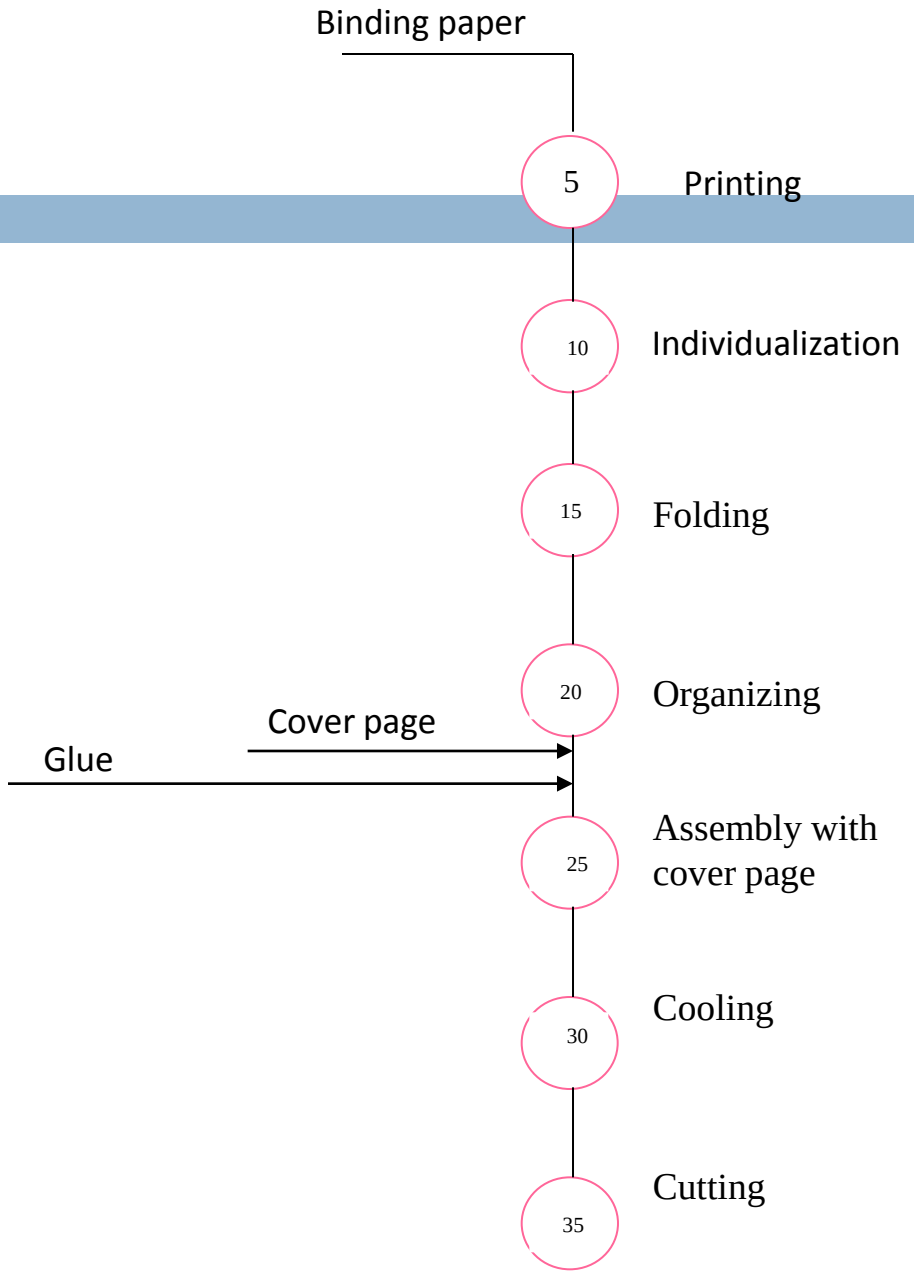
- Move to the tri-scissors saw machine.
- Cutting.

- Move to table by conveyor.
- Inspection.
- Move out by jack.

Flow diagram for present method



Operation chart



FRED MEYERS & ASSOCIATES — PROCESS CHART

■ PRESENT METHOD ☐ PROPOSED METHOD DATE: 6-12-2010 PAGE 1 OF 2

PART DESCRIPTION: Biding paper, size (50*70)

OPERATION DESCRIPTION: From intering hall printing to leaving the hall printing

SUMMARY	PRESENT NO.	PRESENT TIME	PROPOSED NO.	PROPOSED TIME	DIFF. NO.	DIFF. TIME
OPERATIONS						
TRANSPORT.						
INSPECTIONS						
DELAYS						
STORAGES						
DIST. TRAVELED	FT.		FT.		FT.	

ANALYSIS: WHY WHEN WHAT WHO WHERE HOW

FLOW DIAGRAM ATTACHED (IMPORTANT)

STUDIED BY:

STEP	DETAILS OF PROCESS	METHOD	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	DISTANCE IN FEET	QUANTITY	TIME (HOUR)	COST PER UNIT	TIME/COST CALCULATIONS
1	Move to hall printing	Jack	○	➡	□	D	▽					
2	Printing		●	⇨	□	D	▽					
3	Move to table	Jack	○	➡	□	D	▽					
4	Inspection		○	⇨	■	D	▽					
5	individualization		●	⇨	□	D	▽					
6	Move to machine	Hand	○	➡	□	D	▽					
7	Folding		●	⇨	□	D	▽					
8	Move to floor	Hand	○	➡	□	D	▽					
9	Wait		○	⇨	□	◗	▽					
10	Move to table	Hand	○	➡	□	D	▽					
11	Organizing		●	⇨	□	D	▽					
12	Move to machine	Jack	○	➡	□	D	▽					
13	Assembly with cover page		●	⇨	□	D	▽					
14	Move to machine	Conveyor	○	➡	□	D	▽					
15	Cooling		●	⇨	□	D	▽					
16	Move to machine	Conveyor	○	➡	□	D	▽					
17	Cutting		●	⇨	□	D	▽					

STEP	DETAILS OF (PRESENT / PROPOSED) METHOD	METHOD	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	DISTANCE (IN FEET)	QUANTITY	TIME (MINUTES)	COST PER UNIT	TIME/COST CALCULATIONS
18	Move to table	Conveyor	○	➡	□	D	▽					
19	Inspection		○	⇨	■	D	▽					
20	Move to store	Jack	○	➡	□	D	▽					
21			○	⇨	□	D	▽					
22			○	⇨	□	D	▽					
23			○	⇨	□	D	▽					
24			○	⇨	□	D	▽					
25			○	⇨	□	D	▽					
26			○	⇨	□	D	▽					
27			○	⇨	□	D	▽					
28			○	⇨	□	D	▽					
29			○	⇨	□	D	▽					
30			○	⇨	□	D	▽					
31			○	⇨	□	D	▽					
32			○	⇨	□	D	▽					
33			○	⇨	□	D	▽					
34			○	⇨	□	D	▽					
35			○	⇨	□	D	▽					
36			○	⇨	□	D	▽					
37			○	⇨	□	D	▽					
38			○	⇨	□	D	▽					
39			○	⇨	□	D	▽					
40			○	⇨	□	D	▽					
41			○	⇨	□	D	▽					
42			○	⇨	□	D	▽					

Proposed method

Elimination

- WE CAN NOT.
- EVERY STEP IS IMPORTANT.

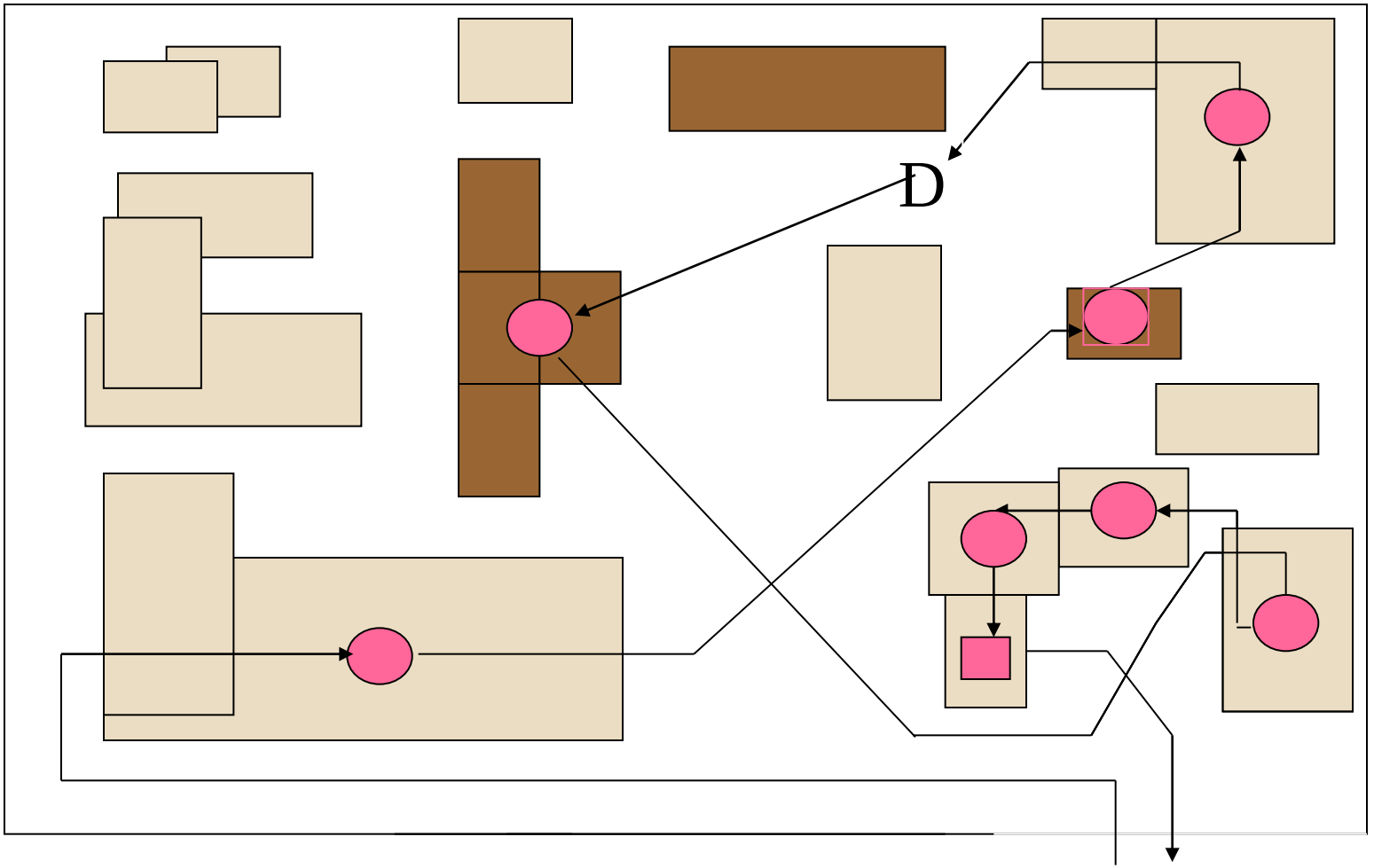
Combination

- WE CAN NOT.
- THERE IS NO MACHINE COMBINES TWO OPERATIONS TOGETHER, TECHNICIAN SAID.

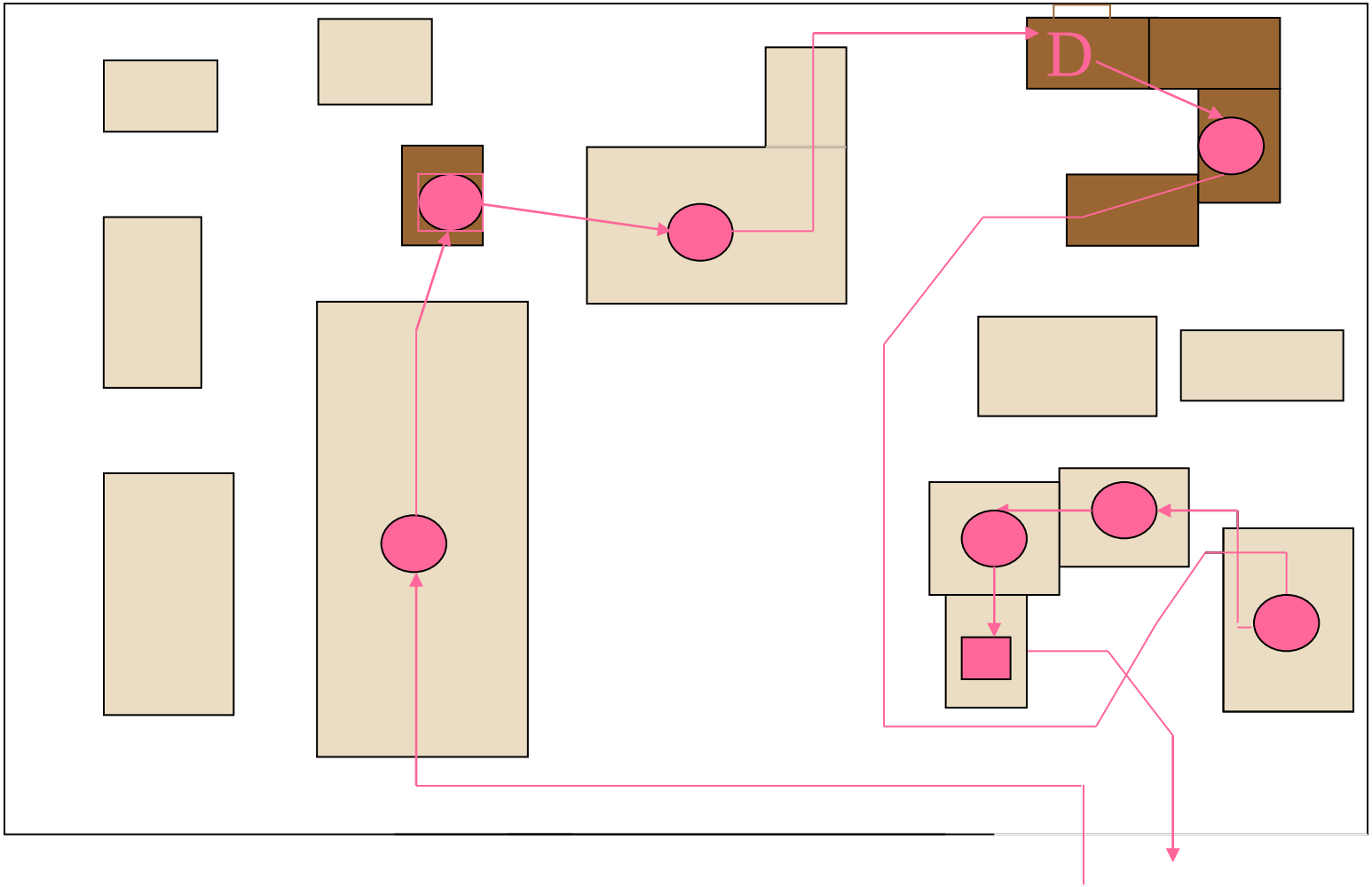
Rearranging

- MACHINES CAN BE MOVED.
- REDUCE DISTANCE TRAVELED.
  ELIMINATE CROSS TRAFFIC.

Flow diagram for present method



Flow diagram for propose method



FRED MEYERS & ASSOCIATES — PROCESS CHART

☐ PRESENT METHOD ■ PROPOSED METHOD DATE: 6-12-2010 PAGE 1 OF 2

PART DESCRIPTION: **Biding paper, size (50*70)**

OPERATION DESCRIPTION: **From intering hall printing to leaving the hall printing**

SUMMARY	PRESENT NO.	PRESENT TIME	PROPOSED NO.	PROPOSED TIME	DIFF. NO.	DIFF. TIME
OPERATIONS						
TRANSPORT						
INSPECTIONS						
DELAYS						
STORAGES						
DIST. TRAVELED		FT.		FT.		FT.

ANALYSIS:

WHY	WHEN
WHAT	WHO
WHERE	HOW

FLOW DIAGRAM ATTACHED (IMPORTANT)

STUDIED BY:

STEP	DETAILS OF PROCESS	METHOD	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	DISTANCE (IN FEET)	QUANTITY	TIME (0.0001 PER UNIT)	COST PER UNIT	TIME/COST CALCULATIONS
1	Move to hall printing	Jack	○	■	□	D	▽					
2	Printing		●	⇨	□	D	▽					
3	Move to table	Hand	○	■	□	D	▽					
4	Inspection		○	⇨	■	D	▽					
5	individualization		●	⇨	□	D	▽					
6	Move to machine	Hand	○	■	□	D	▽					
7	Folding		●	⇨	□	D	▽					
8	Move to table	Hand	○	■	□	D	▽					
9	Wait		○	⇨	□	◗	▽					
10	Move to table	Hand	○	■	□	D	▽					
11	Organizing		●	⇨	□	D	▽					
12	Move to machine	Jack	○	■	□	D	▽					
13	Assembly with cover page		●	⇨	□	D	▽					
14	Move to machine	Conveyor	○	■	□	D	▽					
15	Cooling		●	⇨	□	D	▽					
16	Move to machine	Conveyor	○	■	□	D	▽					
17	Cutting		●	⇨	□	D	▽					

STEP	DETAILS OF (PRESENT / PROPOSED) METHOD	METHOD	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	DISTANCE (IN FEET)	QUANTITY	TIME (HOURS)	COST PER UNIT	TIME/COST CALCULATIONS
18	Move to table	Conveyor	○	➡	□	D	▽					
19	Inspection		○	⇨	■	D	▽					
20	Move to store	Jack	○	➡	□	D	▽					
21			○	⇨	□	D	▽					
22			○	⇨	□	D	▽					
23			○	⇨	□	D	▽					
24			○	⇨	□	D	▽					
25			○	⇨	□	D	▽					
26			○	⇨	□	D	▽					
27			○	⇨	□	D	▽					
28			○	⇨	□	D	▽					
29			○	⇨	□	D	▽					
30			○	⇨	□	D	▽					
31			○	⇨	□	D	▽					
32			○	⇨	□	D	▽					
33			○	⇨	□	D	▽					
34			○	⇨	□	D	▽					
35			○	⇨	□	D	▽					
36			○	⇨	□	D	▽					
37			○	⇨	□	D	▽					
38			○	⇨	□	D	▽					
39			○	⇨	□	D	▽					
40			○	⇨	□	D	▽					
41			○	⇨	□	D	▽					
42			○	⇨	□	D	▽					

Activity chart

- Activity chart: is a listing of the work activity of one or more subjects(workers , machines) plotted against a time scale to indicate graphically how much time is spent on each activity.
- The format of the activity chart is activity description against a vertical time scale. (vertical line or bars indicating the activities)

Activity chart

Types of activity chart:

- worker –machine activity chart.
- Worker- multimachine chart.
- Multiple-activity chart.
- Right hand-lift hand activity chart.
- Gang chart.
- Multiworker activity chart.

worker –machine activity chart:

- indicate how the work elements and associated times are allocated between a worker and a machine for the repetitive cycle of a worker-machine system.
- It consist of two main columns one for the worker and the other for the machine.
- The worker-machine activity chart can help to improve and identify opportunities for cycle time improvement.

worker –machine activity chart:

- Operator ---one unit of production
- Machine --- one unit of production.

Notes:

Loading +unloading = set up time

Total Working Time (TWT) of both worker or machine not including the Idle time.

Cycle time = MAX Total working Time (worker /machine).

worker –multimachine activity chart:

- Similar to the worker-machine chart except that the worker is responsible for more than one machine .
- A worker cycle must be developed that minimize or eliminate machine interference(the idle time of the machine).
- Example:
  - Loading time=1 min
  - Unloading time=2 min
  - Machine running time=7 min

worker –machine activity chart:

- Worker multimachine: (one worker + n machine).
- Two conditions:

1- Identical machine time

  - CASE1: TWT (operator) =TWT (machine) ==no idle time
  - Case2: TWT(operator) < TWT(machine)== operator idle
  - Case3: TWT(operator)> TWT(machine)==machine idle

2- Different machine time

worker –machine activity chart:

- Example on case 1:
  - A system of 2 identical machine A and B
  - Setup time=2 min
  - Walking time to the next machine= 1 min.
  - Machine running time =4 min.

TWT(operator)=n(Setup +walk).

TWT(A) = (S+R)

TWT(B)=(S+R)

worker –machine activity chart:

- Example on case 2:
  - A system of 2 identical machine A and B
  - Setup time=2 min
  - Walking time to the next machine= 1 min.
  - Machine running time =5min.

TWT(operator)=n(Setup +walk).

TWT(A) = (S+R)

TWT(B)=(S+R)

worker –machine activity chart:

- Example on case 3:
  - A system of 2 identical machine A and B
  - Setup time=2 min
  - Walking time to the next machine= 1 min.
  - Machine running time =3min.

TWT(operator)=n(Setup +walk).

TWT(A) = (S+R)

TWT(B)=(S+R)