Facilities planning

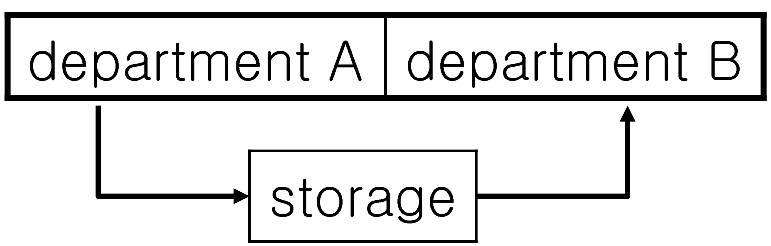
Flow analysis

Introduction

- Which comes first, the material handling system design or the facility layout design?
  - Layout first and then material handling system design
  - Example
    - Manufacturing process: department A->department B
    - Layout design:

department A	department B

    - MHS design:



    - Better design:

department A	storage	department B

Introduction

- Which comes first, the material handling system design or the facility layout design?
  - Both should be designed simultaneously.
  - However, the complexity of the design problem, generally requires that a sequential process be used.
  - Develop a number of alternative layout plans and appropriate handling system must be designed for each. Select a preferred layout.
- Basic layout types
  - Production line product layout
  - Process layout
  - Product family layout
  - Fixed product layout

Basic layout types

- Production line product layout
  - Materials typically flow from one workstation directly to the next adjacent one.
  - High-volume, low-variety environments
- Process layout
  - Similar processes are grouped together and process departments are placed based on flow between departments.
  - There exists a high degree of interdepartmental flow and little intradepartmental flow.
  - The layout is used when the volume of parts or groups of parts is not sufficient to justify a production line product layout.

Basic layout types

- Product family layout
  - Nonidentical parts are grouped into families based on common processing sequences, shapes, material composition, tooling requirement, handling/storage/control requirements.
  - The processing equipments required for pseudoproduct are grouped together and placed in a manufacturing cell.
  - The layout has a high degree of intradepartmental flow and little interdepartmental flow
- Fixed product layout
  - Workstations are brought to the material.
  - Aircraft assembly, shipbuilding and most construction projects.

Basic layout types

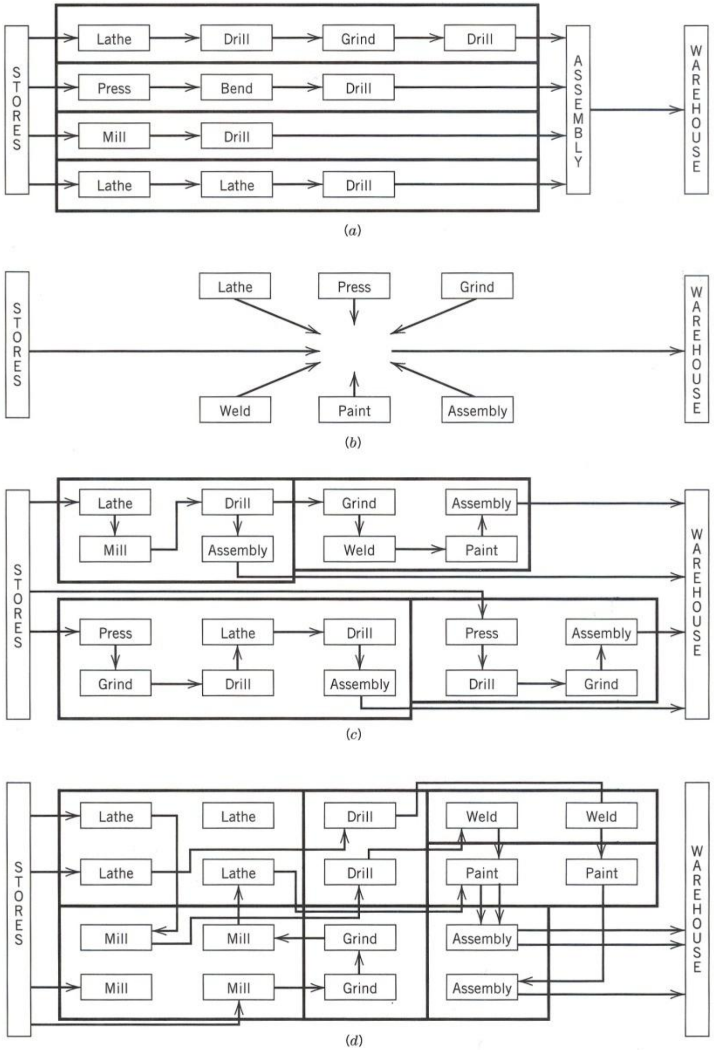


Figure 6.1 Alternative types of layouts. (*a*) Production line product layout. (*b*) Fixed product layout. (*c*) Product family layout. (*d*) Process layout.

Flow analysis

- From to chart

From \ To	Store	Milling	Turning	Press	Plate	Assembly	Warehouse
Stores		12	6	9	1	4	
Milling					7	2	
Turning		3			4		
Press					3	1	1
Plate		3	1			4	3
Assembly	1						7
Warehouse							

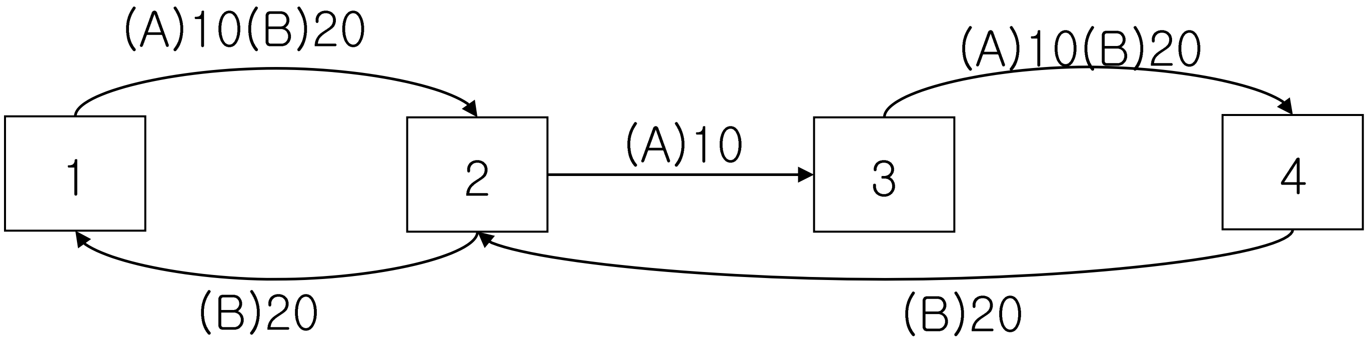
Figure 3.31 From-to chart.

Example

- A factory has four planning departments (1,2,3,4). Product A is manufactured according to the sequence 1-2-3-4 and product B according to the sequence 3-4-2-1-2. The daily production volumes of products A and B are 10 and 20 parts, respectively. Both products A and B have similar sizes, shapes and material handling requirements
- 1)Construct the from-to chart indicating the number of trips from one department to another.

Example

1)



From-to	1	2	3	4
1	–	30	–	–
2	20	–	10	–
3	–	–	–	30
4	–	20	–	–

Flow analysis

- Let M denote the number of departments, f_{ij} and c_{ij} denote the flow volume, cost of moving a unit load one distnace unit from department i to j respectively.
- Consider a from-to matrix of $M \times M$ and each entry is denoted by a weight, $w_{ij} = f_{ij} c_{ij}$
- Standard deviation of the from-to matrix is

$$\sqrt{\frac{\sum_{i=1}^{M}\sum_{j=1}^{M}\left(w_{ij}-\bar{w}\right)^2}{\left(M^2-1\right)}}$$

where $\bar{w} = \dfrac{\sum_{i=1}^{M}\sum_{j=1}^{M} w_{ij}}{M^2}$

- Coefficient of variance of from-to matrix is

$$f = \frac{\sqrt{\dfrac{\sum_{i=1}^{M}\sum_{j=1}^{M}\left(w_{ij}-\bar{w}\right)^2}{\left(M^2-1\right)}}}{\bar{w}} = \frac{\sqrt{\dfrac{\sum_{i=1}^{M}\sum_{j=1}^{M} {w_{ij}}^2 - M^2\bar{w}^2}{\left(M^2-1\right)}}}{\bar{w}}$$

Flow analysis

- Consider two extreme cases of from-to matrix
- All weights are equal

$$L = \begin{bmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{bmatrix}$$

In this case, $\sum_{i=1}^{M}\sum_{j=1}^{M} w_{ij}^{2} = M^{2} - M$ and $\bar{w} = \dfrac{M^{2} - M}{M^{2}}$

- Coefficient of variance of L is

$$f_L = \frac{\sqrt{\dfrac{\sum_{i=1}^{M}\sum_{j=1}^{M} w_{ij}^{2} - M^{2}\bar{w}^{2}}{\left(M^{2}-1\right)}}}{\bar{w}} = M\sqrt{\frac{1}{(M-1)\left(M^{2}-1\right)}}$$

Flow analysis

- One dominent flow

$$U = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

In this case, $\sum_{i=1}^{M}\sum_{j=1}^{M} w_{ij}^{\ 2} = M - 1$ and $\overline{w} = \dfrac{M-1}{M^2}$

- Coefficient of variance of U is

$$f_U = \frac{\sqrt{\dfrac{\sum_{i=1}^{M}\sum_{j=1}^{M} w_{ij}^{\ 2} - M^2\overline{w}^2}{\left(M^2-1\right)}}}{\overline{w}} = M\sqrt{\frac{M^2 - M + 1}{(M-1)\left(M^2-1\right)}}$$

Flow analysis

- Let $f^{'}$ be the coefficient of variation for a from-to matrix then

we define a flow dominant measure as follows:

$$f = \frac{f_U - f^{'}}{f_U - f_L}$$

f is a number between 0 and 1.

- If $f \rightarrow 0$, then a large flow exists. A production line product layout is suitable
- If $f \rightarrow 1$, then there is no large flow. Any layout is appropriate
- If $f \rightarrow 0.5$, then there exit multiple parts of of large flows.

  A process or group layout might be appropriate

Example

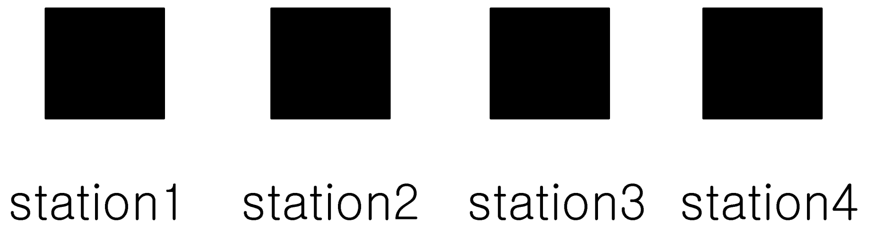
From-to	1	2	3	4
1	–	30	–	–
2	20	–	10	–
3	–	–	–	30
4	–	20	–	–

- Calculate the flow dominant measure for the above from-to matrix. What kind of layout do you suggest?

Ideal factory

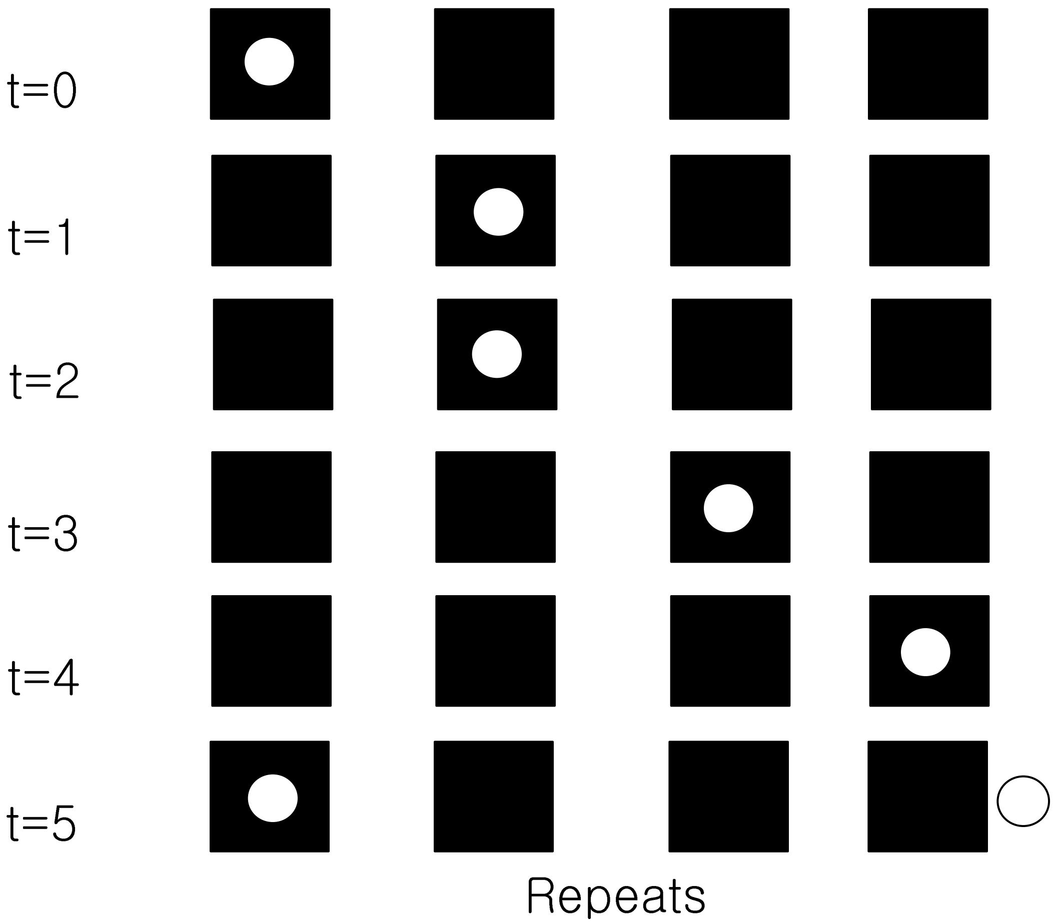
- Throughput(TH)=output rate(units/time)
- WIP(Work In Process)=amount of inventory in the system(units)
- Lead Time(LT)=time required to traverse the system(time)

Ideal factory



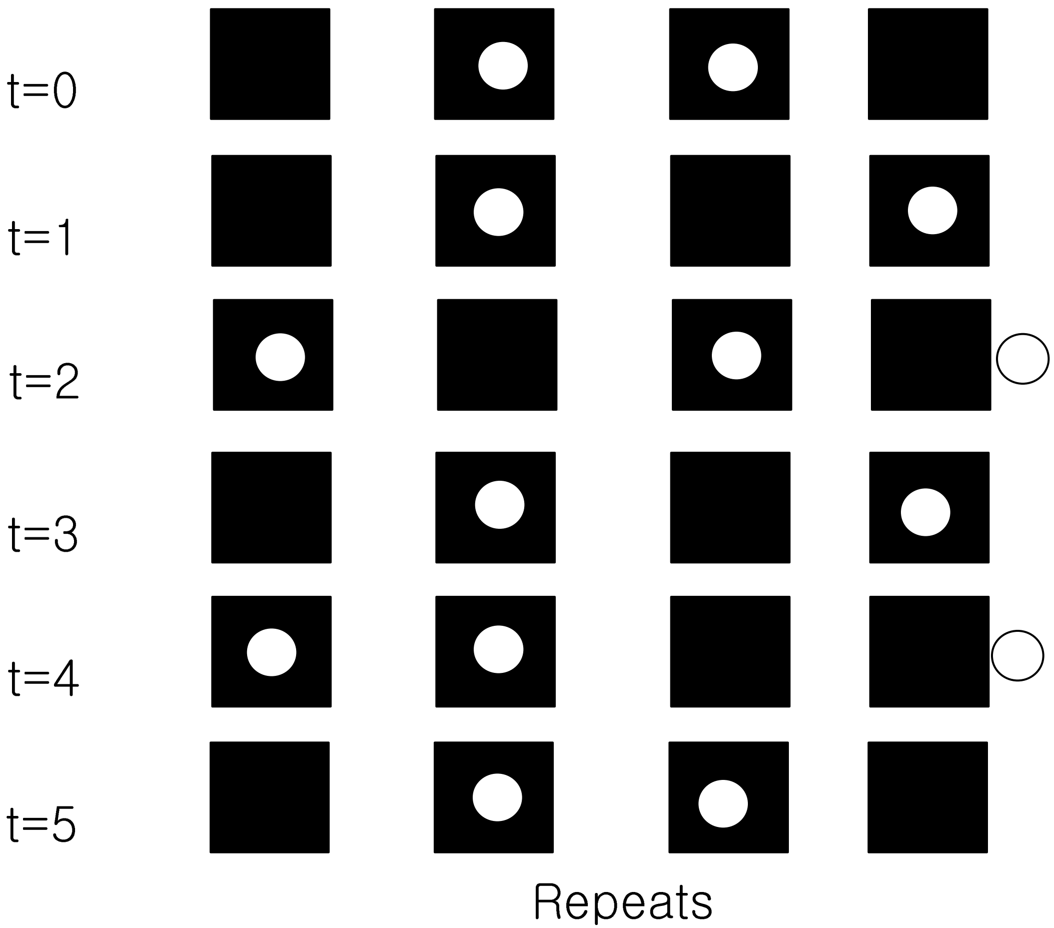
- Assumptions
  - Processing times are 1, 2, 1 and 1 min. for station 1, 2, 3 and 4 respectively.
  - A station can process one item at the time.
  - No handling time (instantaneous movement to next station)
  - No variability
  - WIP in the system is kept at a constant level(a new unit is introduced into the system every time an unit is completed)
- Let's simulate this factory for WIP=1,2,3,4, and 5 and evaluate its performance with respect to LT, TH and Utilization(U)

Ideal factory



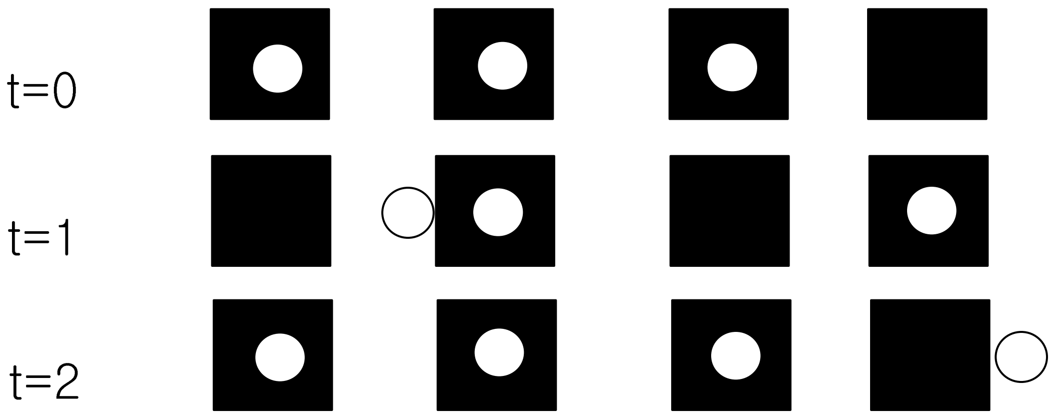
WIP=1
TH=1/5
LT=5
U_B=2/5

Ideal factory



WIP=2
TH=2/5
LT=5
U_B=4/5

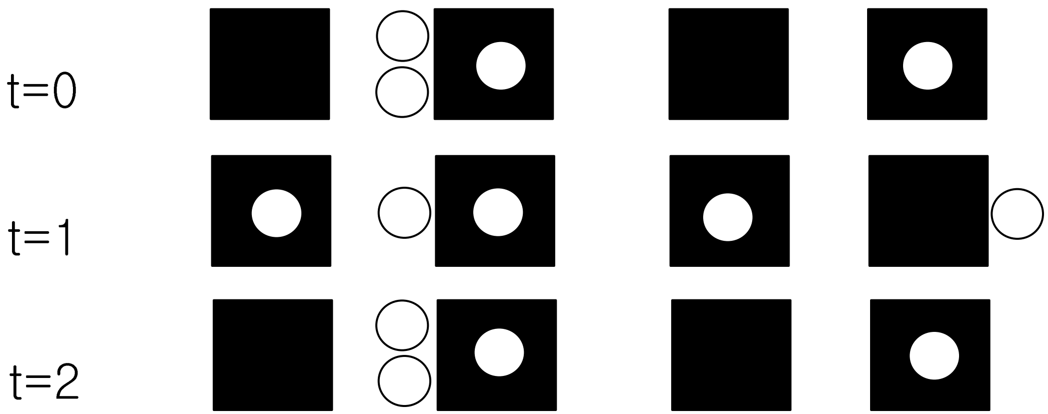
Ideal factory



Repeats

WIP=3
TH=1/2
LT=6
U_B=2/2

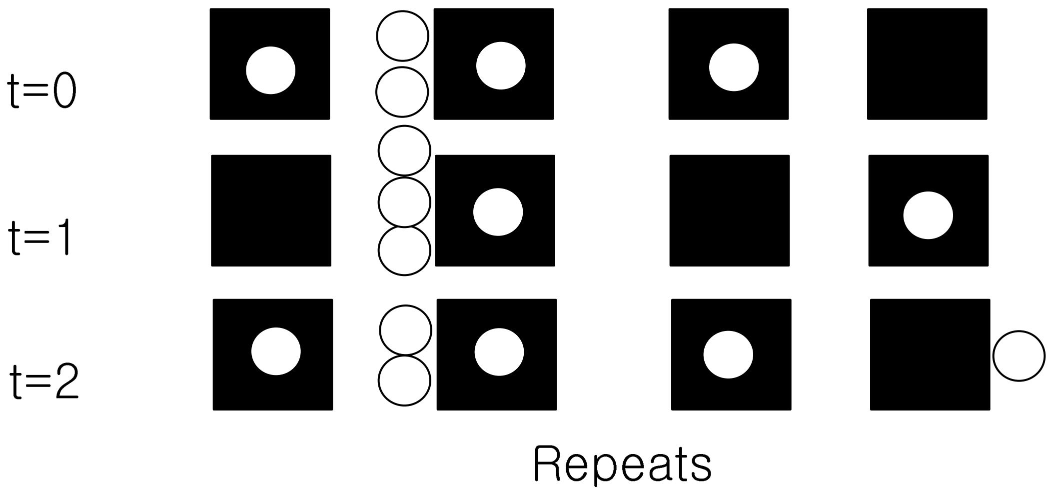
Ideal factory



Repeats

WIP=4
TH=1/2
LT=8
U_B=2/2

Ideal factory



WIP=5
TH=1/2
LT=10
U_B=2/2

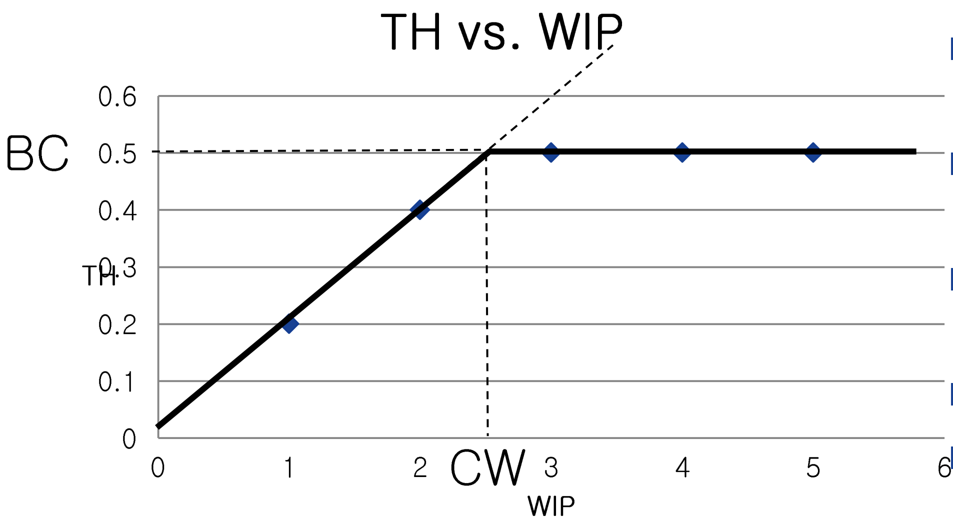
Ideal factory

WIP	LT	TH	U	LT x TH
1	5	1/5	0.4	1
2	5	2/5	0.8	2
3	6	1/2	1	3
4	8	1/2	1	4
5	10	1/2	1	5

- WIP=LT x TH(Little's Law)

Ideal factory

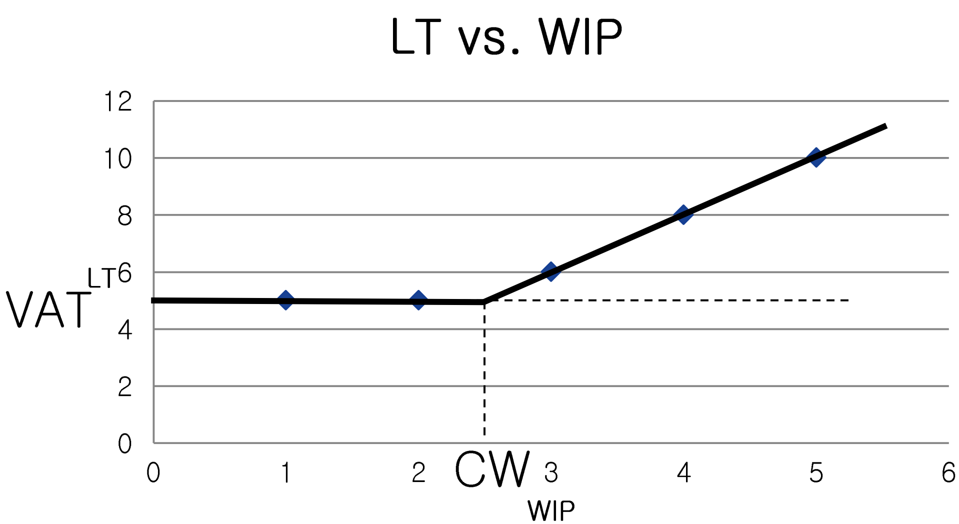
WIP	LT	TH	U	LT x TH
1	5	1/5	0.4	1
2	5	2/5	0.8	2
3	6	1/2	1	3
4	8	1/2	1	4
5	10	1/2	1	5



- BT(Bottleneck time):process time at bottleneck
- BC(Bottleneck capacity):max achievable TH =1/BT
- VAT(Value added time):sum of all process time
- Slope=1/VAT
- CW(Critical WIP):min. WIP to achieve max. TH=BC/slope=BC*VAT

Ideal factory

WIP	LT	TH	U	LT x TH
1	5	1/5	0.4	1
2	5	2/5	0.8	2
3	6	1/2	1	3
4	8	1/2	1	4
5	10	1/2	1	5



- Slope=BT=1/BC

Example

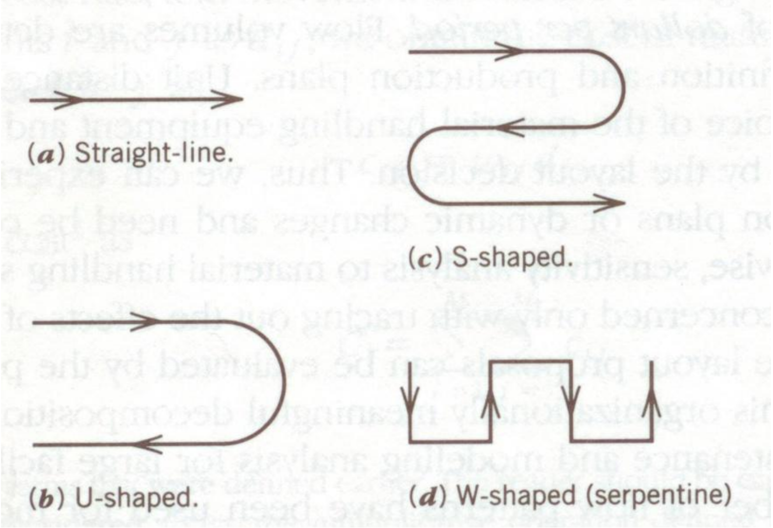
- A production line has 3 processing steps. The processing times are 20, 30, 15 sec/part. Under the current operation condition, the average WIP=10 parts and TH=0.03parts/sec. A consultant hired by your company is recommending increasing the WIP levels by 30% in order to achieve additional throughput. Do you agree with the consultant? Use the ideal TH vs. WIP plot to justify your answer.
- What do you suggest for the layout of your company's production line?

Example

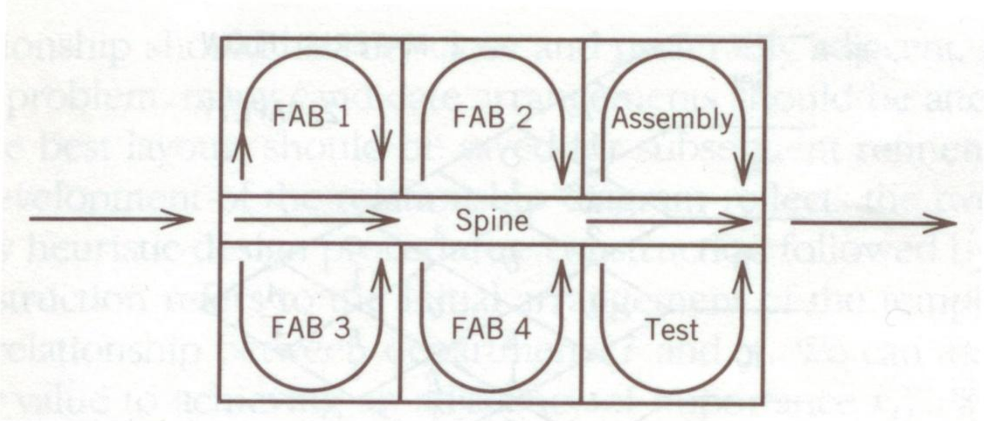
- Consider a production line where the total value added time for a product is 40 min. and the slowest process has a capacity of 3 parts/min. Currently the average WIP=210 units. A consultant recommending the WIP to a third of its current level in order to reduce the LT while maintaining similar TH performance. Use the ideal LT vs. WIP plot to justify your answer.

Flow analysis

- Basic flow patterns

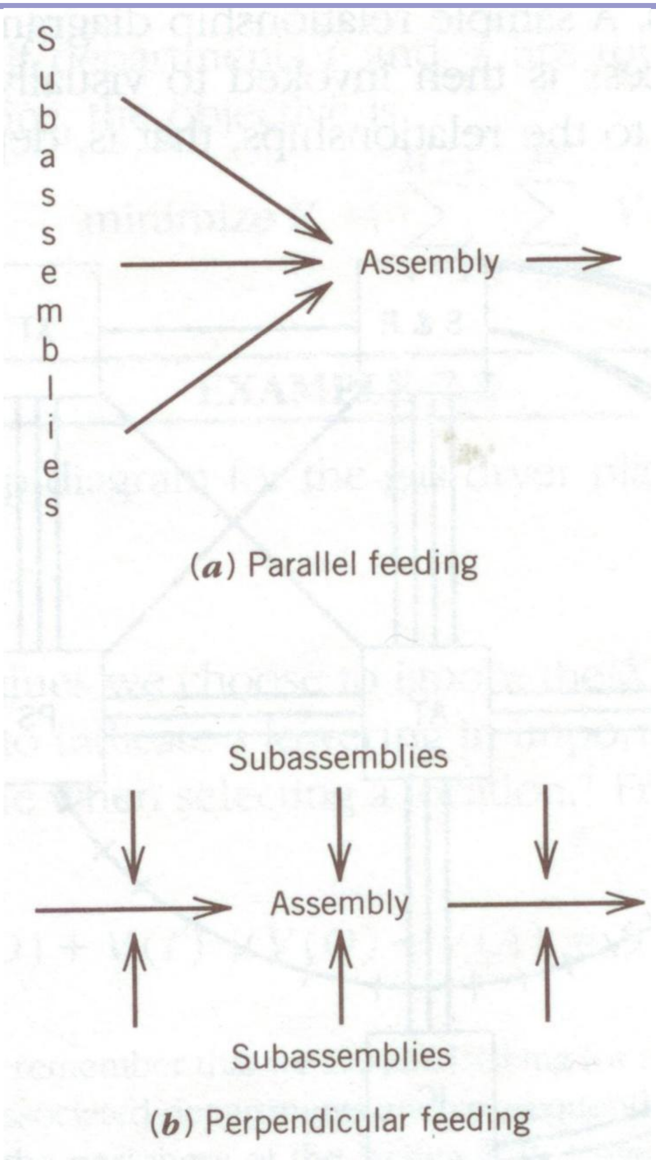


- An example of plant flow pattern: Between departments: spine-oriented straight-line pattern, within departments: U-shaped pattern



Flow analysis

- Assembly flow patterns



Flow analysis

- Principles of flow patterns
  - Flow within workstations: should be simultaneous, symmetrical, natural, rhythmical and habitual flow.
    - Simultaneous flow implies the coordinated use of hands, arms and feet->motion studies
    - Symmetrical flow implies the coordination of movements about the center of the body.
    - Natural movements are continuous, curved and make use of momentum.
    - Rhythmical and habitual flow implies a methodical and automatic sequence of activity.

Flow analysis

- Principles of flow patterns(cont.)
  - Flow between departments
    - Flow between departments is a criterion often used to evaluate overall flow within a facility
    - Usually the location of receiving department and shipping department is fixed at a given location and flow between department must conform to these restrictions.