Problem 06
Total Flow Volume

SCHOOL OF ENGINEERING

Problem Objectives

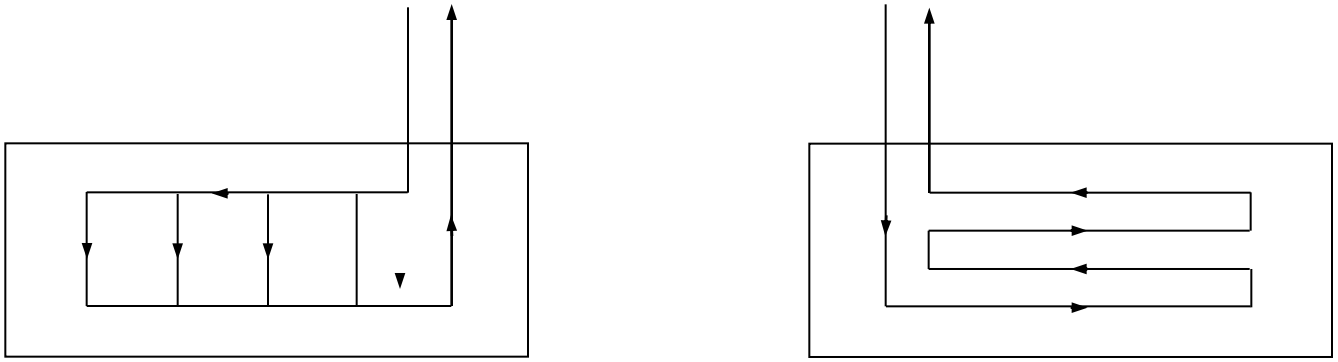
- Represent the process of manufacturing using a flow diagram
- Layout different departments within a facility to ensure a good flow of materials and finished goods
  - Quantitative analysis (Calculate the total flow volume between the departments)
- Determine the equipment requirement based on production output, scrap ratio and maintenance requirement

Flow Planning

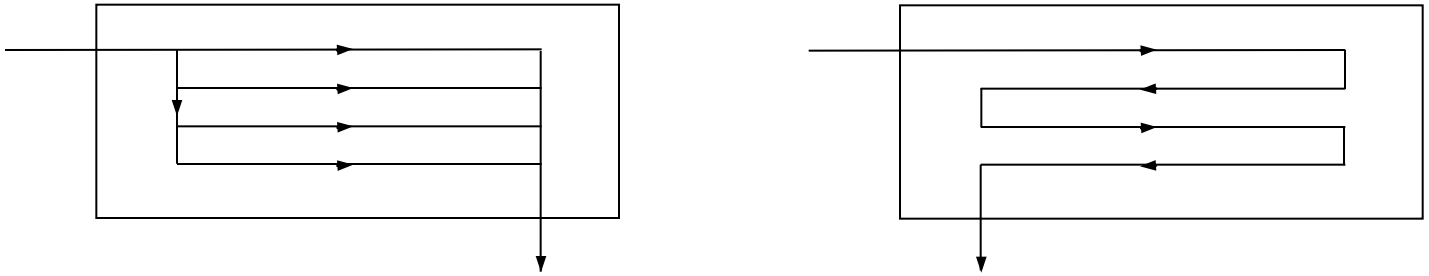
- Process of arranging activities in combinations of basic flow patterns (based on flow analysis), both quantitative (from-to chart) and qualitative (activity relationship diagram).
- Types of flow
  - Materials
  - People
  - Equipment
  - Documents
- Flow can be within workstation, within a department (intra-cell) or between departments (inter-cell)

Flow within a facility considering the locations of entrance and exit

At the same location

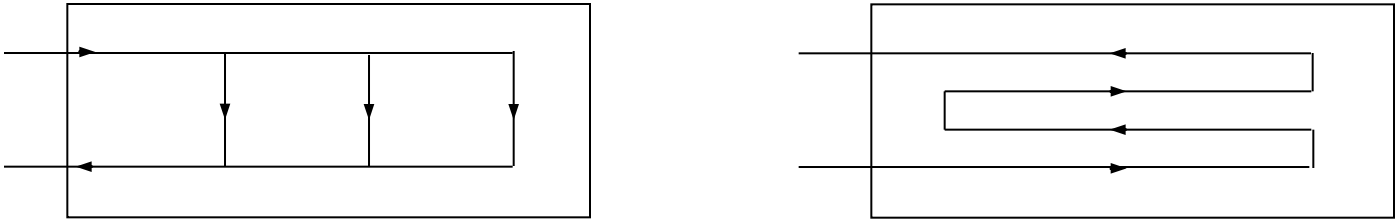


On adjacent sides

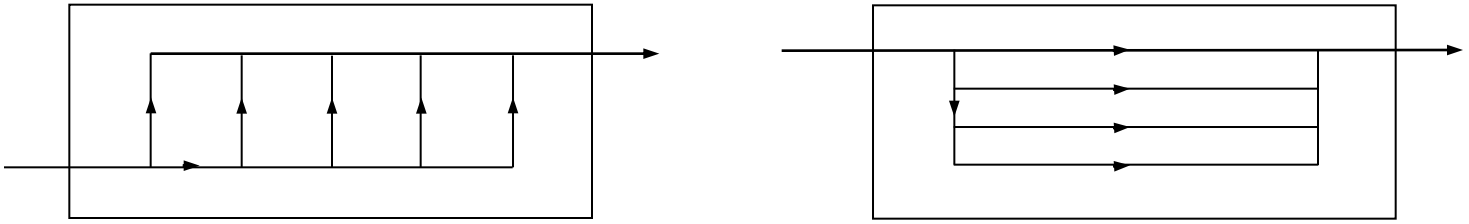


Flow within a facility considering the locations of entrance and exit (cont'd)

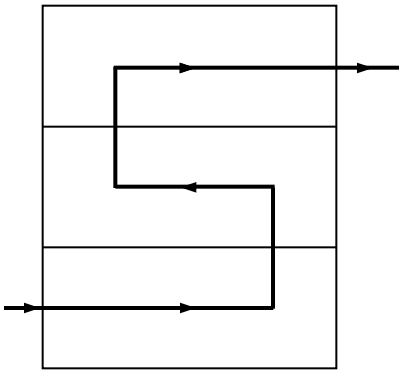
On the same side but
at opposite ends



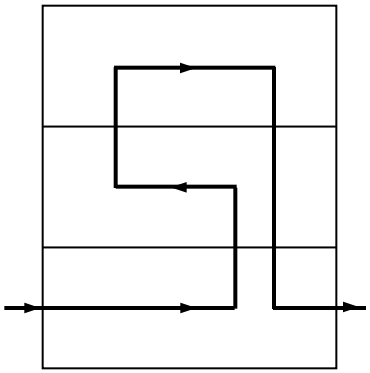
On opposite sides



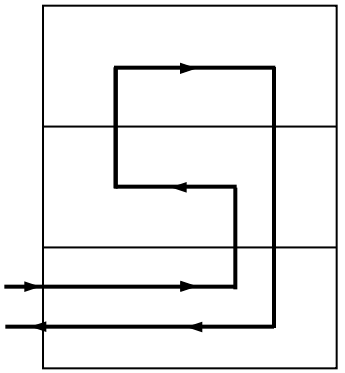
Vertical Flow Pattern



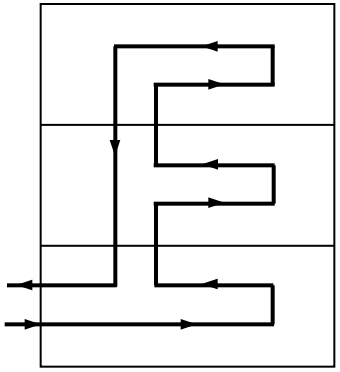
Flow between buildings exists and the connection between buildings is elevated



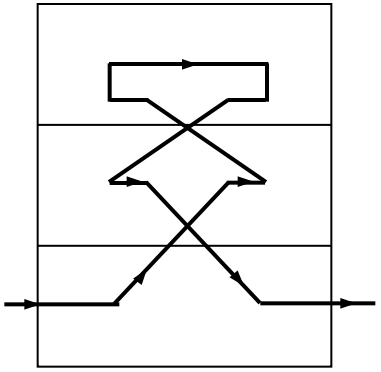
Ground level ingress (entry) and egress (exit) are required



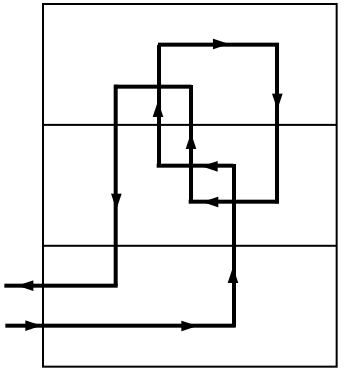
Ground level ingress (entry) and egress (exit) occur on the same side of the building



Travel between floors occurs on the same side of the building

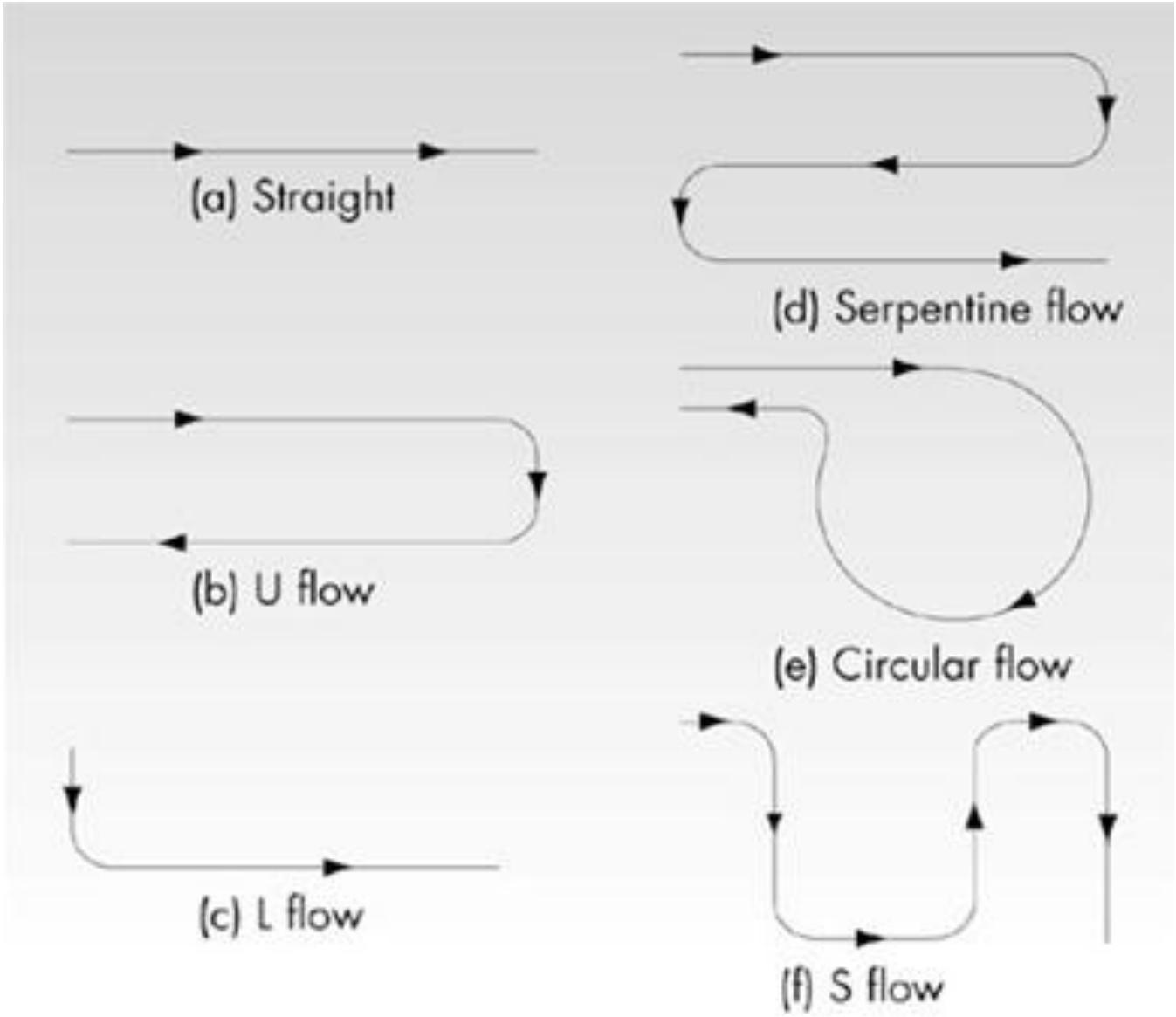


Some bucket and belt conveyors and escalators result in inclined flow



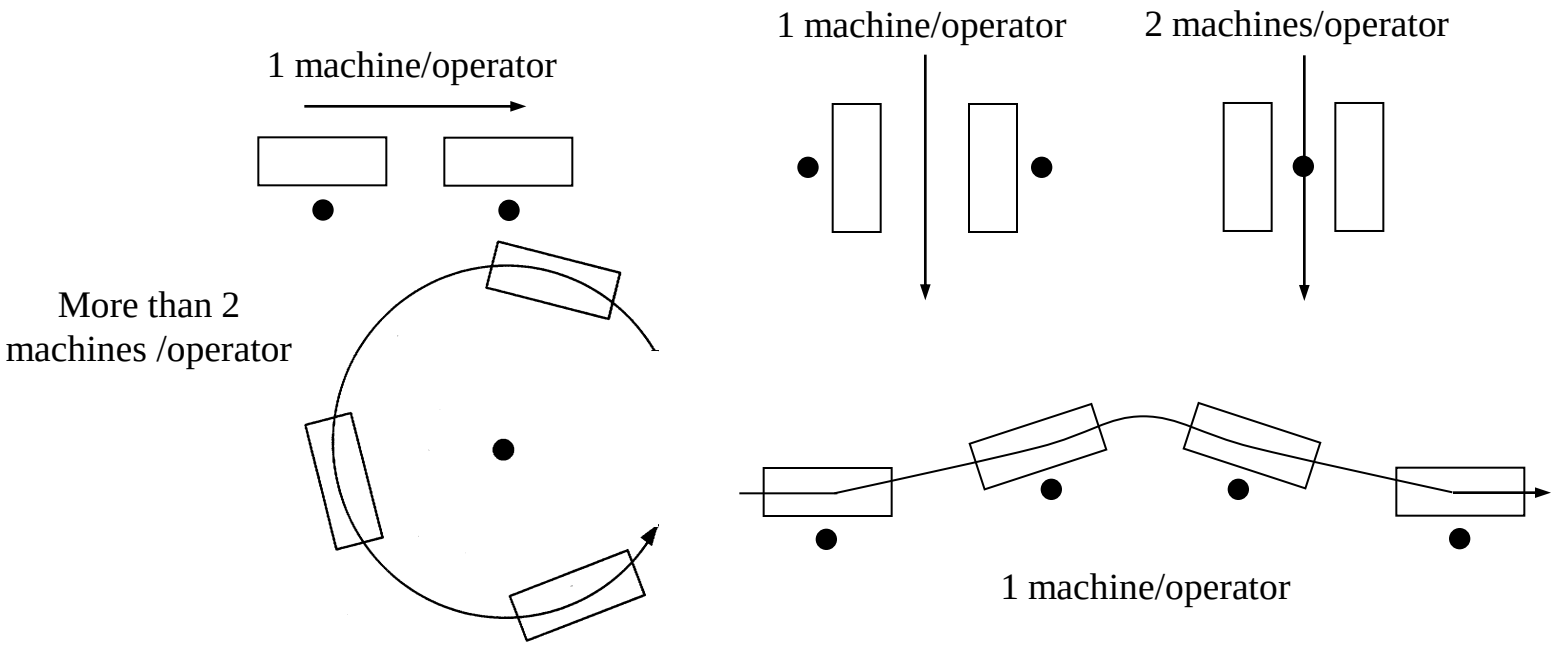
Backtracking occurs due to the return to the top floor

Flow Patterns (between departments)



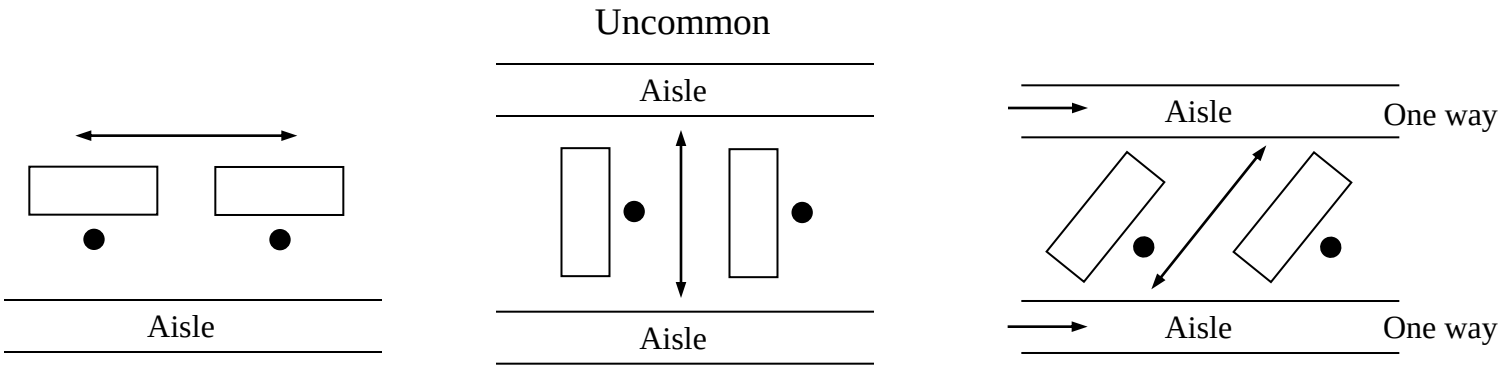
Flow Patterns (within department)

- The flow pattern within departments depends on the type of department.
- In a product and/or product family department, the flow follows the product flow.



Flow Pattern (within department) (cont'd)

- In a process department, little flow should occur between workstations within departments. Flow occurs between workstations and isles.



Dependent on: - **interactions among workstations**

- available space

- size of materials

Flow Patterns: Flow within Workstations

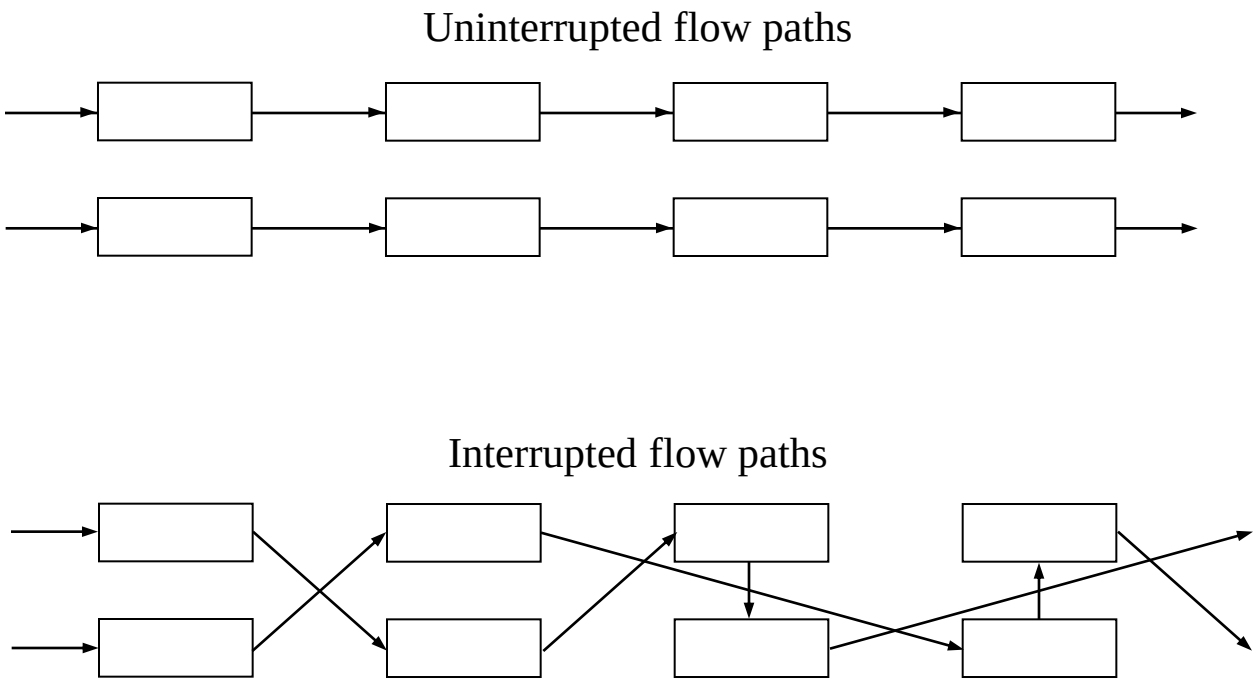
Motion studies and ergonomics considerations are important. Flow should be:

- **Simultaneous**: coordinated use of hands, arms and feet.
- **Symmetrical**: coordination of movements about the center of the body.
- **Natural**: movements are continuous, curved, and make use of momentum.
- **Rhythmical and Habitual**: flow allows a methodological and automatic sequence of activities. It should reduce mental, eye and muscle fatigue, and strain.

Principles of Flow Planning

- Maximize directed flow
  - Directed flow: uninterrupted flow, does not intersect others
  - No backtracking of material
- Minimize frequencies of flow through work simplification
  - Deliver directly to the point of use - eliminate waste
  - Plan appropriate unit of load, use pallets to minimize trips
  - Combine flows and operations, e.g. Automobile assembly
- Minimize cost of flow
  - Reduce travel distance
  - Mechanize or automate transfer

Uninterrupted Flow Path



Flow Analysis Information

A. <u>Product Structured Parts List</u>

- Provides a listing of all component/parts of a product, includes part name, part number, drawing references, quantity of parts
- Product structure is a hierarchy referring to the level of product assembly: such as final product, sub-assemblies.
- Product Structure information and Structured Parts List will make up the Bill of Materials

B. <u>Operation Process Chart</u>

- Presents information on production method and assembly flow of the product
- Differentiates between in-house produced part and purchased part
- Can also include information on raw material used, operation times, inspection stations

Flow analysis information

C. From-To Chart

- A matrix that contains numbers representing a measure (unts, unit loads, etc) of the material flow between machines, departments, buildings, etc.

D. Others

- Assembly chart
- Flow process chart
- Multi product process chart
- Flow diagram

Flow Dominance Measure (FDM)

- **Notation:**

  M: number of activities.

  N_{ij}: number of different types of items moved between activities i and j.

  f_{ijk}: flow volume between i and j for item k (in moves/time period).

  h_{ijk}: equivalence factor for moving item k with respect to other items moved between i and j (dimensionless)

  [all $h_{ijk} = 1$ since assume equal ease of movement]

  w_{ij}: equivalent flow volume specified in from-to chart (in moves/time period),

$$w_{ij} = \sum_{k=1}^{N_{ij}} f_{ijk}\, h_{ijk}.$$

Flow Dominance Measure (cont'd)

- Flow dominance measure = $f = \dfrac{f_U - f'}{f_U - f_L}$

  where

$$f' = \frac{\left[\dfrac{\sum_{i=1}^{M}\sum_{j=1}^{M} w_{ij}^{\,2} - M^2\overline{w}^2}{M^2 - 1}\right]^{\frac{1}{2}}}{\overline{w}}, \qquad \overline{w} = \frac{\sum_{i=1}^{M}\sum_{j=1}^{M} w_{ij}}{M^2}$$

$$f_U = M\left[\frac{M^2 - M + 1}{(M-1)(M^2-1)}\right]^{\frac{1}{2}}, \qquad f_L = M\left[\frac{1}{(M-1)(M^2-1)}\right]^{\frac{1}{2}}$$

Flow Dominance Measure (cont'd)

Three cases:

- **$f \approx 0$ (a few dominant flows exist) $\Rightarrow$ product layout**
  - can use operations process chart as starting point for developing layout and material handling system design
  - quantitative measures principal source of activity relationship.
- **$f \approx 1$ (many nearly equal flows exist)**
  - any layout equally good with respect to flows .
  - qualitative measures principal source of activity relationship.
- **$0 << f << 1$ (no dominant flows exist) difficult to develop layout**
  - process or product family layout .
  - both quantitative and qualitative measures important source of activity relationship.

Equipment Requirements Planning

Equipment Capacity Table

- Can have different formats

- Links product forecasted demand with available equipment to generate equipment requirements

- Contains detailed information on machine/equipment run-rates, allowances

P06 Sample Solution

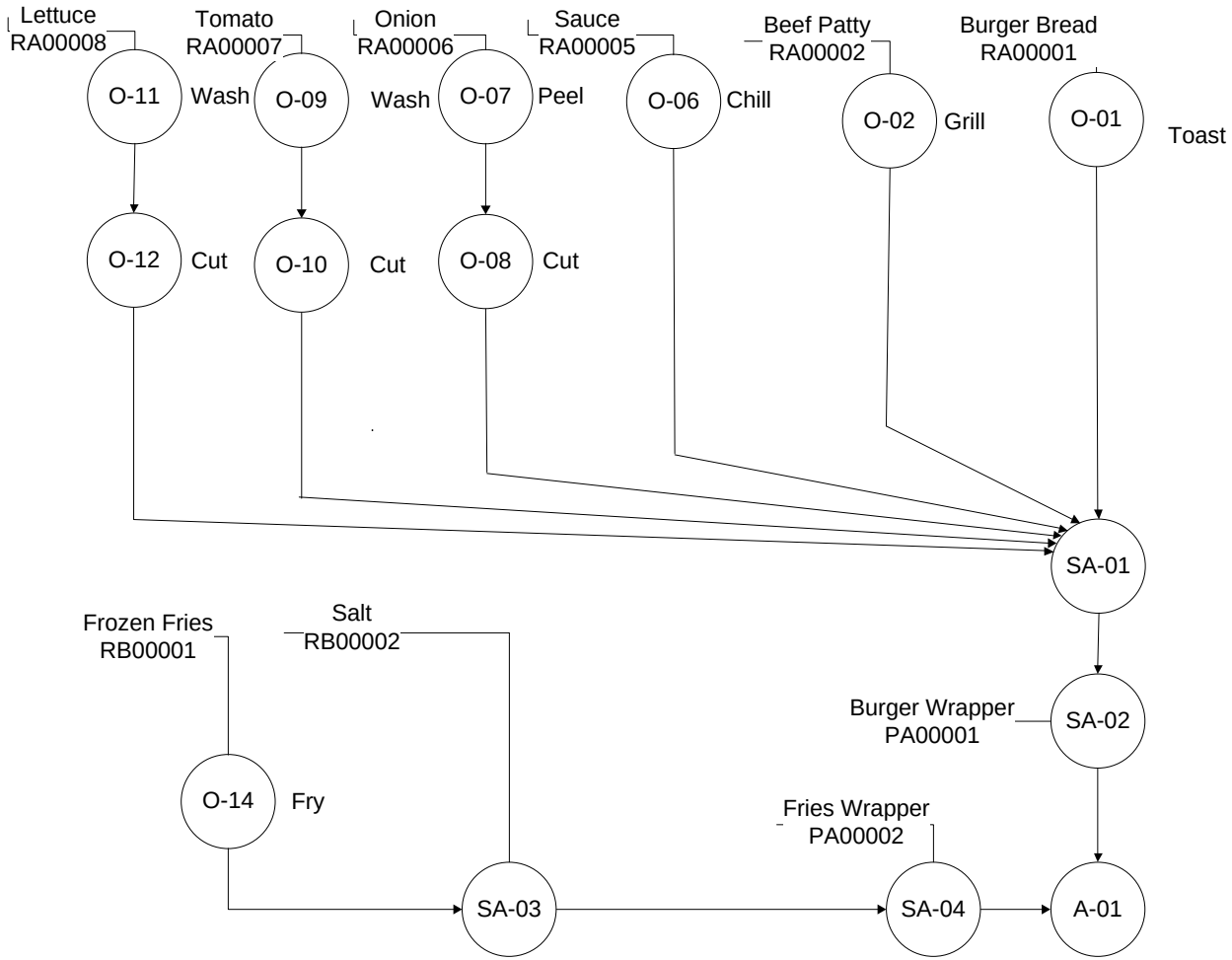
Flow Analysis Information

Structured Parts List

Part Number	Part Description	Part type
RA00001	Burger bread	Raw material
RA00002	Beef patty	Raw material
RA00003	Chicken patty	Raw material
RA00004	Fish patty	Raw material
RA00005	Sauce	Raw material
RA00006	Onion	Raw material
RA00007	Tomato	Raw material
RA00008	Lettuce	Raw material
RB00001	Fries (frozen)	Raw material
RB00002	Salt	Raw material
PA00001	Burger wrapper	Packing
PA00002	Fries wrapper	Packing
FA00001	Wrapped Burger	Finished goods
FA00002	French Fries	Finished goods

Operations Process Chart

Flow Analysis Information



Flow Analysis Information

Parts-Machine Routing & Forecasted Demand

Item	Hourly Peak Demand (forecast)
Grilled Beef Burger set (includes one pack of fries)	50 sets
Fried Chicken Burger set (includes one pack of fries)	56 sets
Special Fish Burger set (includes one pack of fries)	75 sets
Grilled Beef Burger	8 burgers
Fried Chicken Burger	10 burgers
Special Fish Burger	15 burgers
French Fries	53 packets

Part Number	Part Description	Equipment Routing
RA00001	Burger bread	3 - 1 - 4
RA00002	Beef patty	3 - 2 - 4
RA00003	Chicken patty	3 – 6 – 4
RA00004	Fish patty	3 – 2 – 6 - 4
RA00005	Sauce	3 - 4
RA00006	Onion	3 - 4
RA00007	Tomato	3 - 4
RA00008	Lettuce	3 - 4
RB00001	Fries (frozen)	3 - 6
RB00002	Salt	3 - 6
PA00001	Burger wrapper	8 - 5
PA00002	Fries wrapper	8 - 6
FA00001	Wrapped Burger	5 - 7 - 9
FA00002	Fries	6 - 9

From-To Chart (Shows the flow volume)

From \ To	1	2	3	4	5	6	7	8	9
1				107					
2				14.5		22.5			
3	=214/2 = 107	37		42.8		41.1			
4									
5							107		
6				39					117
7									107
8						23.4			
9									

Sample calculation

From shelf to assembly workdesk:
58 beef burger, 66 chicken burger and 90 fish burger per hour (2 breads per batch)

From-To Chart (Shows equivalent flow volume)

- Taking into account of difficulty to move

From \ To	1	2	3	4	5	6	7	8	9
1				107					
2				14.5		22.5			
3	107	37		42.8x2=85.6		41.1			
4									
5							107		
6				39					117
7									107
8					21.4	23.4			
9									

Sample calculation

Assuming moving the vegies is twice as difficult, 1 trip with the vegie cartons= 2 trips of other items = (4*214units/20per batch) x 2

Calculation of f’

$$\overline{w} = \frac{\sum_{i=1}^{M}\sum_{j=1}^{M} w_{ij}}{M^2}$$

$$f' = \frac{\left[\dfrac{\sum_{i=1}^{M}\sum_{j=1}^{M} w_{ij}^{\,2} - M^2\overline{w}^2}{M^2 - 1}\right]^{\frac{1}{2}}}{\overline{w}}$$

Where $\sum_{i=1}^{M}\sum_{j=1}^{M} w_{ij}^{\,2} = 107^2 + 37^2 + 107^2 + \ldots + 117^2 = 73111.12$

$M = 9$

$\overline{w} = (107 + 37 + 107 + \ldots + 117)/9^2 = 10.24$

$$f' = \frac{\left(\dfrac{73111.12 - 9^2(10.2404)^2}{9^2 - 1}\right)^{1/2}}{10.2404}$$

$= 2.78$

Calculation of F_U and F_L

$$f_U = M\left[\frac{M^2 - M + 1}{(M-1)(M^2-1)}\right]^{\frac{1}{2}}, \qquad f_L = M\left[\frac{1}{(M-1)(M^2-1)}\right]^{\frac{1}{2}}$$

$$f_u = 9\left(\frac{9^2-9+1}{(9-1)(9^2-1)}\right)^{1/2}$$

$$= 3.04$$

$$f_L = 9\left(\frac{1}{(9-1)(9^2-1)}\right)^{1/2}$$

$$= 0.36$$

Flow Dominance Measure (f)

$$\frac{f_U - f'}{f_U - f_L} = 0.098$$

Can be
f~0 (product layout), or
0 << f << 1 (no dominant flows exist) difficult to develop layout

process or product family layout .

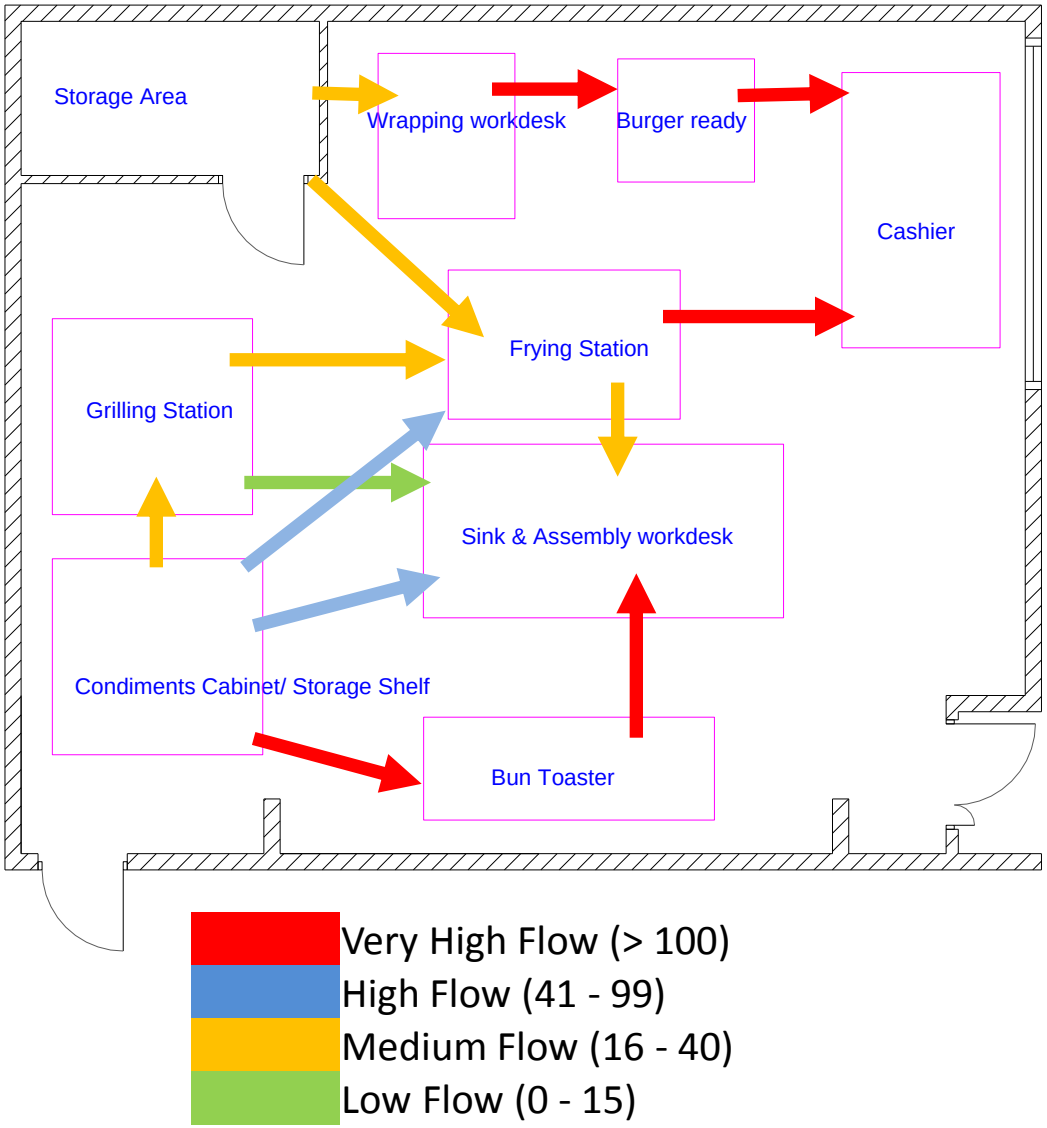
both quantitative and qualitative measures important source of activity relationship.

Between Stations Flow

From \ To	1	2	3	4	5	6	7	8	9
1				107					
2				14.5		22.5			
3	107	37		85.6		41.07			
4									
5							107		
6				39					117
7									107
8					21.4	23.4			
9									

Very High Flow (> 100)
High Flow (41 - 99)
Medium Flow (16 - 40)
Low Flow (0 - 15)

Proposed Layout



A simple layout can be done based on the from-to chart

Process with high flow are placed together to minimize the transportation work

Further modification can be made to the layout on the left to reduce the distance between areas of high flow

Note that the layout will be affected by actual floor plan

Minimum Equipment Requirement

Equipment	Gross Output/hr	Equipment Efficiency	Net Output/hr	Demand/ hr	Number of Equipment Needed
Bread Toaster	120	92%	110	214	2
Grilling Station	72	92%	66	148	3
Sink and Assembly Workdesk	180	92%	165	214	2
Wrapping Workdesk	300	92%	276	214	1
Frying Station	131	92%	120	390	4
Condiments Cabinet / Storage Shelf	-	-	-		1
Burger Picking	-	-	-		1
Storage Area	-	-	-		1
Cashier	-	-	-		1

Learning Objectives

- Analyze and determine the process flow of a product from a flow diagram using Flow Dominance Measure (FDM)
- Calculate the total flow volume for a particular layout
- Identify different areas of inefficiency in a facility and identify areas of changes in order to reduce the flow volume
- Layout different departments within a facility to ensure a good flow of materials and finished goods