

# Undergraduate and Graduate Material Handling Courses: An Interactive Experience

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# Structure of the talk

- Graduate Course
- Undergraduate Course
- Interactions through Design Competition

# Graduate Course

3 credits

Our program is heavy OR centric; this course provides one of the few application courses

Build connections to the other parts of the curriculum

Schedule one either warehouse tour or manufacturing facility tour

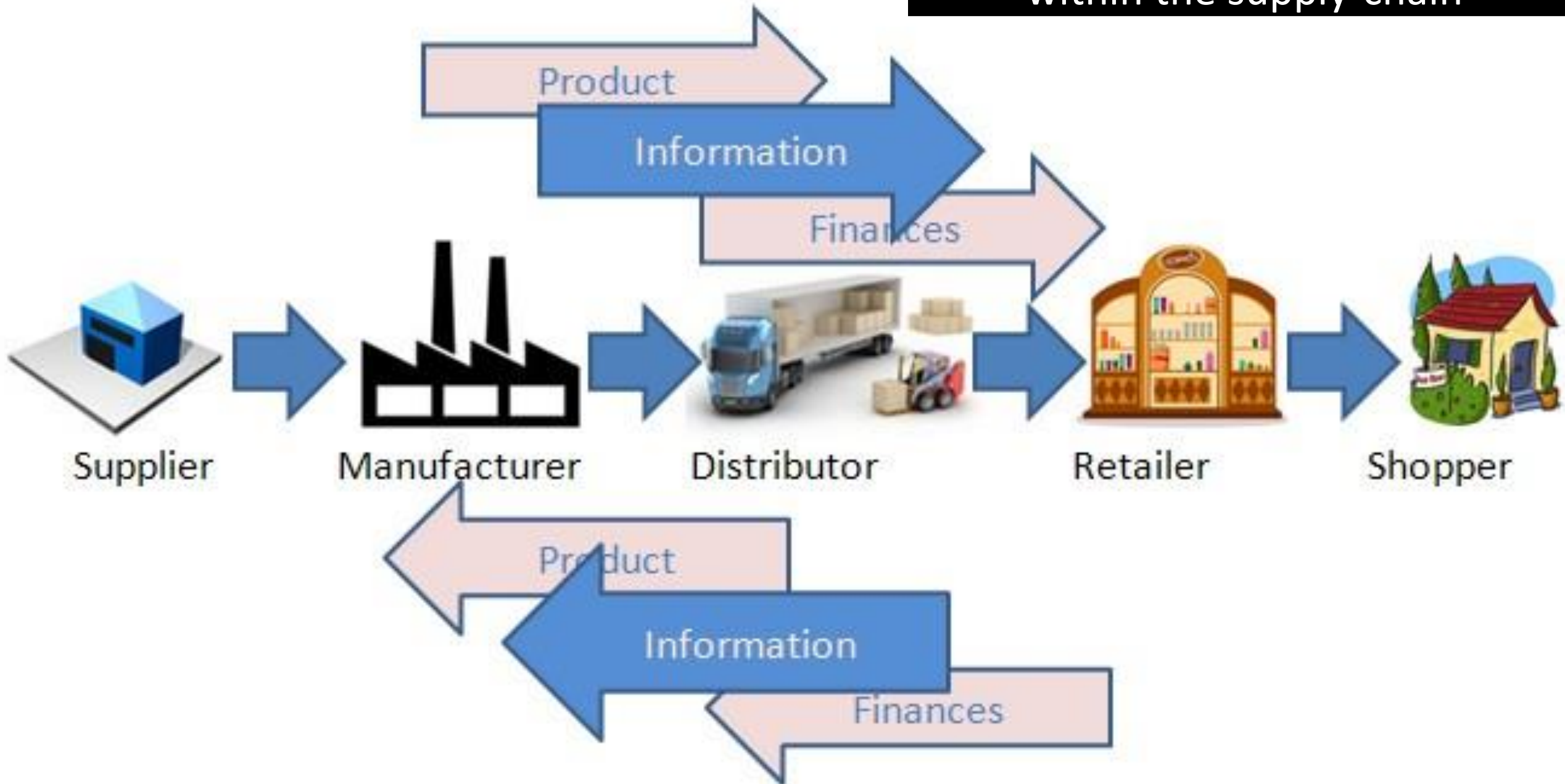
Teach from a combination of:

- Bartholdi and Hackman
- Tompkins et al.
- My own classnotes / research papers

Introduction to the warehouse  
within the supply-chain



# Role of Manufacturing within the supply-chain





**MHI.**

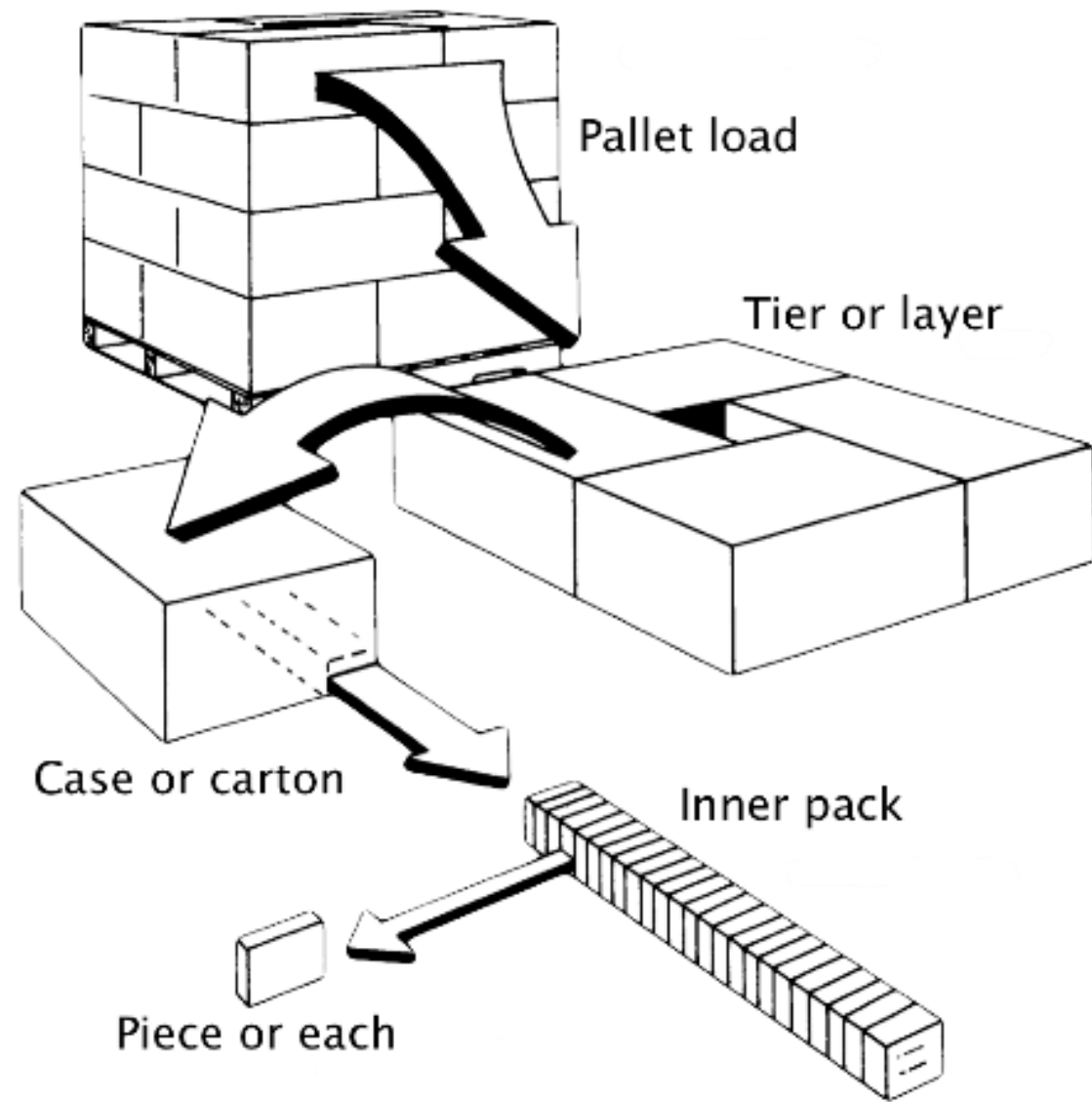
*THE INDUSTRY THAT MAKES SUPPLY CHAINS WORK™*

# Material handling terminology and basic concepts

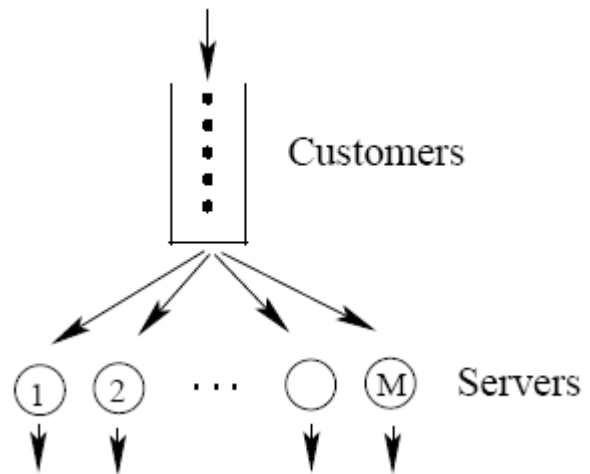




# Warehousing & Distribution



# Modeling Methods



Min  $\theta$

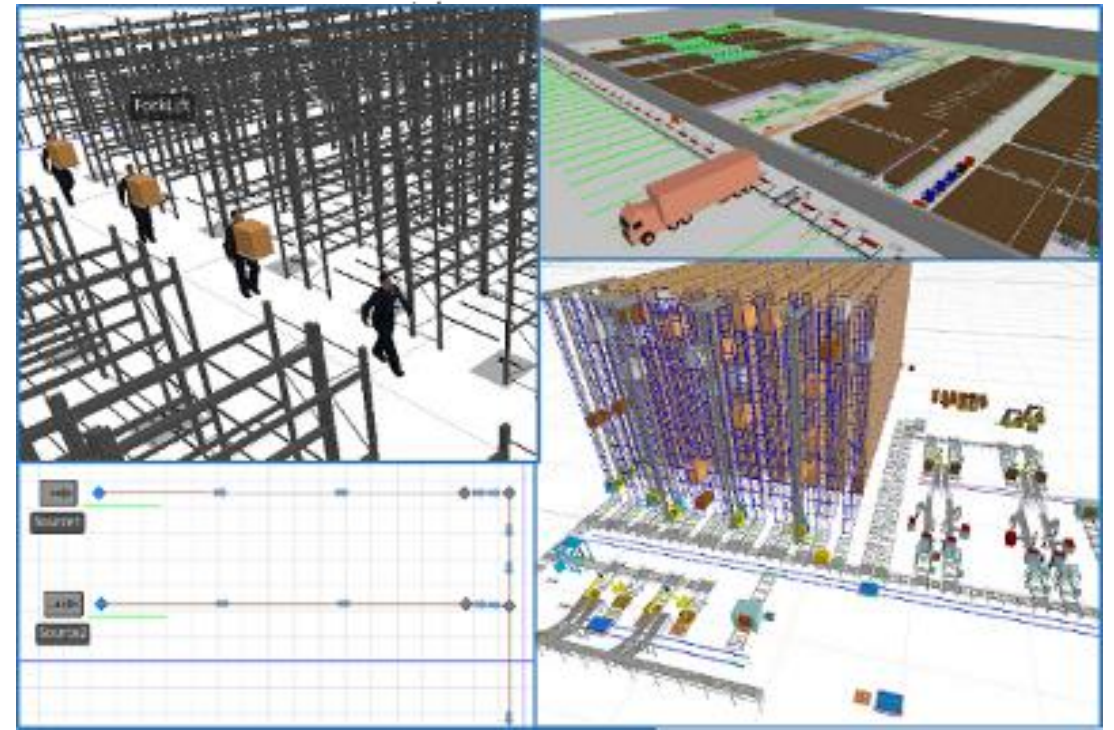
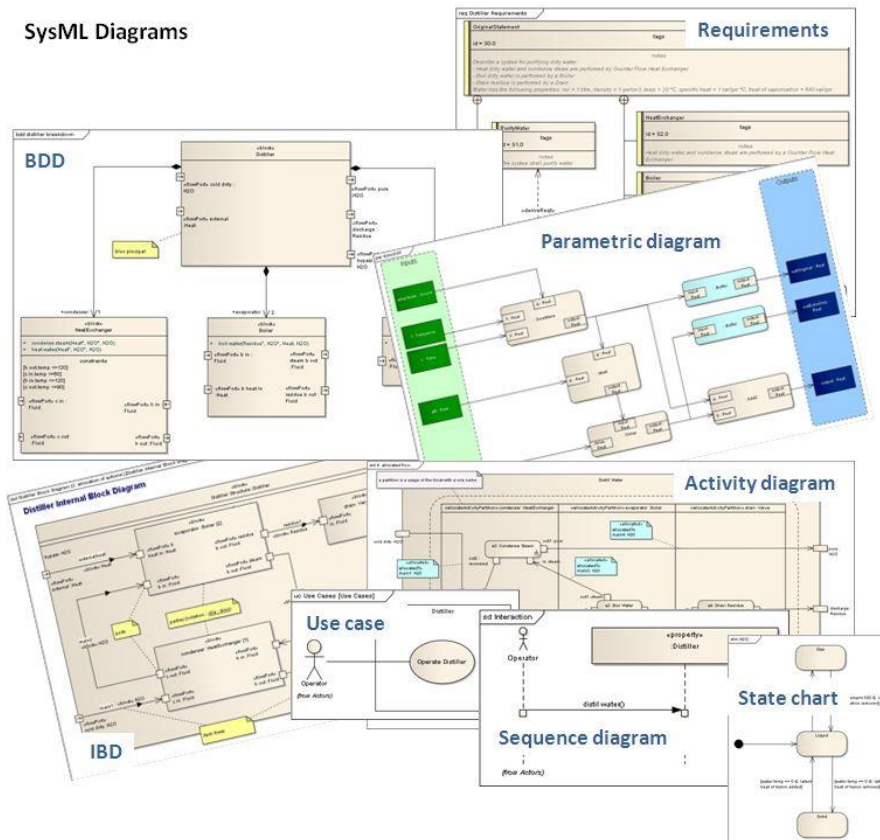
s.t.

$$\sum_{r=1}^n \sum_{j=1}^n \lambda_{jr} x_{ij} \leq \theta \sum_{r=1}^n x_{ir} \quad \forall i$$

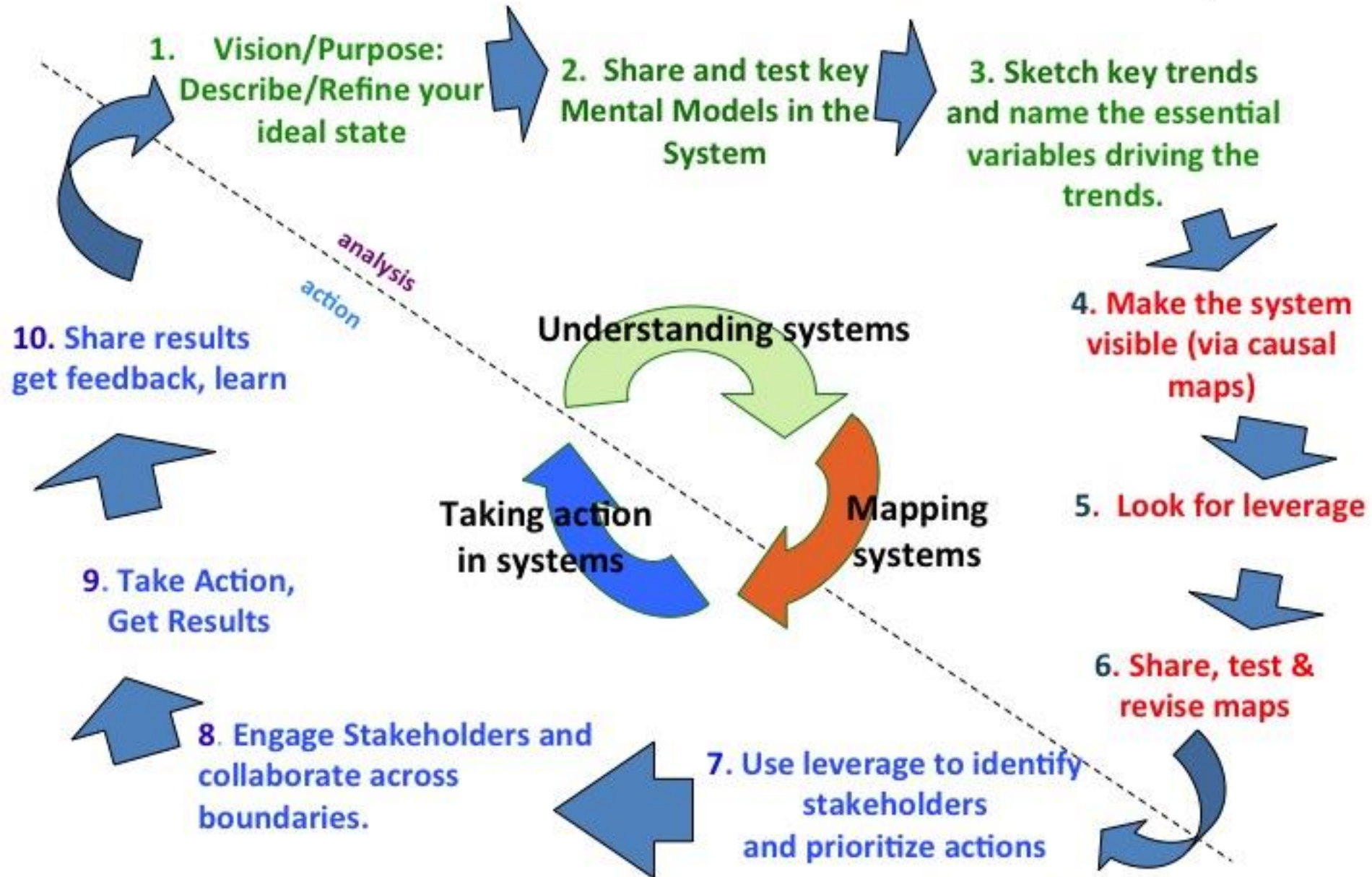
$$\sum_{r=1}^n \sum_{j=1}^n \lambda_{jr} y_{kj} \geq \sum_{r=1}^n y_{kr} \quad \forall k \quad (1)$$

$$\sum_{j=1}^n \lambda_{jr} = \delta_r \quad \forall r$$

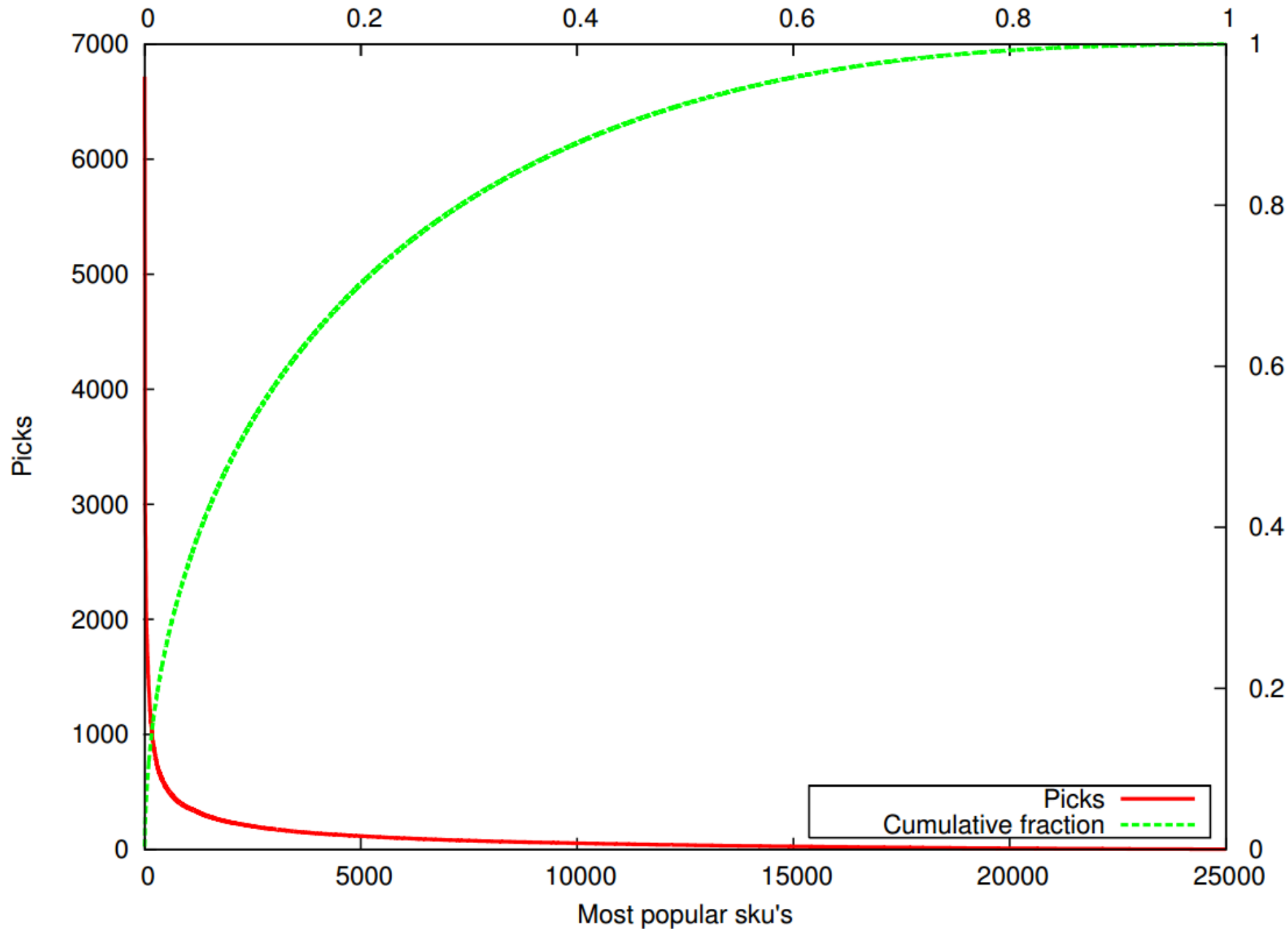
SysML Diagrams



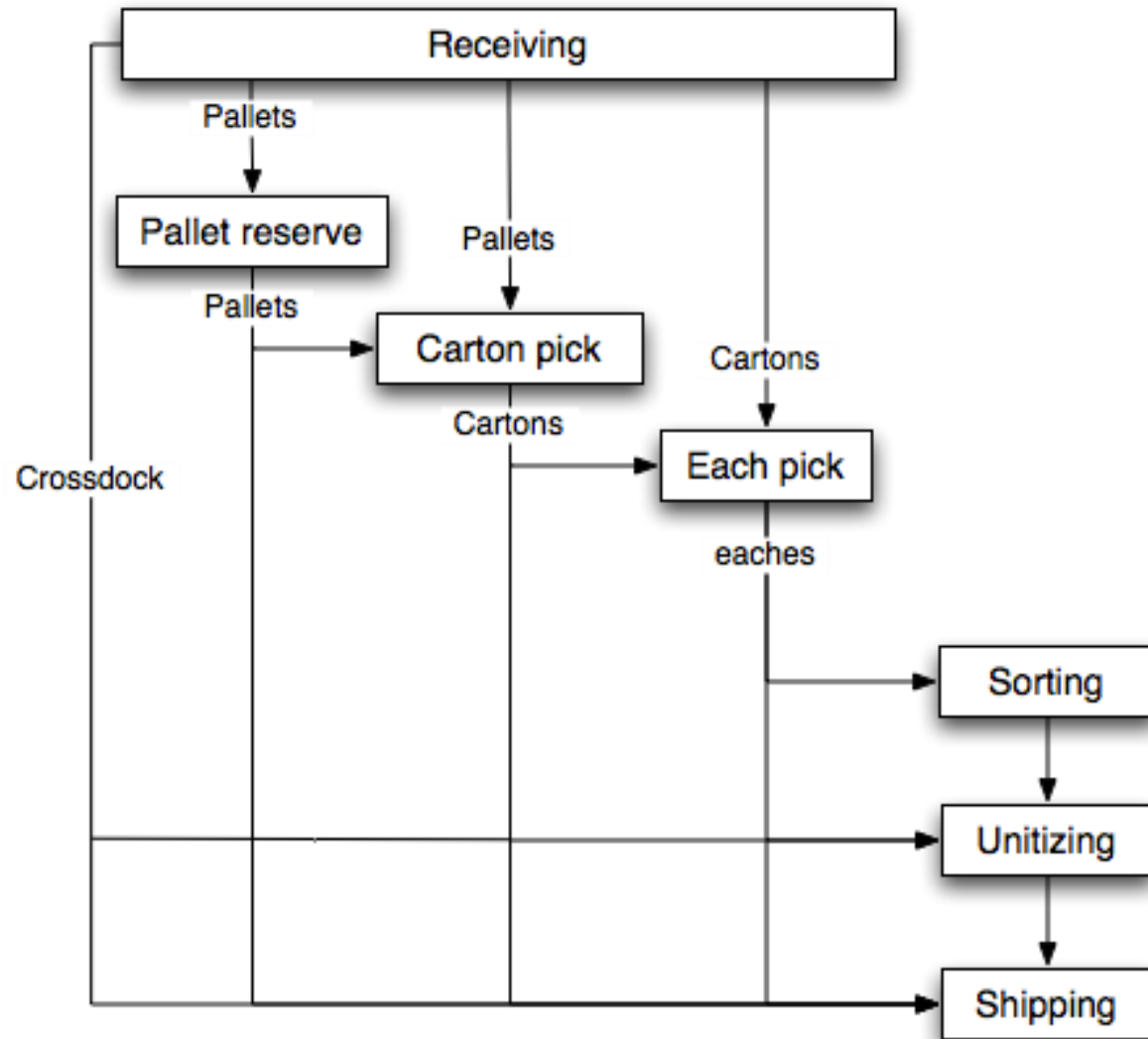
# Systems Thinking in Action



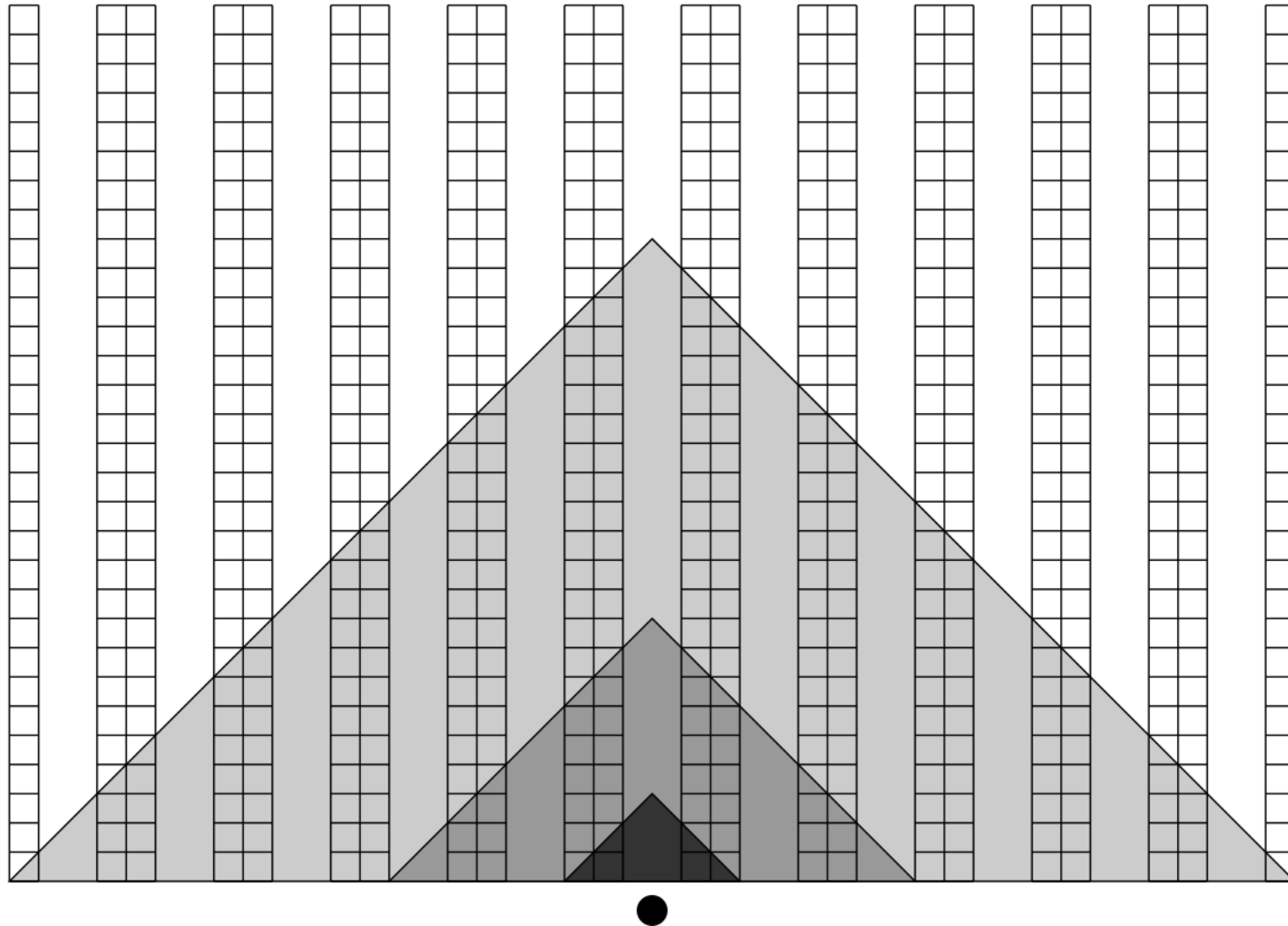
# Activity Profiling

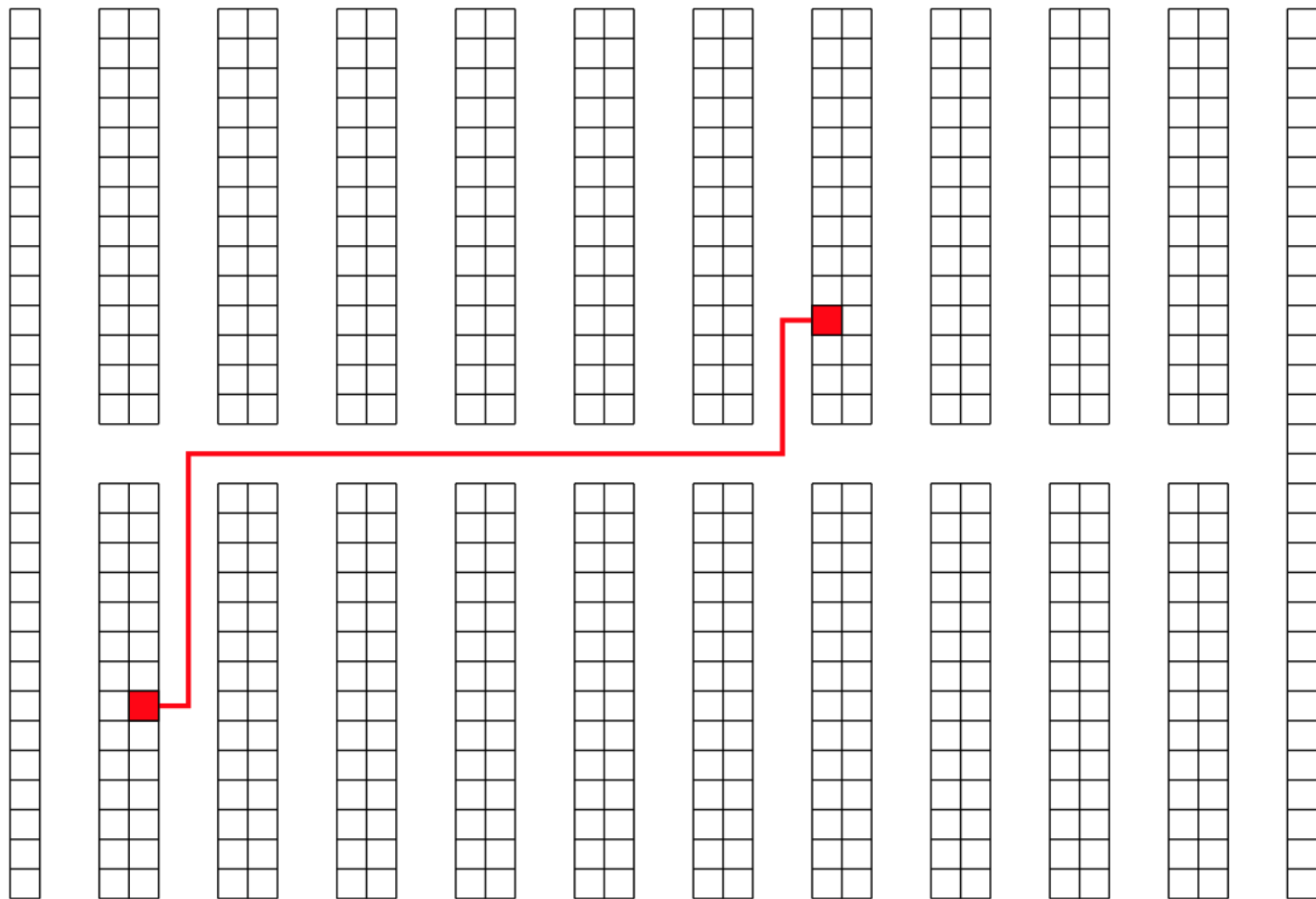


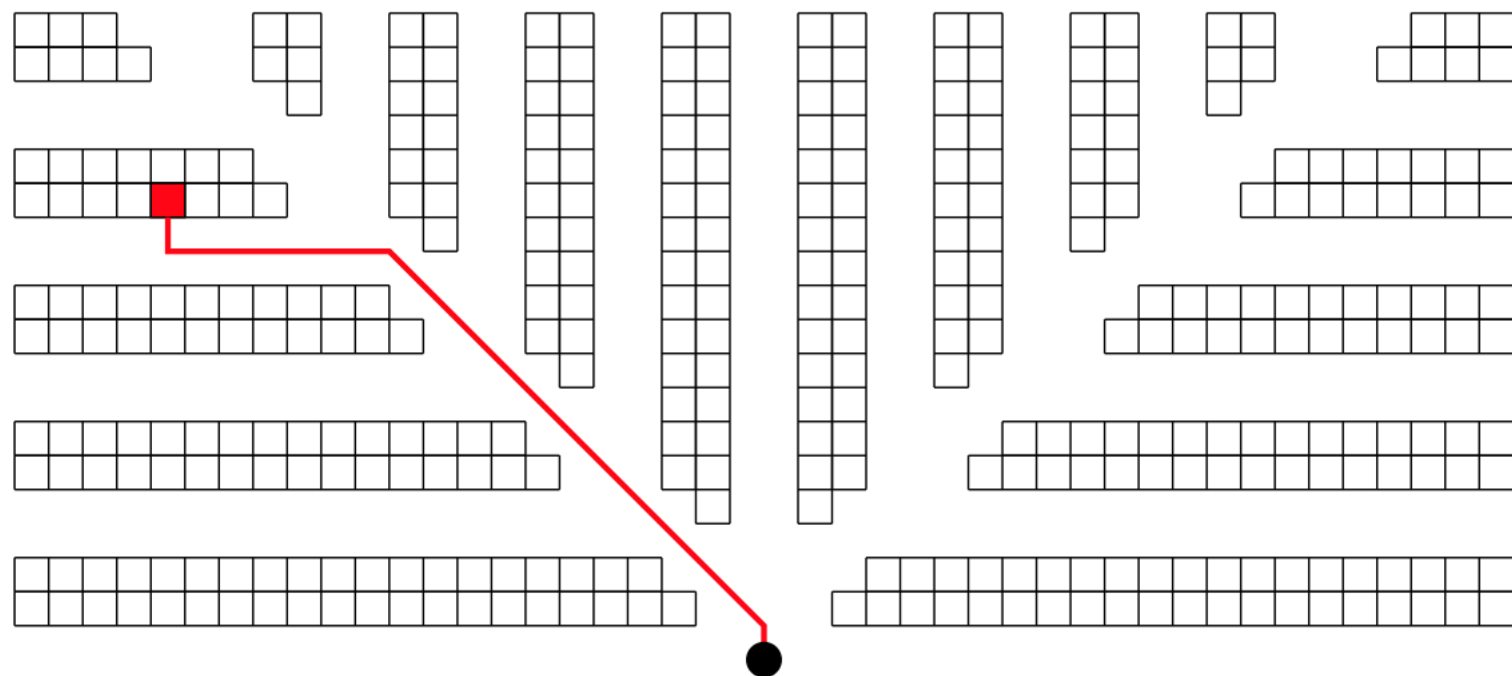
# Functional Flow Diagram



## Unit Load Warehouse



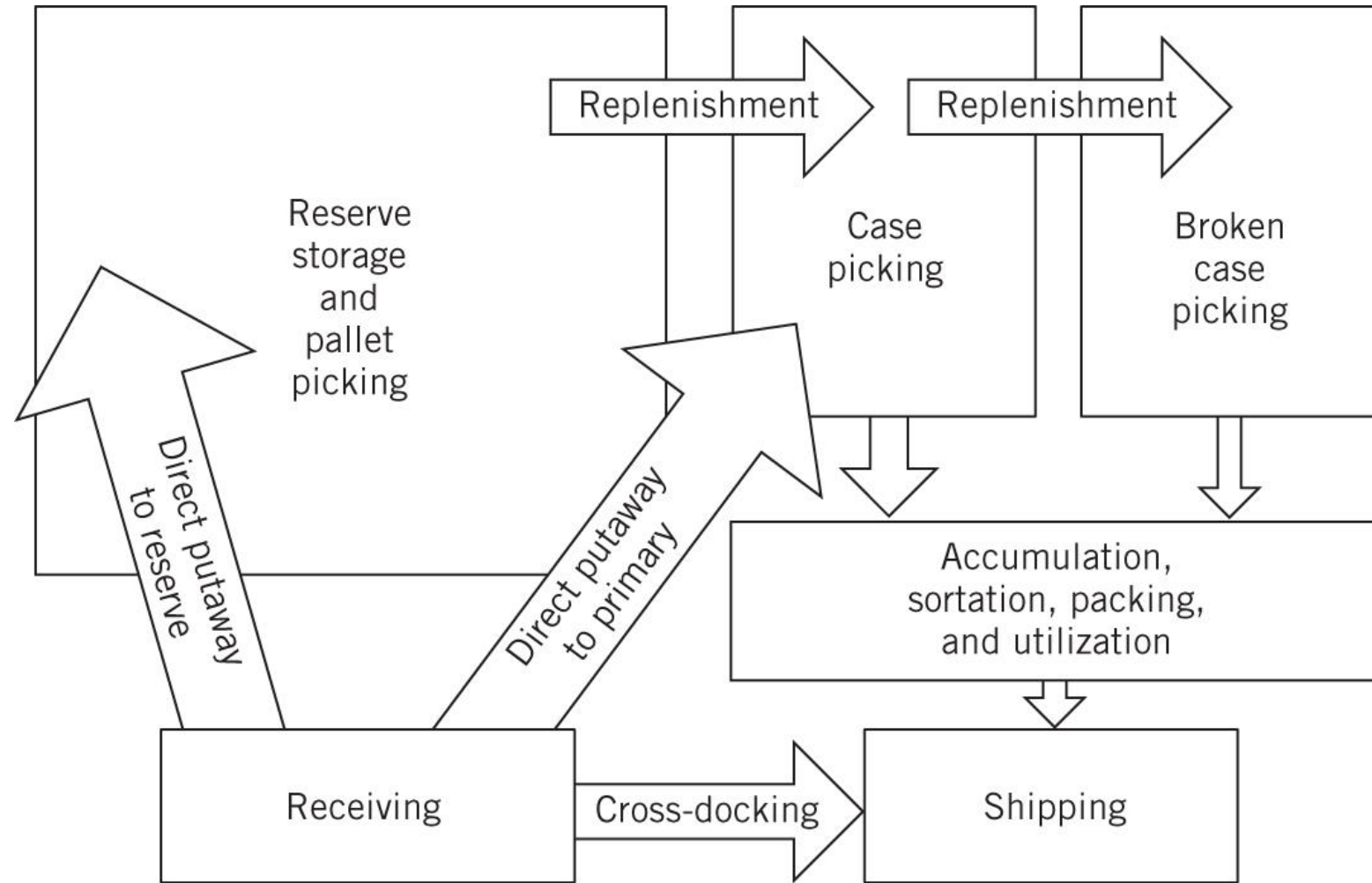




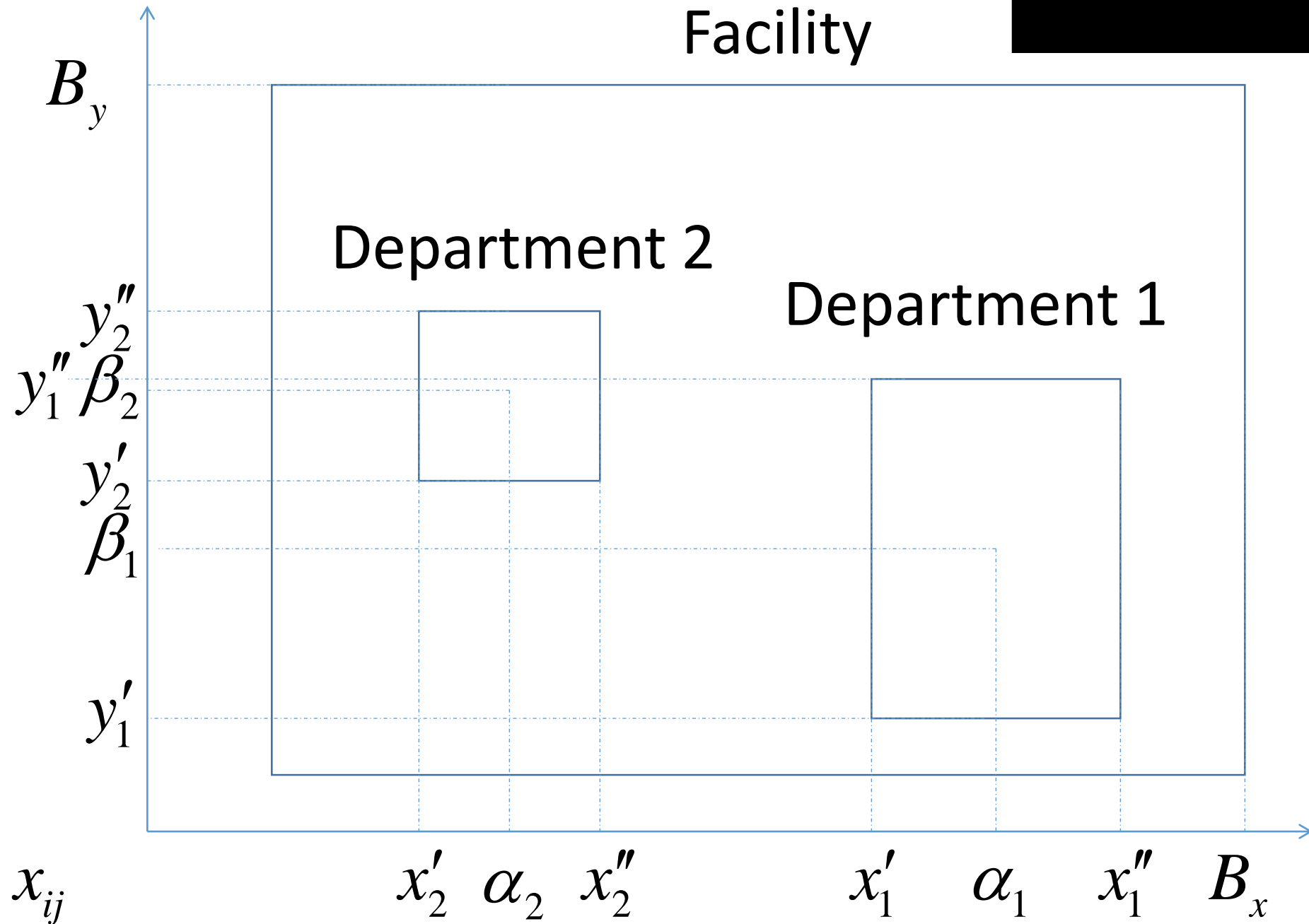
# Automated Storage and Retrieval Systems



# Warehouse Operations



# Mixed Integer Programming Problem



# Mixed Integer Programming Problem

$$\text{Minimize } z = \sum_i \sum_j f_{ij} c_{ij} (|\alpha_i - \alpha_j| + |\beta_i - \beta_j|) \quad (6.5)$$

$$\text{Subject to } L_i^l \leq (x_i'' - x_i') \leq L_i^u \quad \text{for all } i \quad (6.6)$$

$$W_i^l \leq (y_i'' - y_i') \leq W_i^u \quad \text{for all } i \quad (6.7)$$

$$(x_i'' - x_i')(y_i'' - y_i') = A_i \quad \text{for all } i \quad (6.8)$$

$$0 \leq x_i' \leq x_i'' \leq B_x \quad \text{for all } i \quad (6.9)$$

$$0 \leq y_i' \leq y_i'' \leq B_y \quad \text{for all } i \quad (6.10)$$

$$\alpha_i = 0.5x_i' + 0.5x_i'' \quad \text{for all } i \quad (6.11)$$

$$\beta_i = 0.5y_i' + 0.5y_i'' \quad \text{for all } i \quad (6.12)$$

$$x_j'' \leq x_i' + M(1 - z_{ij}^x) \quad \text{for all } i \text{ and } j, i \neq j \quad (6.13)$$

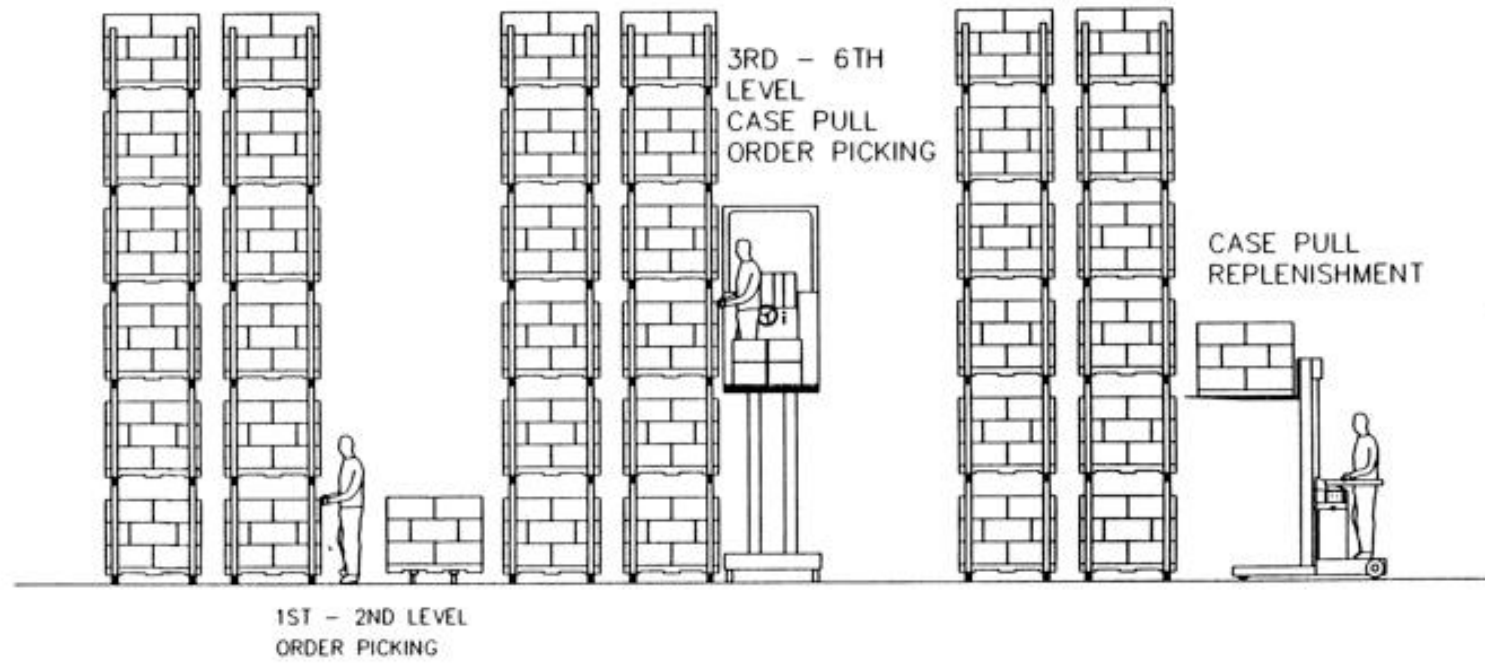
$$y_j'' \leq y_i' + M(1 - z_{ij}^y) \quad \text{for all } i \text{ and } j, i \neq j \quad (6.14)$$

$$z_{ij}^x + z_{ji}^x + z_{ij}^y + z_{ji}^y \geq 1 \quad \text{for all } i \text{ and } j, i < j \quad (6.15)$$

$$\alpha_i, \beta_i \geq 0 \quad \text{for all } i \quad (6.16)$$

$$x_i', x_i'', y_i', y_i'' \geq 0 \quad \text{for all } i \quad (6.17)$$

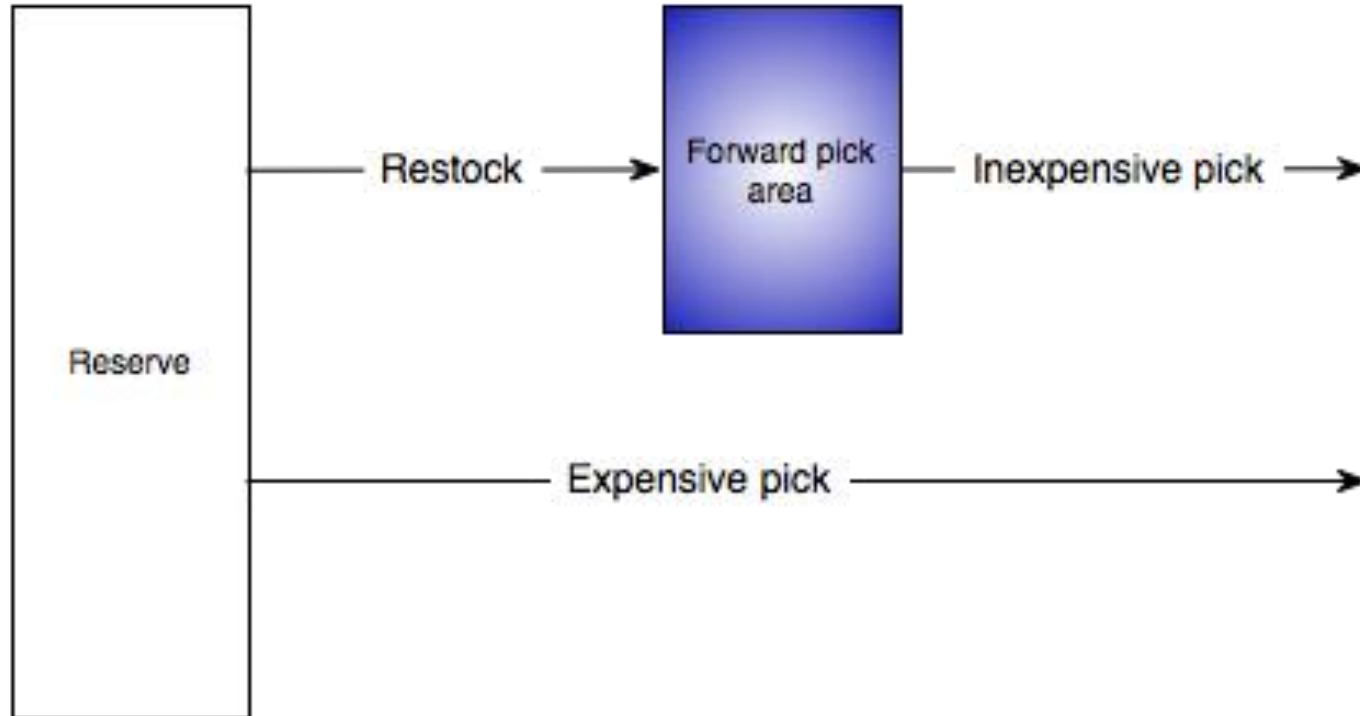
$$z_{ij}^x, z_{ij}^y \text{ 0/1 integer} \quad \text{for all } i \text{ and } j, i \neq j \quad (6.18)$$



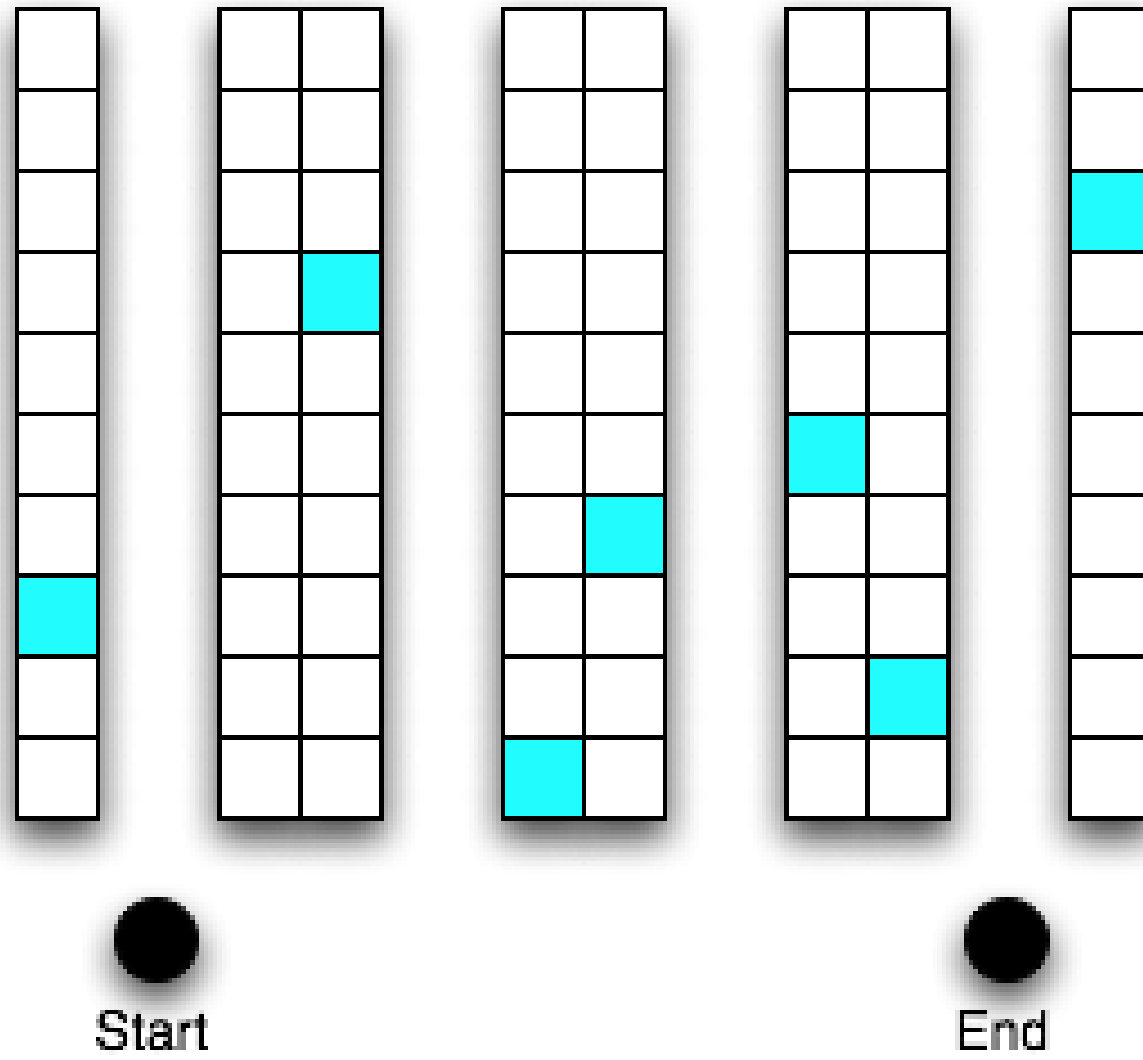
# Forward-Reserve Decisions

**Shared storage**

**Dedicated storage**

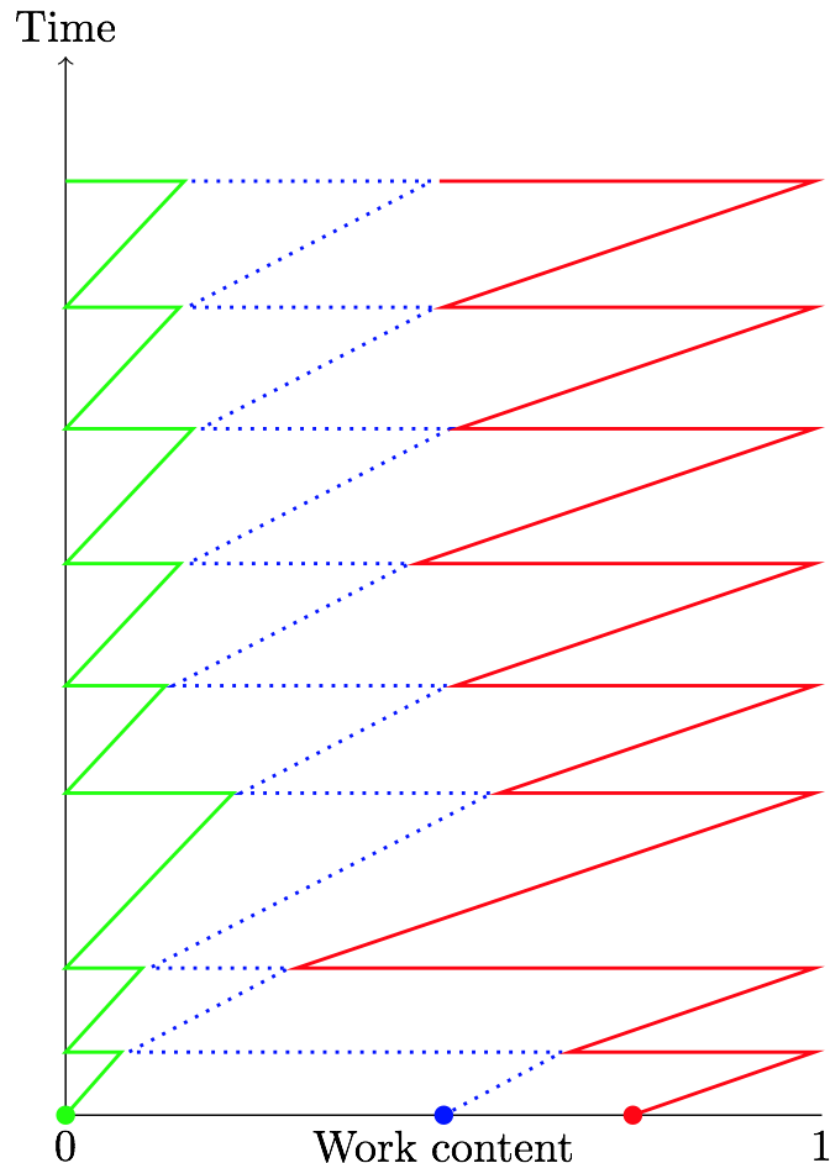


# Routing and Optimal Routing

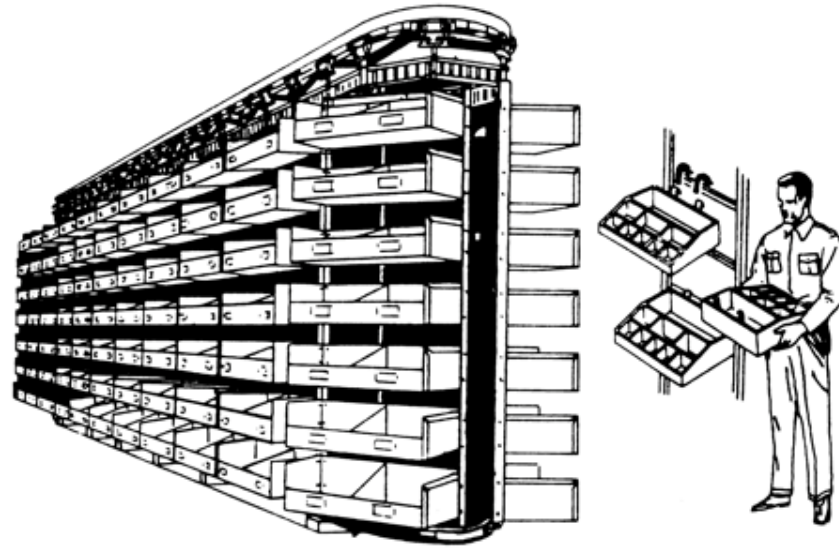


Eventual partition of work

# Bucket Brigades



# Material Handling Equipment



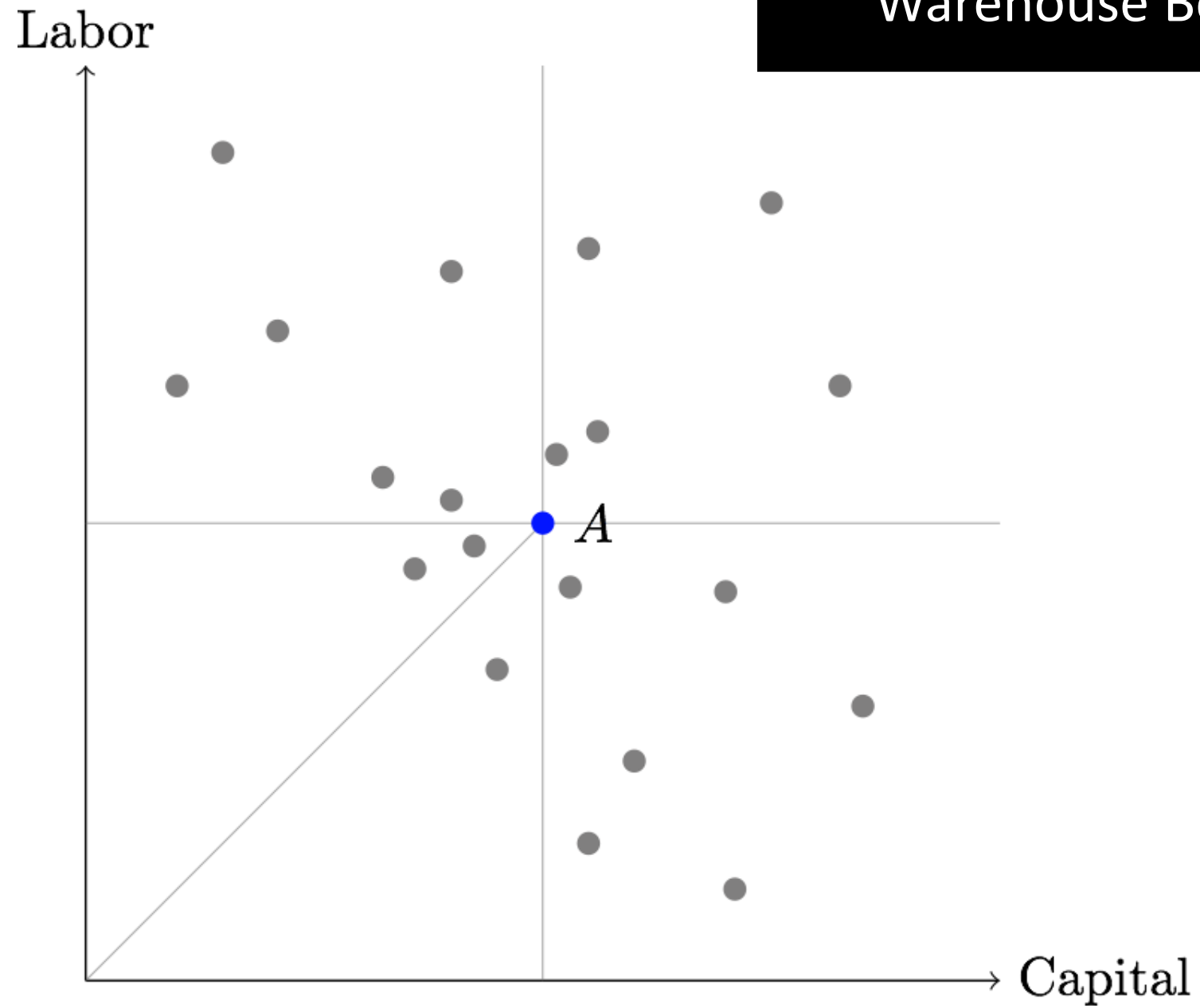
# The Mobile Warehouse CYCLE COUNT



# Pallet Building



# Warehouse Benchmarking



# Denver Airport Baggage Handling System



# Undergraduate Course

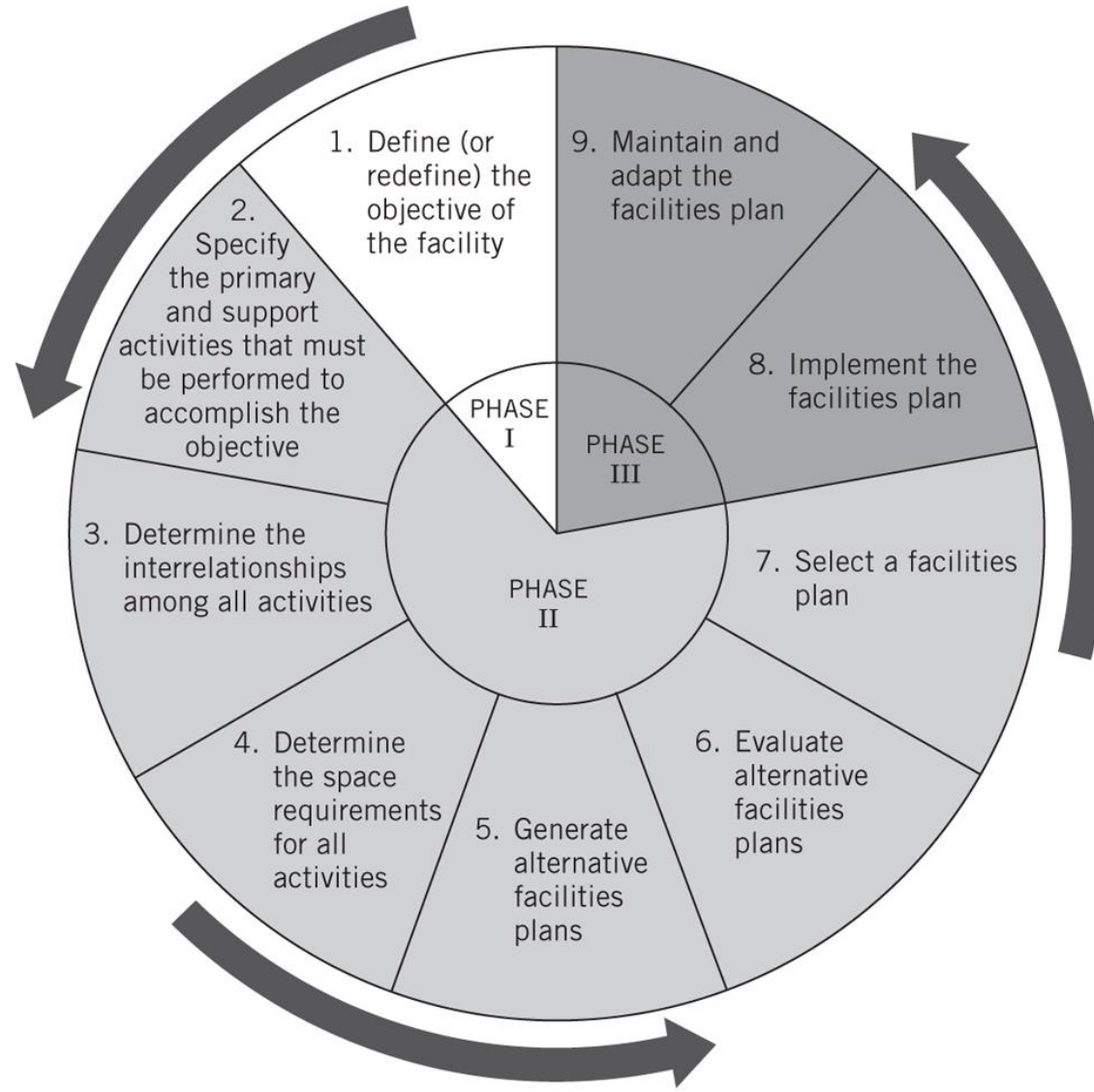
4 credits

Lab section

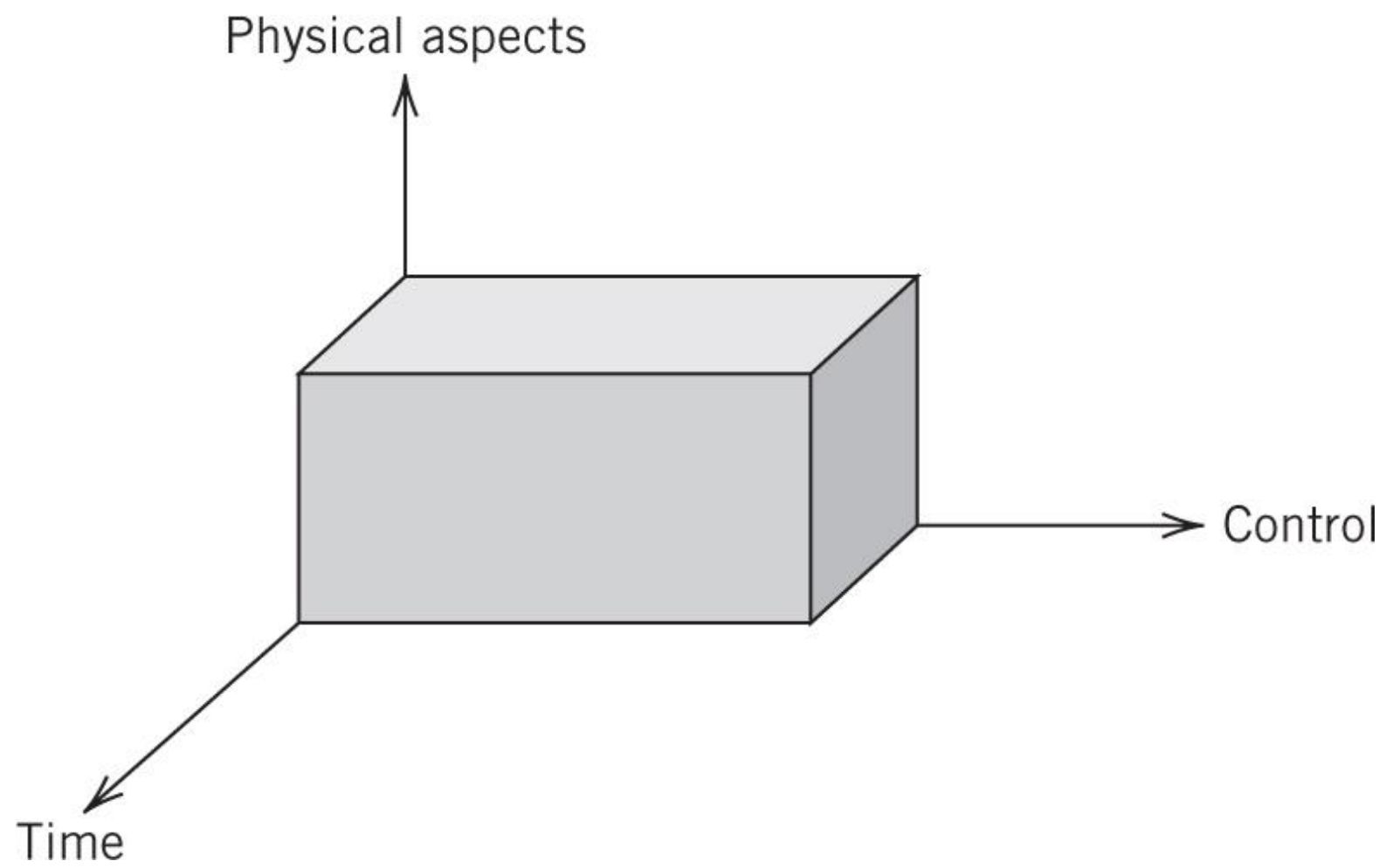
- Case Study 1 – Layout
- Case Study 2 – Layout, Material Handling, Operational Policy
- Case Study 3 – MHI Case Study competition

Writing intensive course

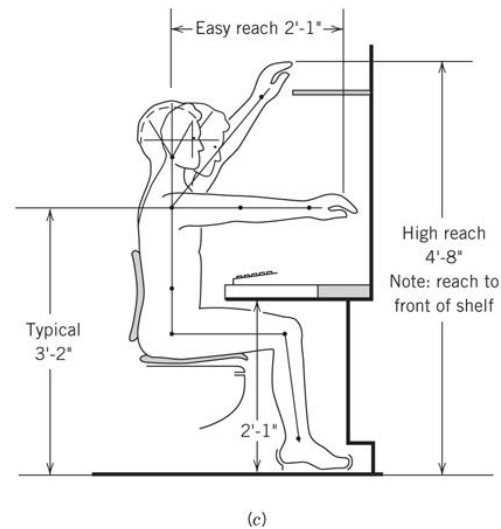
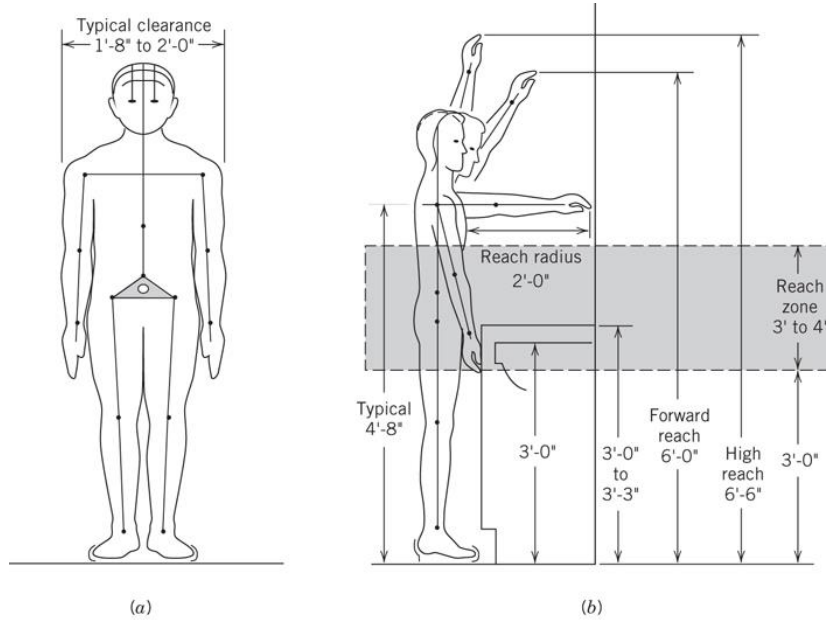
# Facility Planning Introduction



(a)



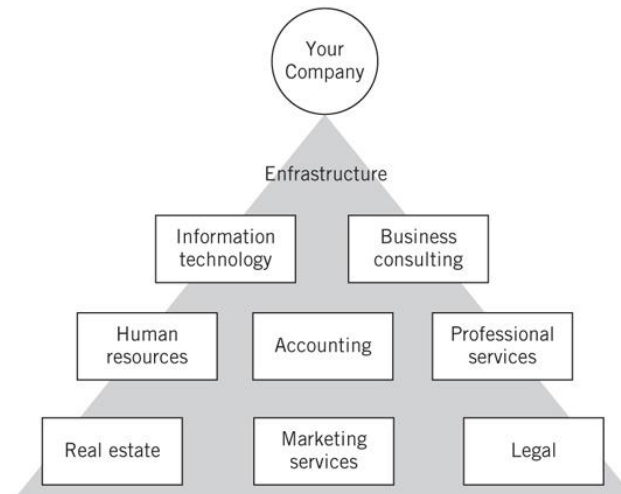
# Personnel Requirements and Detailed Layout

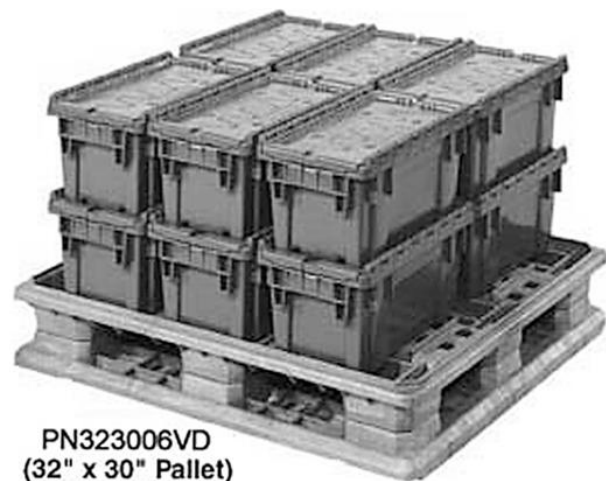


### Traditional Outsourcing

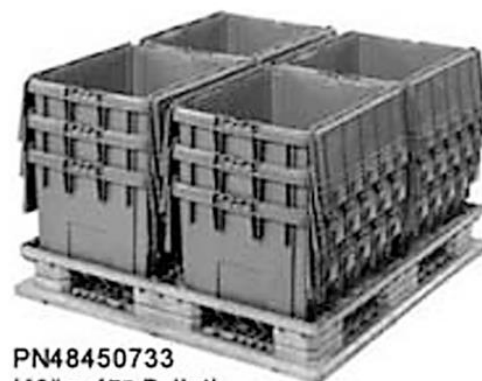


### Outsourcing with Enfrastructure





PN323006VD  
(32" x 30" Pallet)



PN48450733  
(48" x 45" Pallet)



MA24191489



MA24111489



MA24110989



MA12110789



MD48221489  
(Detached Lid)



MA48111489



MA15080789  
(32" x 30" System)



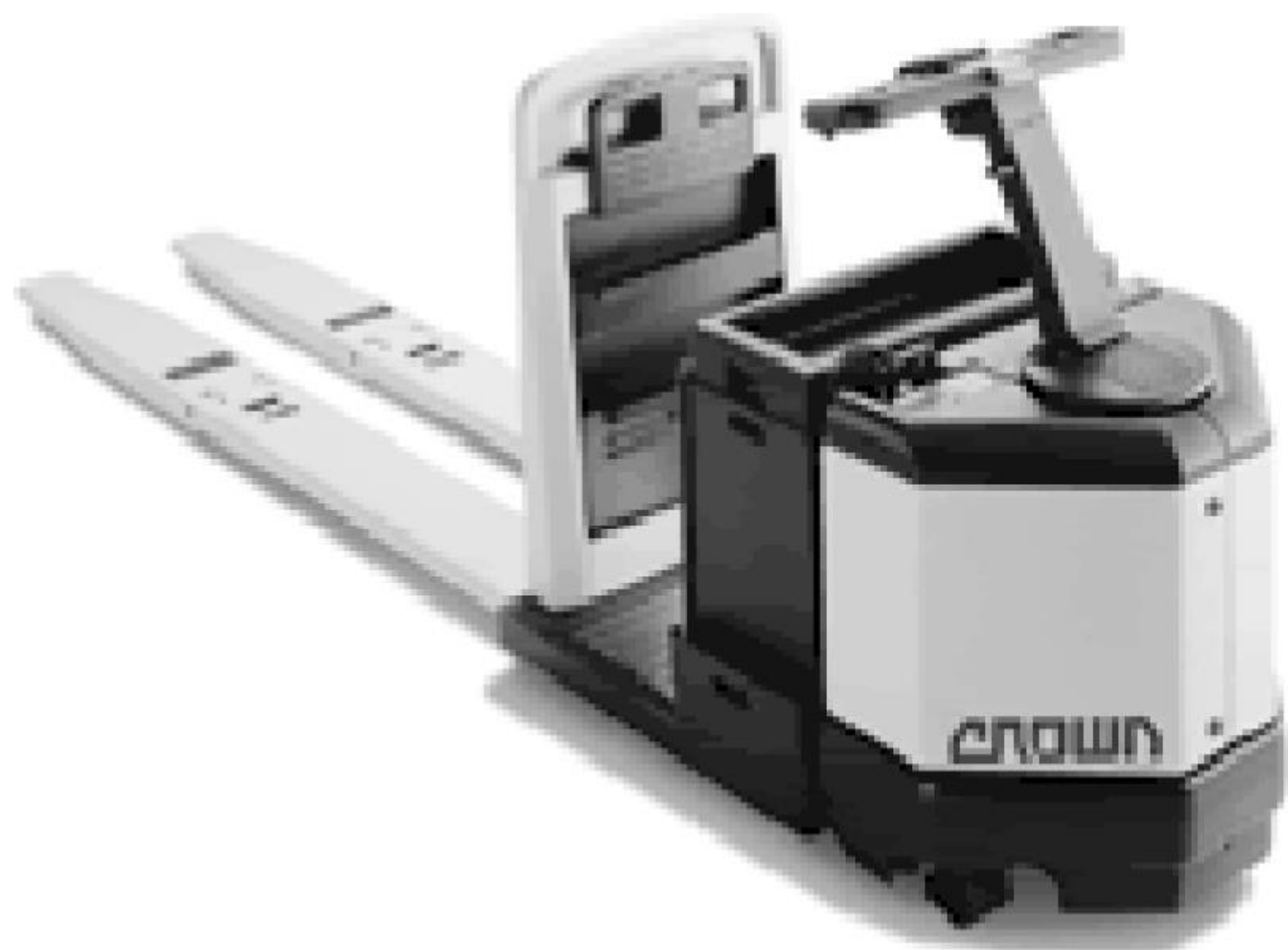
MA10090989  
(32" x 30" System)

# Material Handling







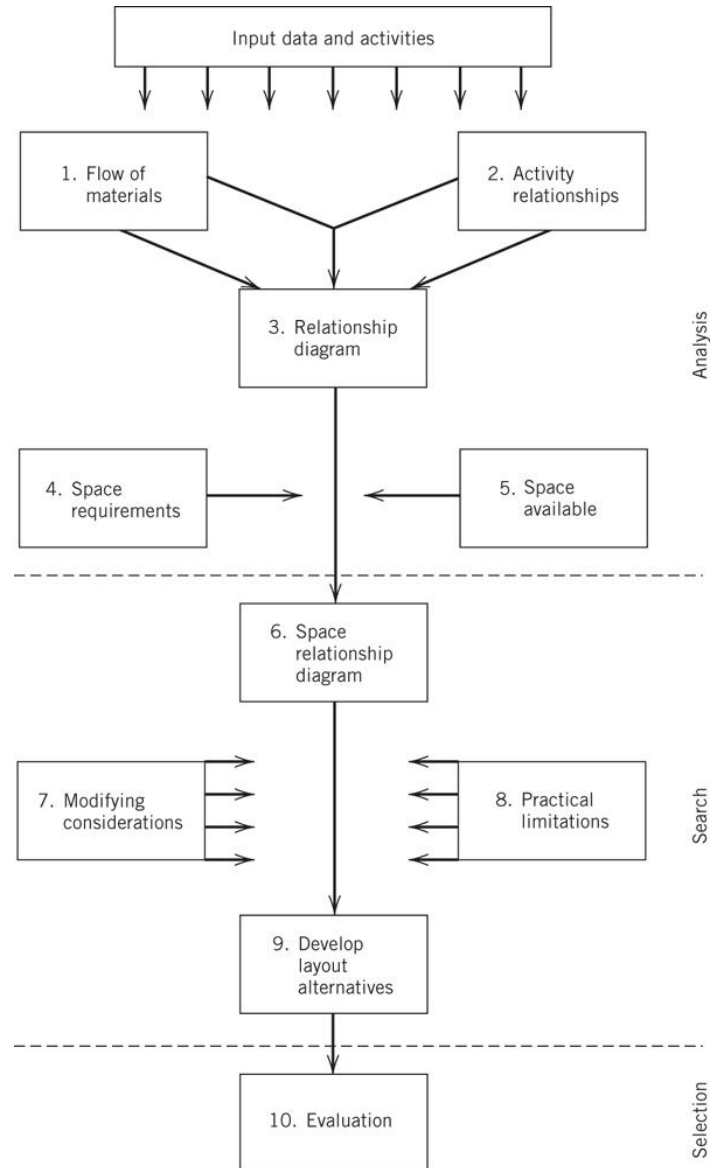








# Systematic Layout Procedure



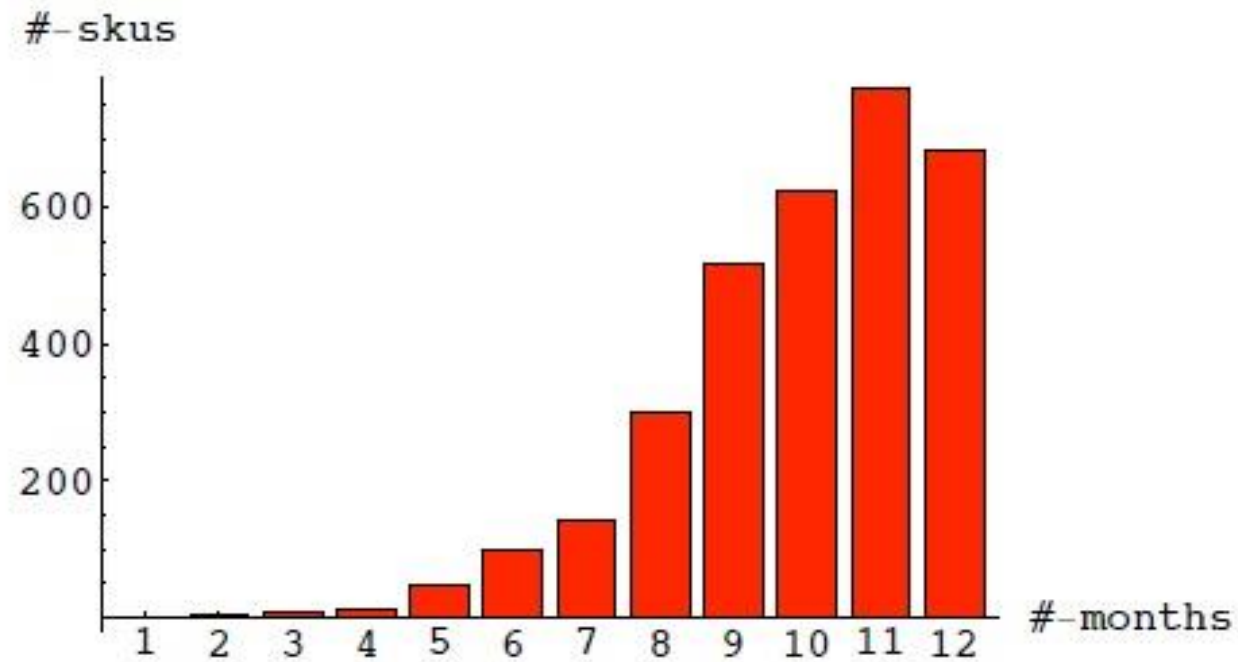
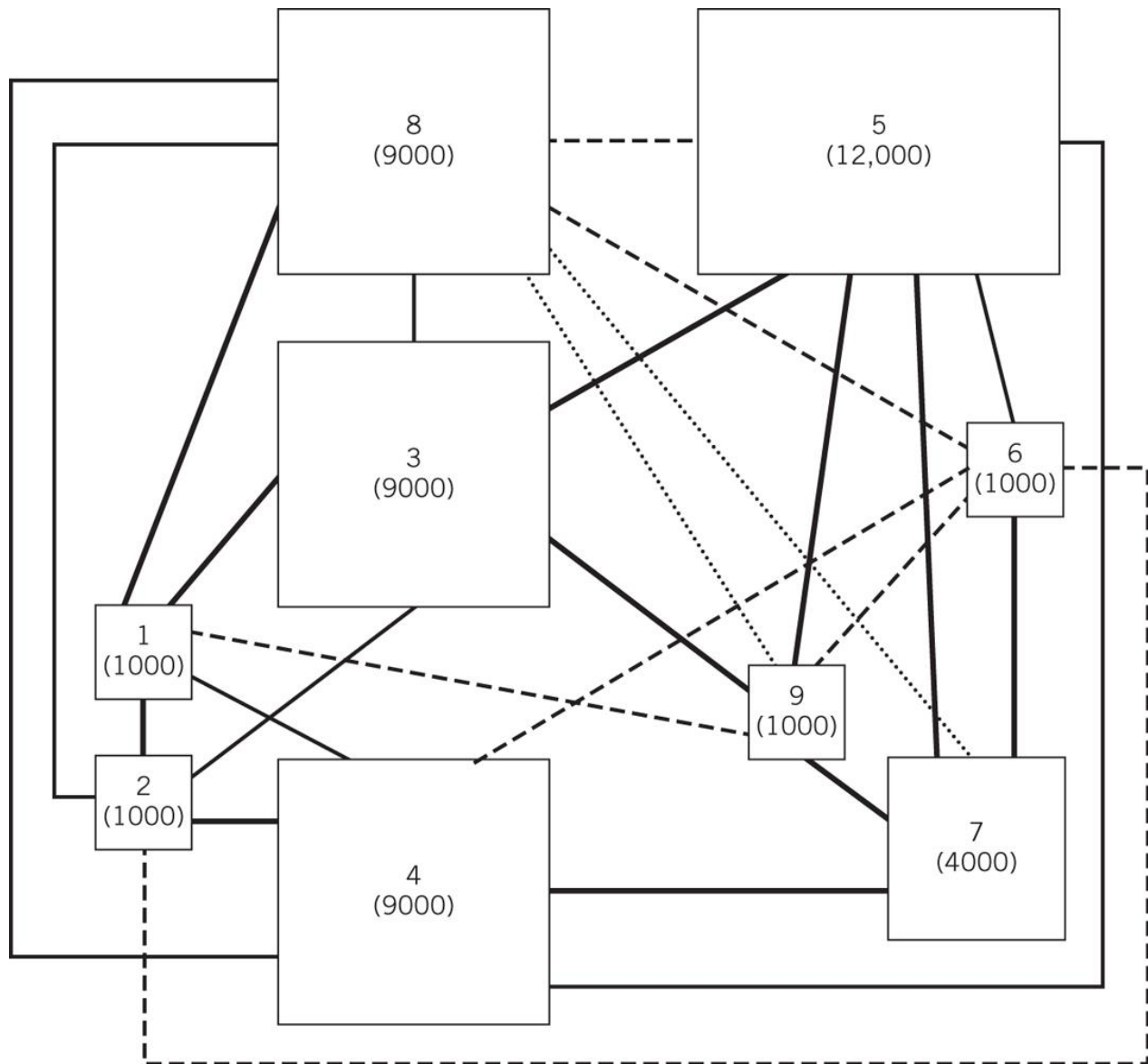
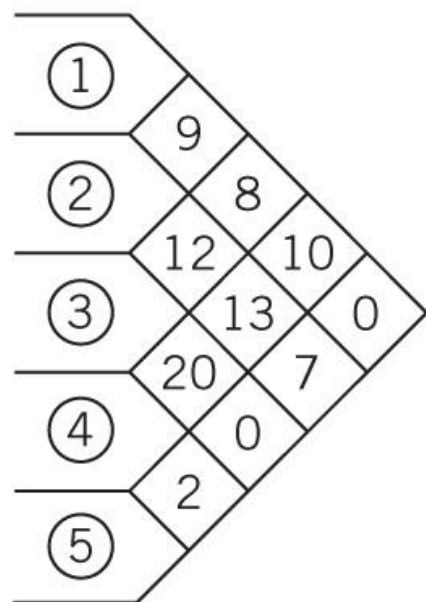
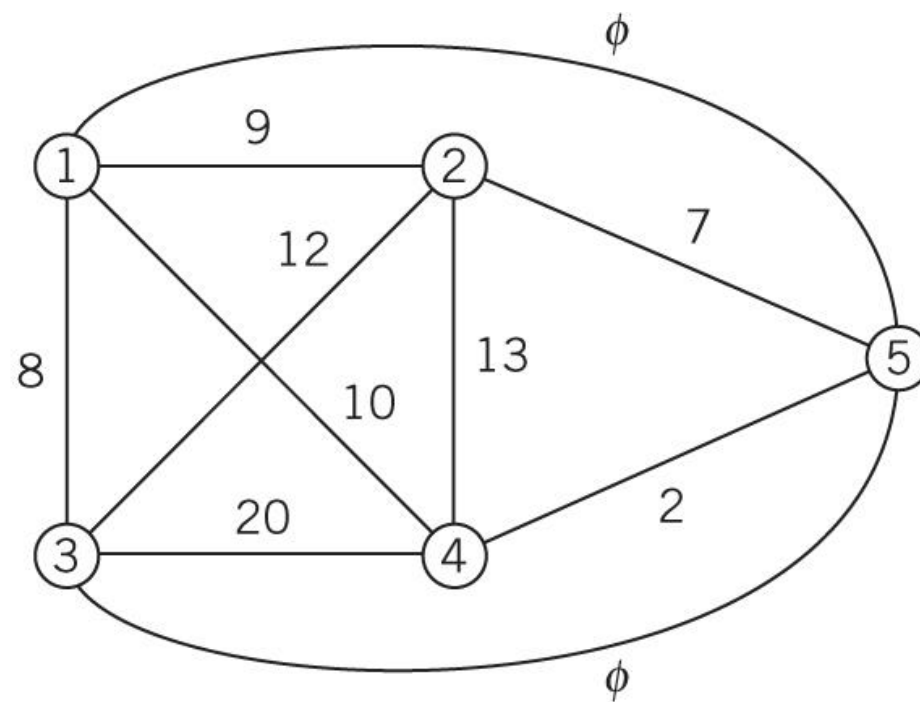


Figure 14.3: Number of the most popular skus that were requested during only  $n$  months of the year ( $n = 1, \dots, 12$ ).





(a) Relationship chart



(b) Relationship diagram

- $b_{ij}$  is the benefit generated by assigning department j to location i
- $x_{ij}$  equal 1 if department j is assigned to location i and 0 otherwise

$$\text{Max}_x \sum_i \sum_j b_{ij} x_{ij}$$

$$s.t. \sum_i x_{ij} = 1$$

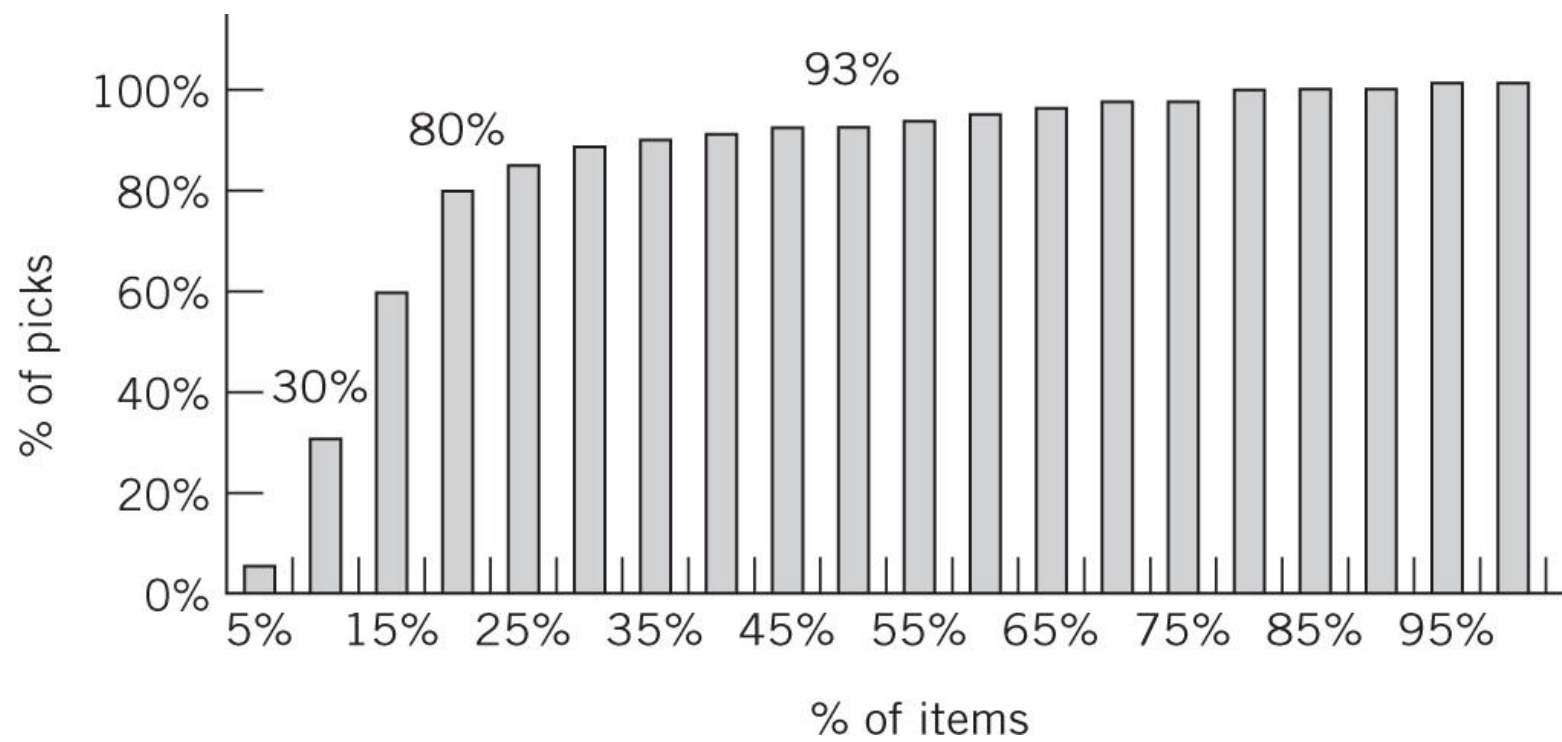
$$\sum_j x_{ij} = 1$$

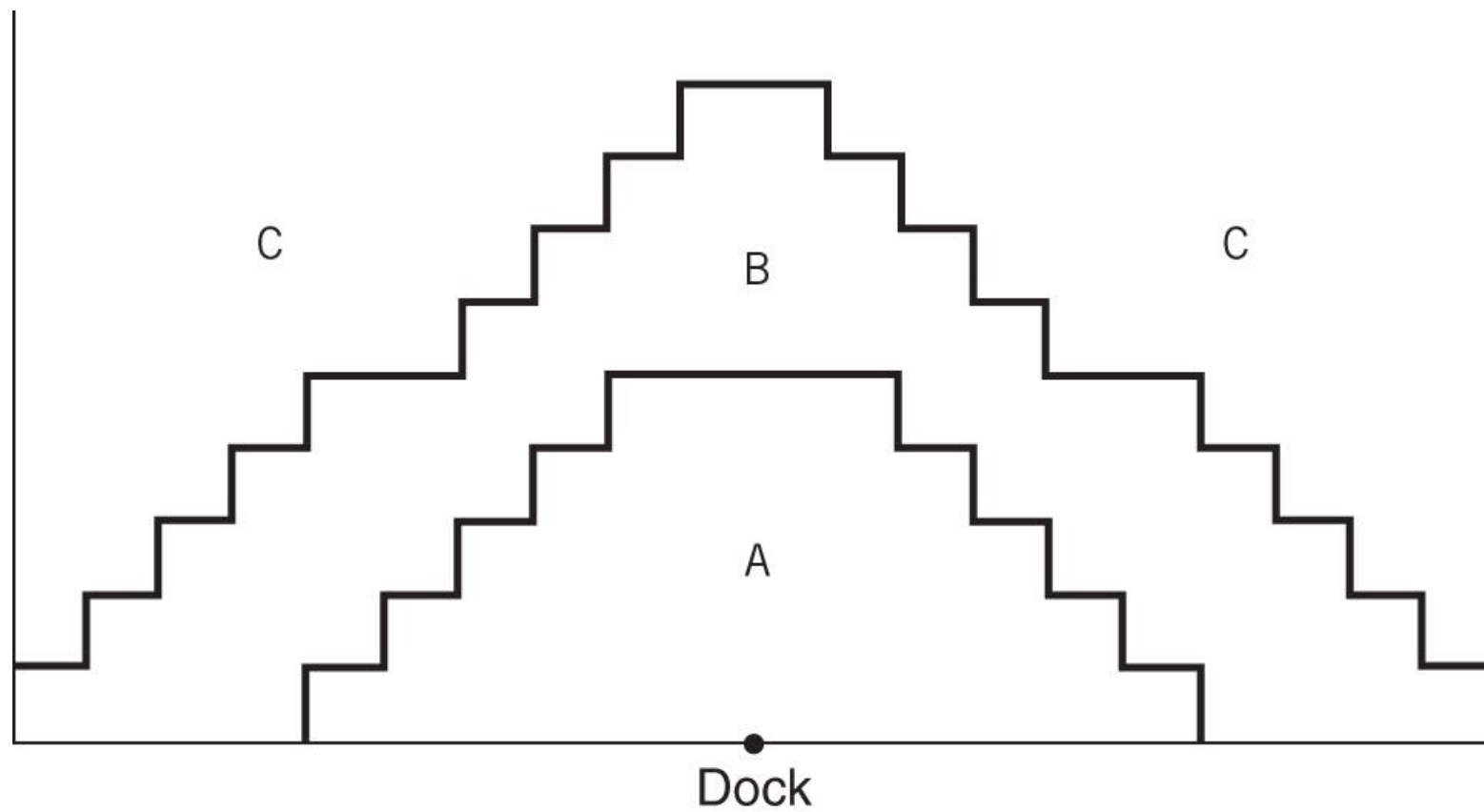
$$x_{ij} \geq 0$$

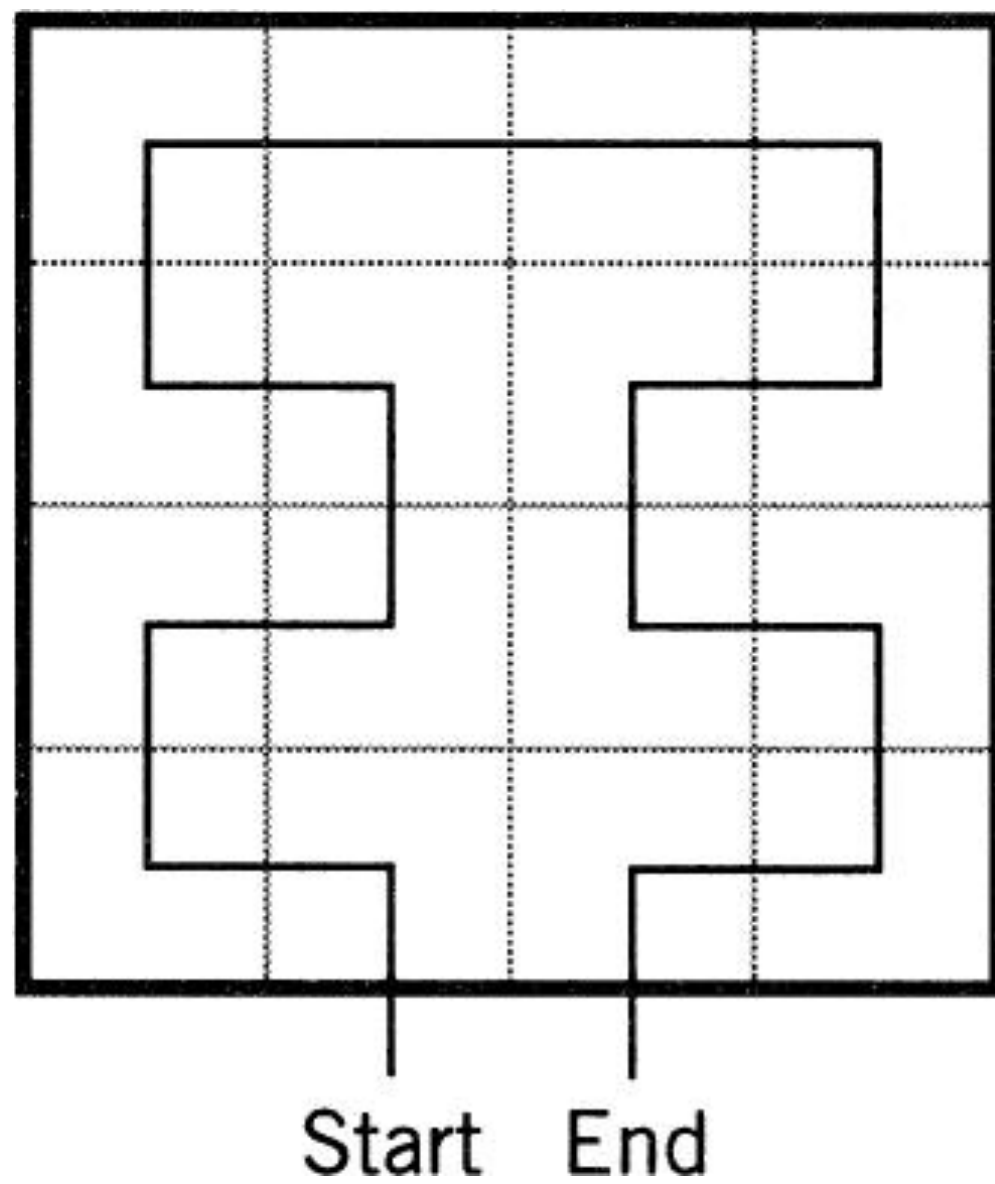
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	A	A	A	A	A	A	A	A	A	A	G	G	G	G	G	G	G	G
2	A					●				A	G				●			G
3	A	A	A	A	A	A	A	A	A	A	G	G	G					G
4	B	B	B	B	B	C	C	C	C	C	E	E	G	G	G	G	G	G
5	B				B	C		●		C	E	E	E	E	E	E	E	E
6	B		●		B	C	C	C	C	C	E	E	E	E	●	E	E	E
7	B	B	B	B	B	D	D	D	D	F	F	F	F	F	F	F	E	E
8	D	D	D	D	D	D			D	F					●	F	F	F
9	D					●			D	D	F	F	F	F	F			F
10	D	D	D	D	D	D	D	D	H	H	H	H	H	F	F	F	F	F



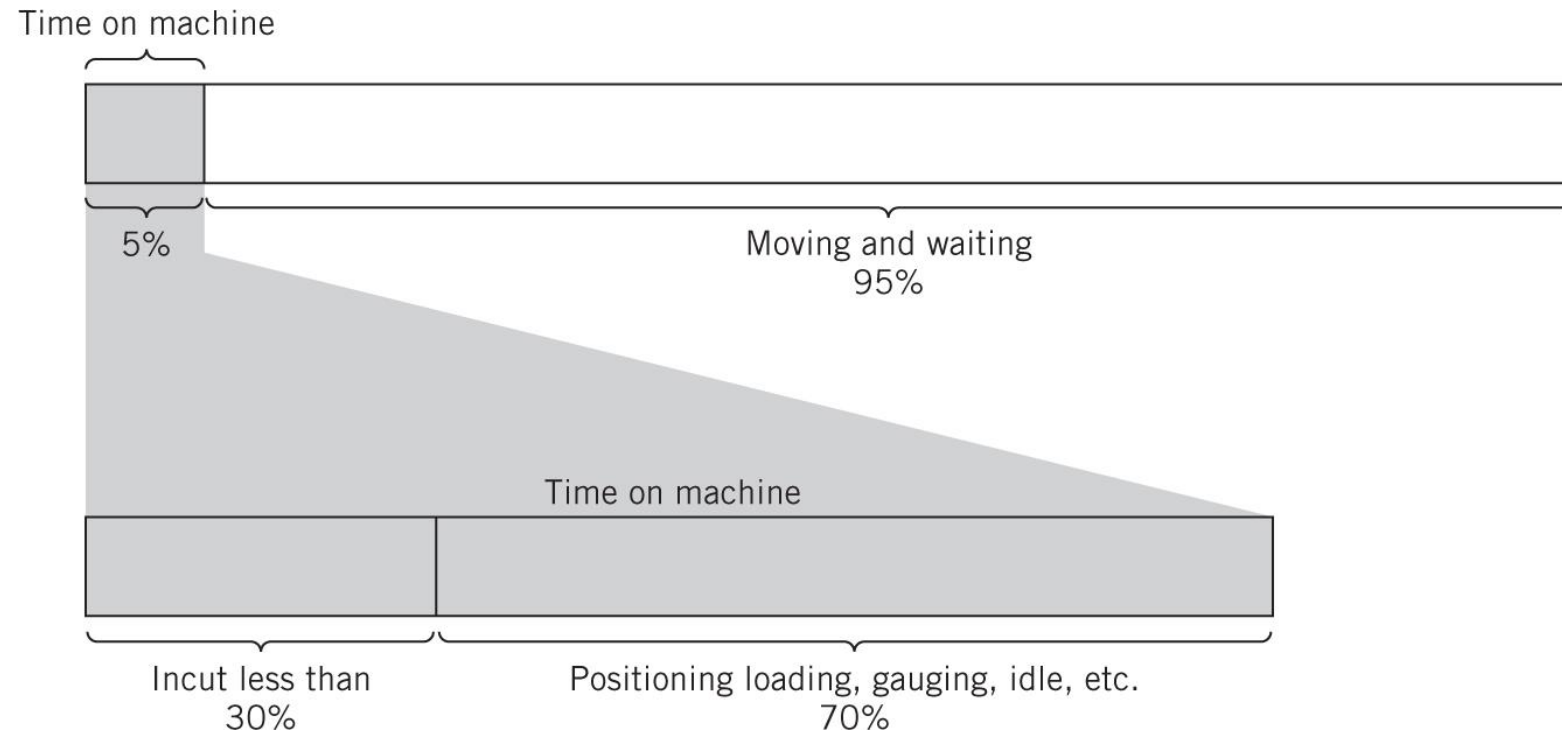
fig\_07\_10



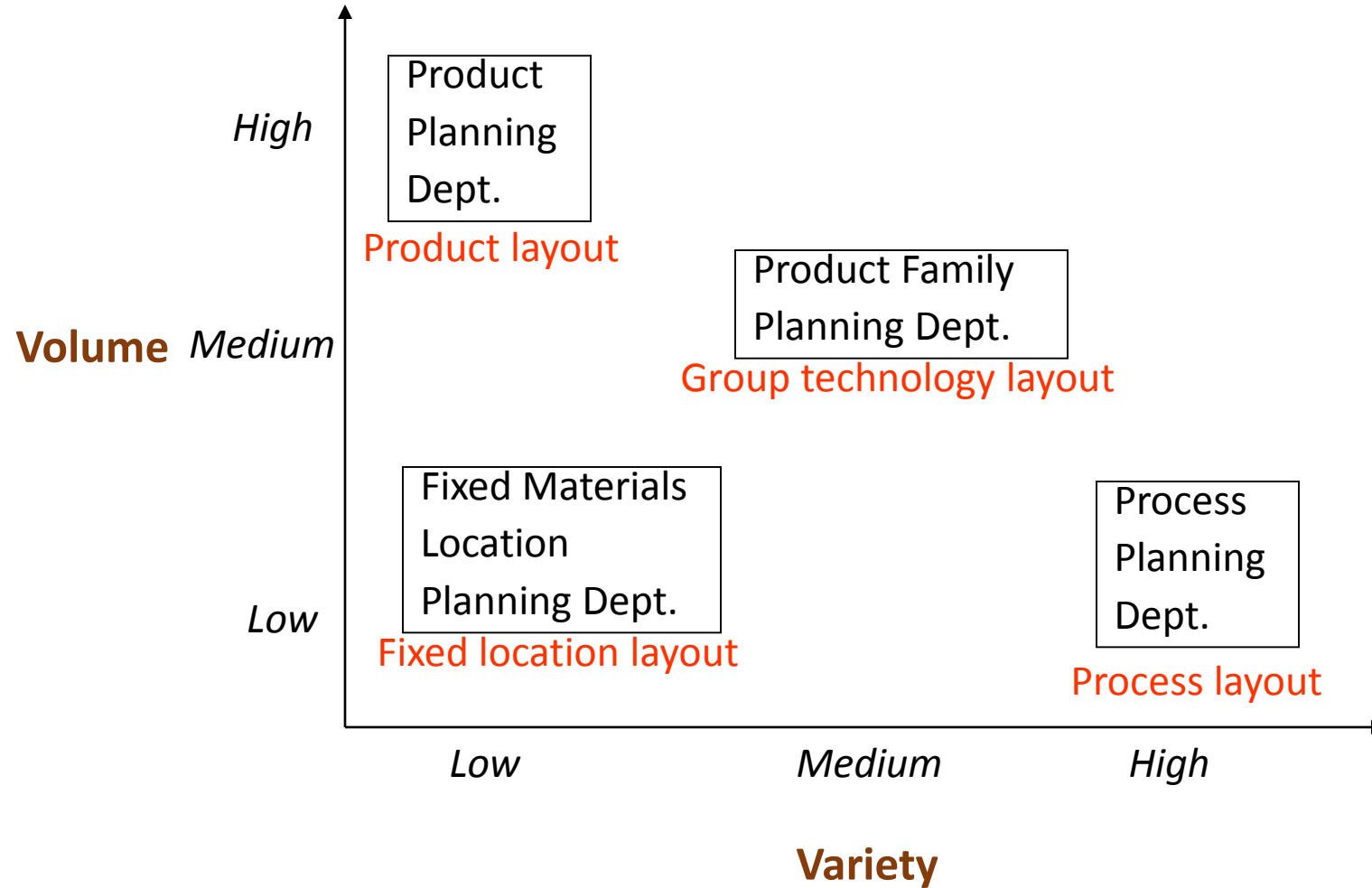




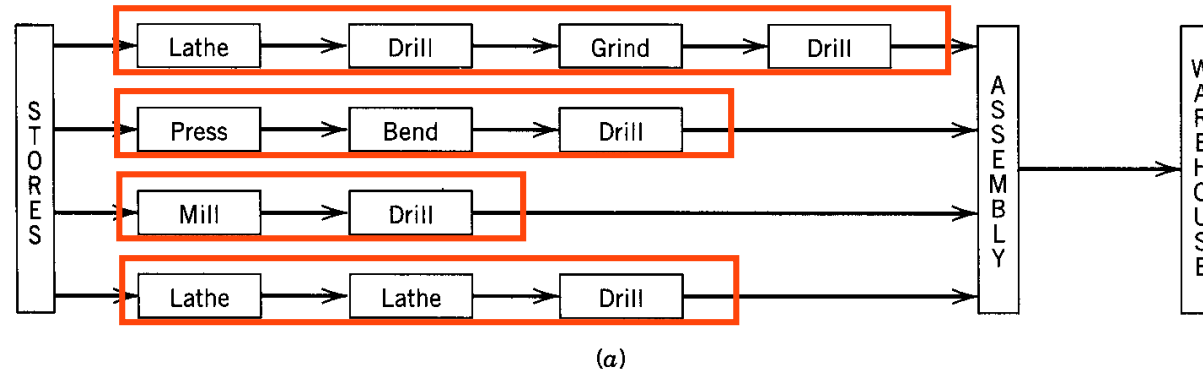
# Manufacturing Systems



# Volume-Variety Layout Classification



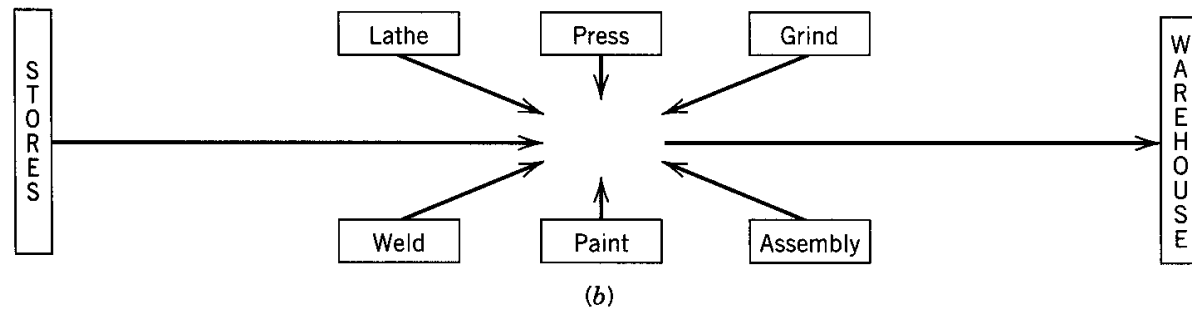
# Production Line Departments



- Used e.g. in assembly line-type production



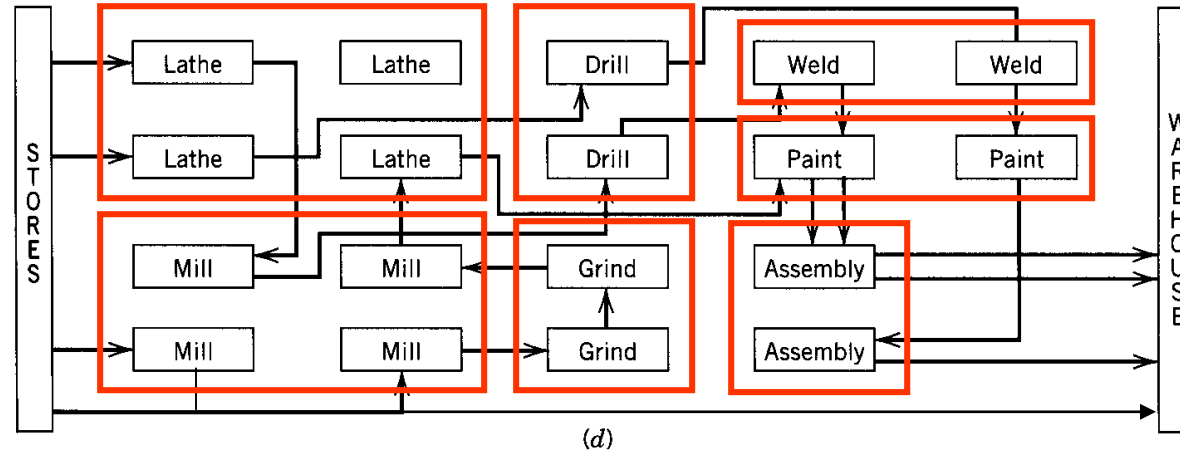
# Fixed Materials Location



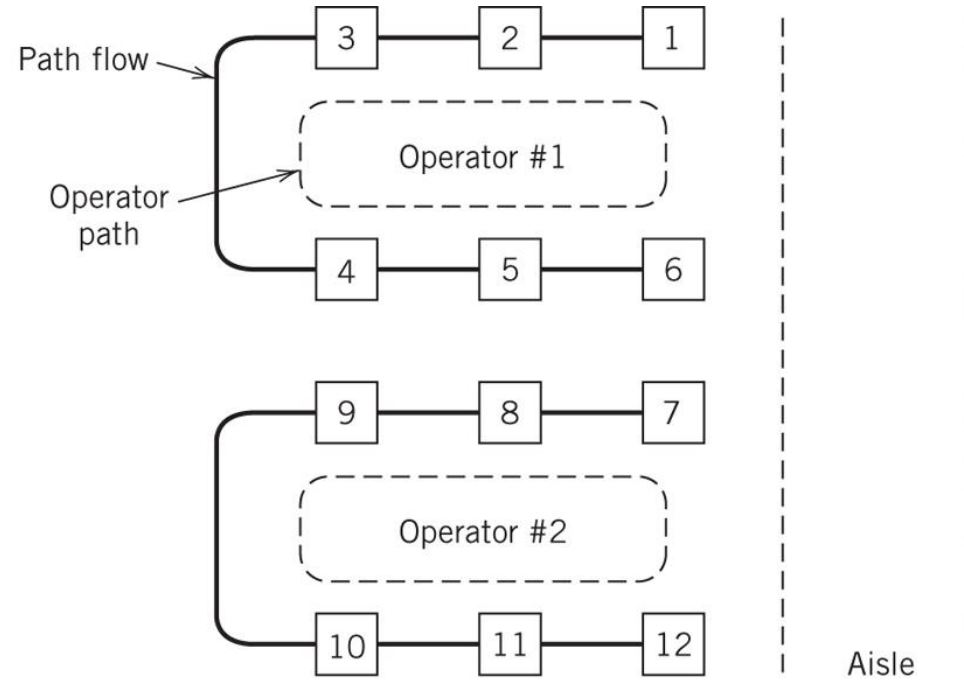
- Used in aircraft assembly, shipbuilding, construction projects



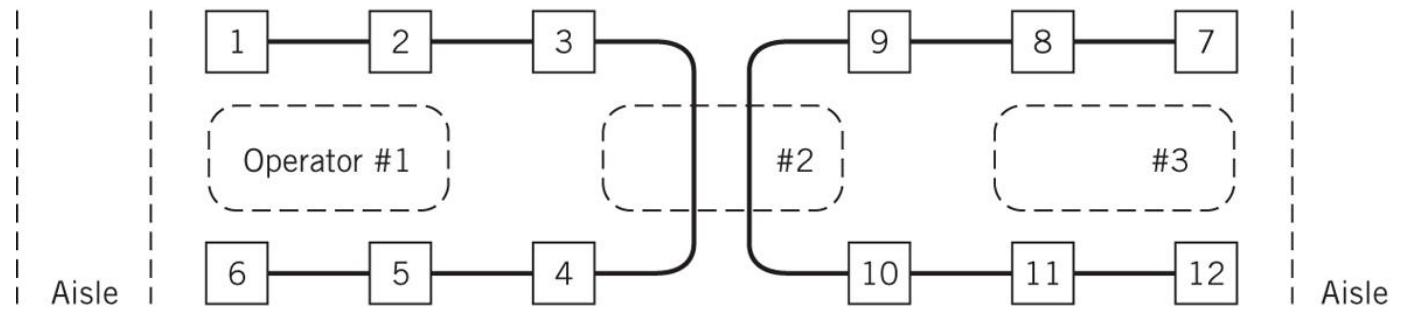
787 production line (Gail Hanusa/Boeing)



- Used in job shops



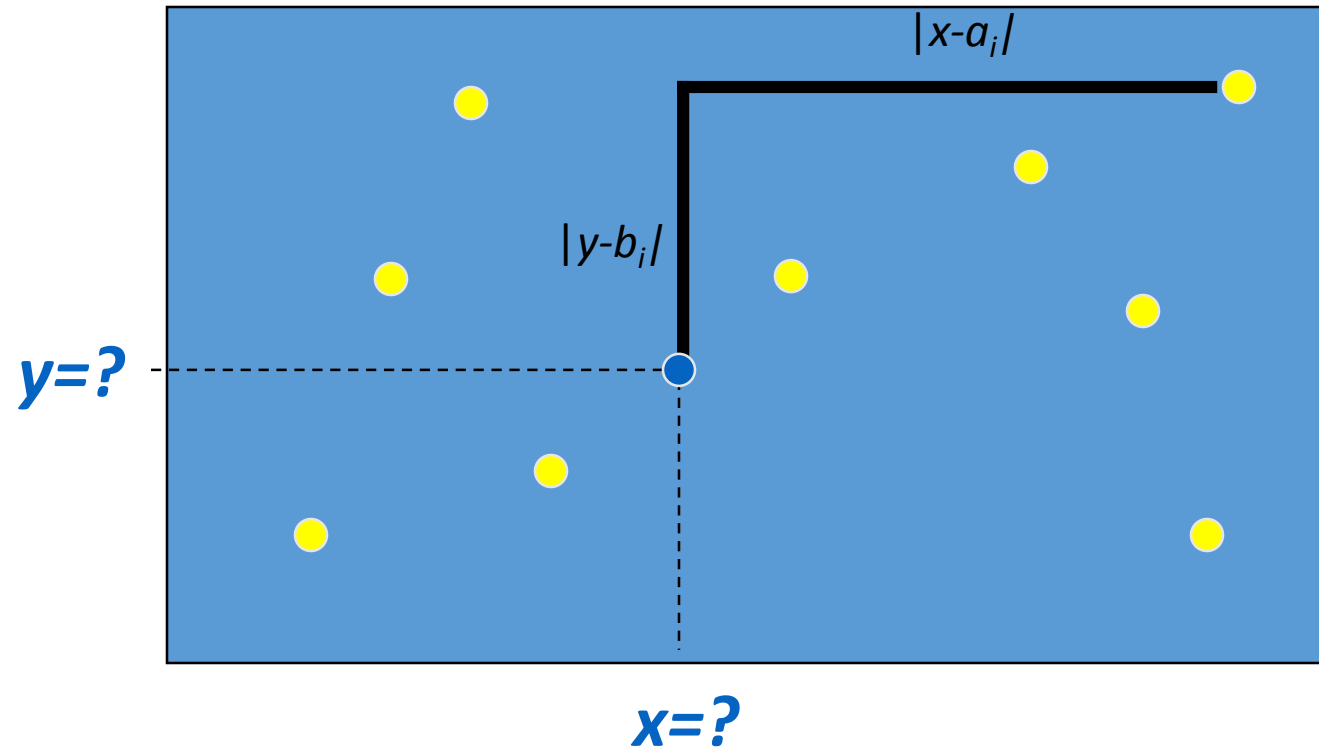
(a) Independent U-lines



(b) Dependent U-lines

# Facility Location Problem

- Existing facility
- New facility



# Design Competition

4 team member – two undergraduates and two graduates

4 weeks to complete the project

We usually have 10-15 teams

## Design Team





Let's  
**Discuss...**