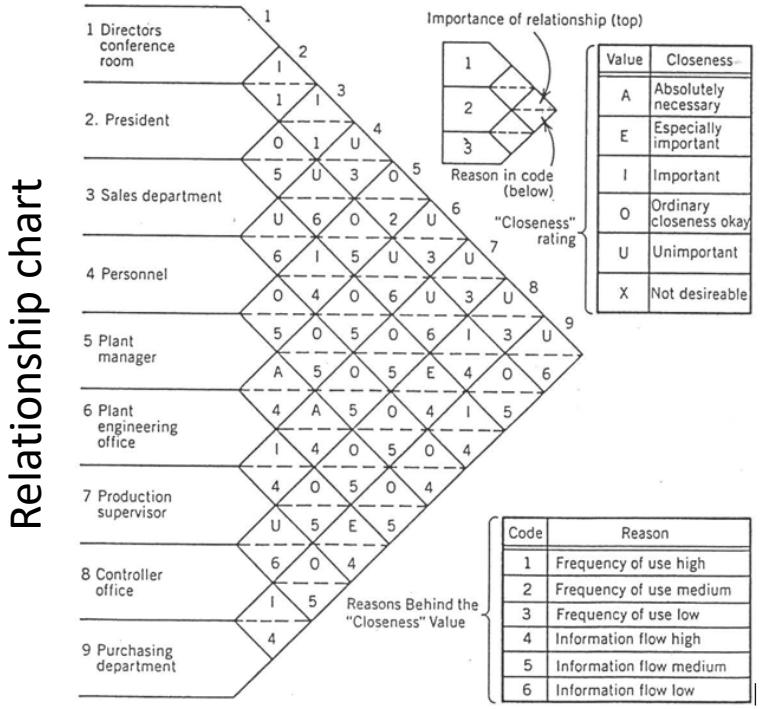
Departmental Layout

- Departmental layout $\Rightarrow$ determine *space* requirements of each department and its *shape* and *relation* to all other departments
  - Space and shape: 2-D CAD (AutoCAD, Visio) with *to-scale templates*
  - Interdepartmental relationships for *n* departments:
    - *Asymmetric*: max $n^2 - n = n(n-1)$, **material flow** (via From/To chart)
    - *Symmetric*: max $n(n-1)/2$, **closeness** (via Relationship chart)

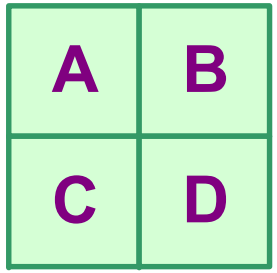
From/To chart

From \ To	1	2	3	4
1	—	6		
2		—	3	5
3			—	4
4	5			—

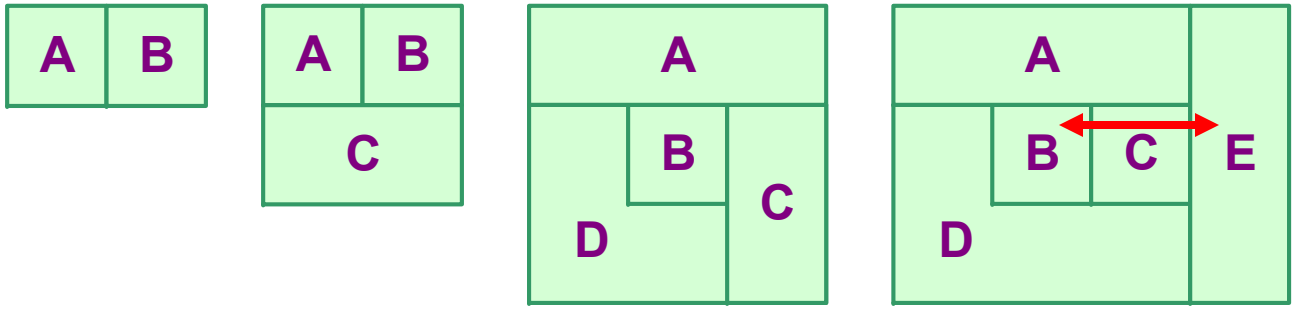


Adjacency

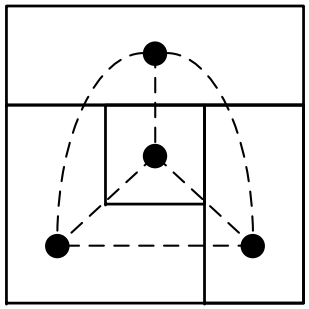
- Two departments *adjacent* if share border of positive length
  - A-B, A-C, B-D, C-D adjacent
  - A-D, B-C not adjacent, meet at point (0 length)
  - Min positive length should equal min clearance for movement between departments



- Maximum adjacency (any size/shape):
  - 2 dept.
  - 3 dept.
  - 4 dept.
  - 5 dept.

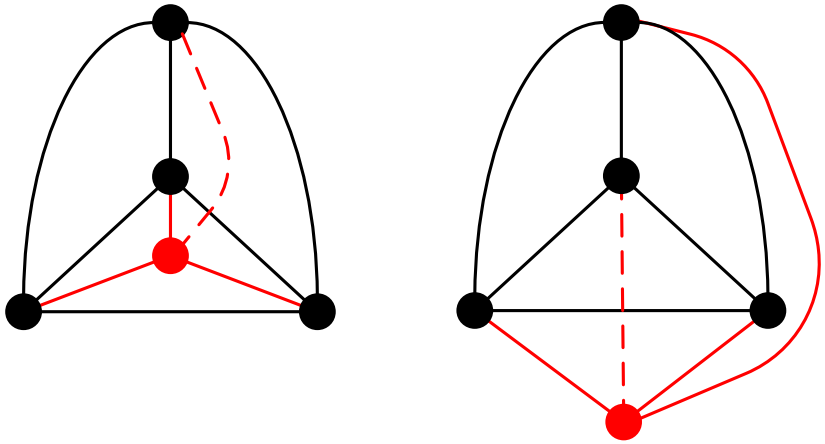


- Dual of layout graph:
  - Node in each department
  - Arc between nodes if departments adjacent



Maximal Planar Graph

- *Maximal planar graph* has $3n - 6$ edges
  - Planar graph has no arcs that cross each other
  - Provides UB on number of possible adjacency relationships
  - Example: for $n = 5$, at least one relationship not adjacency

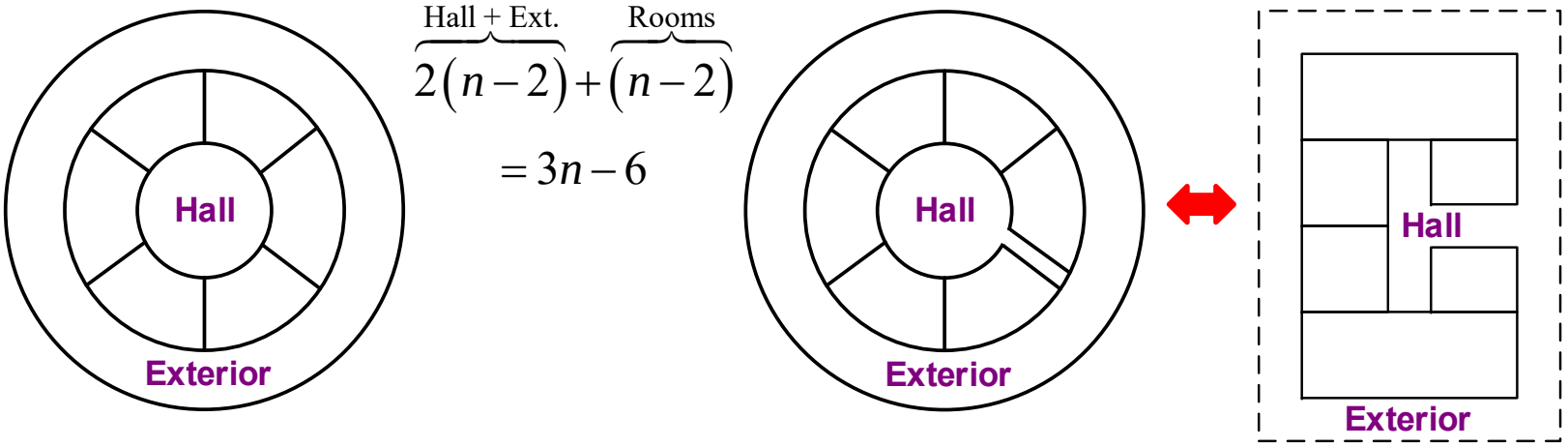


n	Max Sym Rel $n(n-1)/2$	Max Adj Rel $3n-6$
3	3	3
4	6	6
5	10	9
⋮	⋮	⋮
10	90	24

$$\frac{n(n-1)}{2} > 3n-6 \text{ for } n > 4 \Rightarrow \text{can't have all dept adjacent} \Rightarrow \text{need aisles}$$

Maximal Adjacent Layouts

- For $n > 4$, can create layout that
  - Maximizes adjacency
  - Each department can reach all others through at most one intermediate department
  - Example: 6 rooms + Hall + Exterior = 8 departments



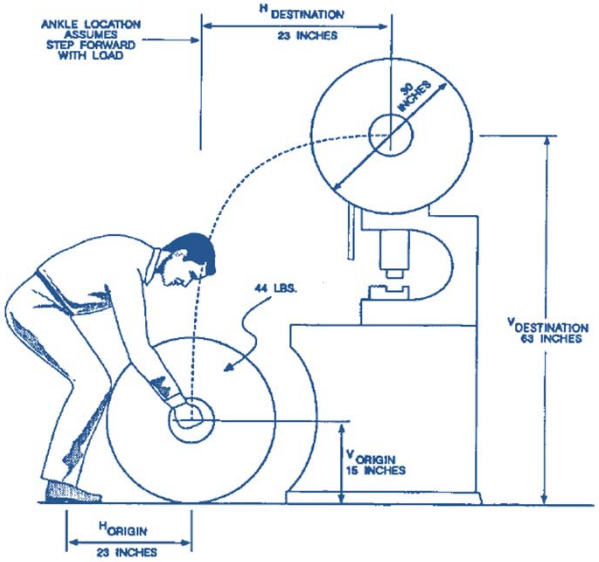
- *Adjacency* $\Rightarrow$ manual, on-floor conveyors, carts
- *Hall/Aisle* $\Rightarrow$ industrial trucks + unit loads + transfer batch

Material Handling

- *Material handling*: short-distance movement within confines of a building or between building and transportation vehicle
  - Creates *time* and *place* utility vs. manufacturing's *form* utility
- Material handling equipment categories:
  - **I. Transport equipment:** move material from one location to another
  - **II. Positioning equipment:** handle material at a single location
  - **III. Unit load formation equipment:** restrict materials so that they maintain their integrity when handled single load during transport and storage
  - **IV. Storage equipment:** holding or buffering materials over period of time
  - Material can also sometimes be
    - transported/positioned *manually* using no equipment
    - *self-restraining* (interlocking), so can be formed into unit load with no equipment
    - *block stacked* directly on floor, requiring no storage equipment

Positioning Equipment

- Why used:
  - To feed, orient, load/unload, or otherwise manipulate materials so they are in correct position for subsequent handling
  - Manipulators/balancers act as “muscle multipliers” by counter-balancing weight of load so operator can lift only 1% of load’s weight
  - Sometimes justified by ergonomic requirements of task (NIOSH eq.)

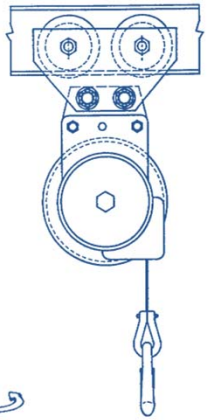


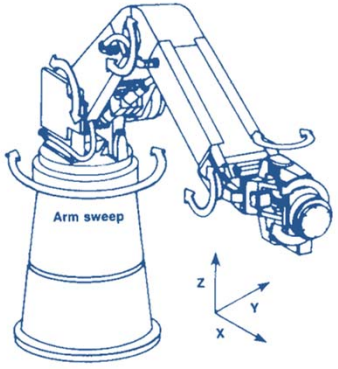
NIOSH Lifting Equation

Lift table

Vacuum manipulator

Balancer

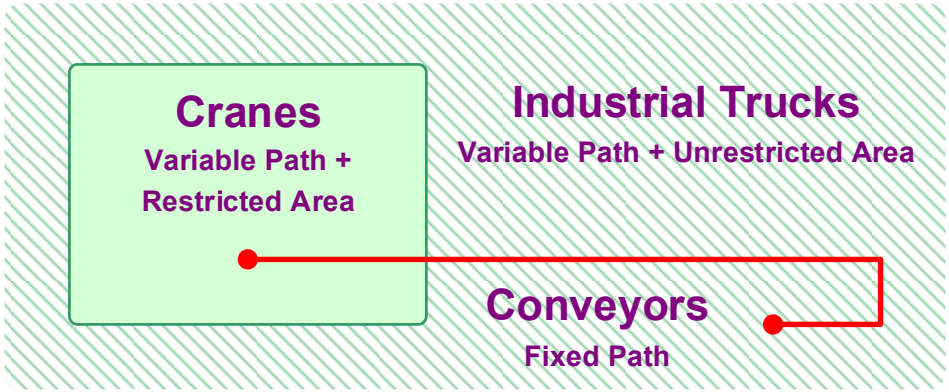




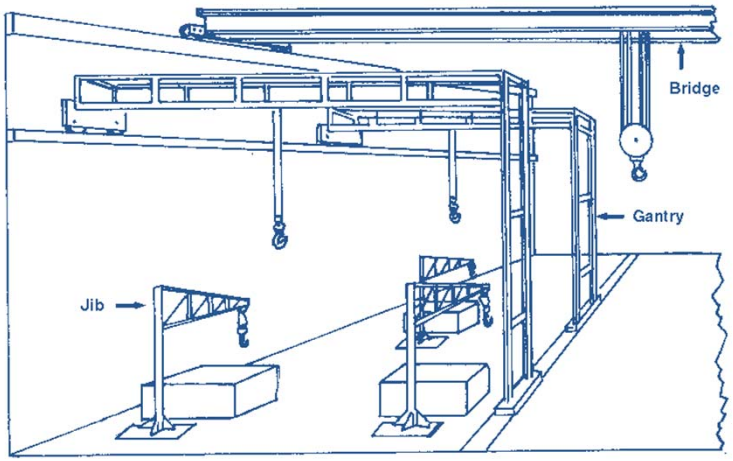
Industrial robot

Transport Equipment

- Selection criteria:
  1. Load moves between locations:
     - Yes ⇒ transport equipment
     - No ⇒ positioning equipment
  2. Load discrete:
     - Yes ⇒ *unit* load transport equipment
     - No ⇒ *bulk* conveyors
  3. Path *fixed* or *variable*:
     - Variable ⇒ industrial truck or crane
  4. Move is between adjacent locations:
     - Yes ⇒ manual, on-floor conveyor, cart
  5. *Accumulation* required:
     - Yes ⇒ non-synchronous processes
     - No ⇒ synchronous ⇒ some conveyors



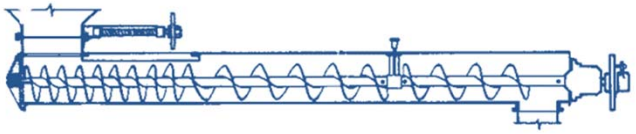
Cranes



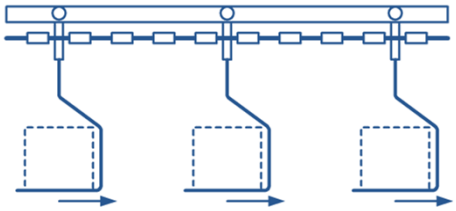
Conveyors

- Classification:
  1. Unit vs Bulk load
  2. Location:
     - In-floor
     - On-floor ($\Rightarrow$ adjacency)
     - Overhead
  3. Accumulate vs
     No accumulation
- Advantage: No labor cost
- Disadvantages:
  - Decreased flexibility
  - Congestion (on-floor)
  - Capital cost (overhead)
  - WIP on conveyor

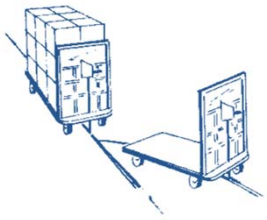
(mobile) Wheel
(Unit+On-floor+Accum)



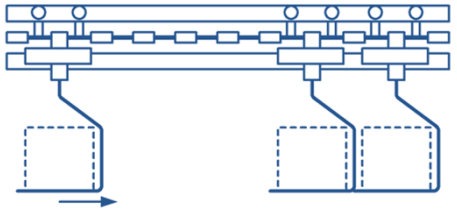
Screw (Bulk+On-floor)



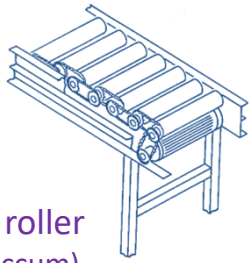
Trolley (Unit+Overhead+No Accum)



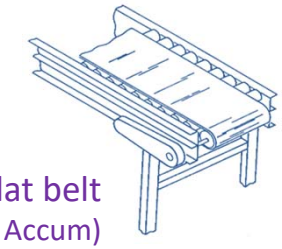
Tow
(Unit+In-floor+Accum)



Power-and-free (Unit+Overhead+Accum)



Live (powered) roller
(Unit+On-floor+Accum)



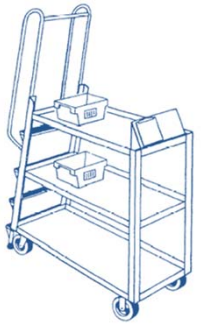
Flat belt
(Unit+On-floor+No Accum)

Industrial Trucks

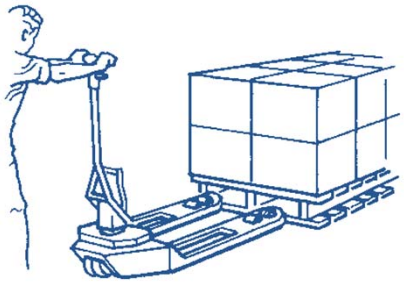
- Industrial trucks are trucks that are not licensed to travel on public roads—"commercial trucks" are licensed

	Technical Parameters		Economic Parameters	
Industrial Truck	Pallet vs. No Pallet	Stacking vs. No Stacking	Manual vs. Powered	Walk vs. Ride
Hand truck	NP	NS	M	W
Platform truck	NP	NS	P	W/R
Pallet jack	P	NS	M/P	W
Walkie stacker	P	S	M/P	W
Pallet truck	P	NS	P	R
CB lift truck	P	S	P	R

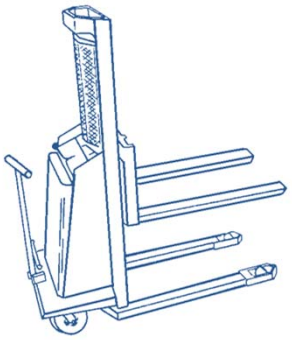
Two-wheeled hand truck



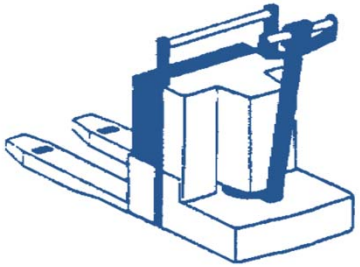
Cart (hand truck)



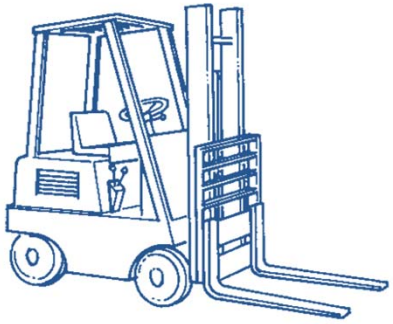
Manual pallet jack



Manual walkie stacker



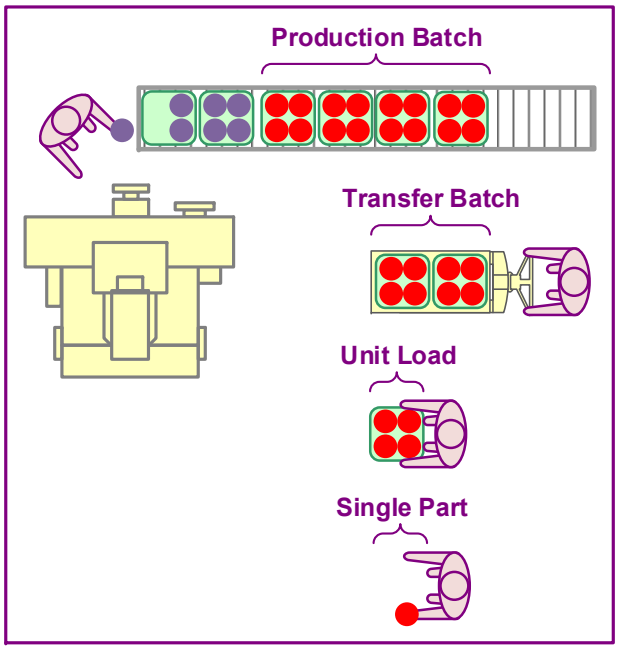
Pallet truck

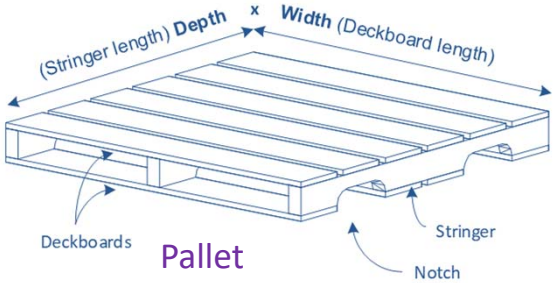


Counterbalanced lift truck

Unit Load Formation Equipment

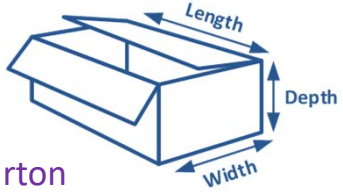
- Advantage of unit loads:
  - More items moved per trip, potentially reducing handling costs
- Disadvantages:
  - Increase in cycle times due to batching
  - Cost of returning empty containers/pallets





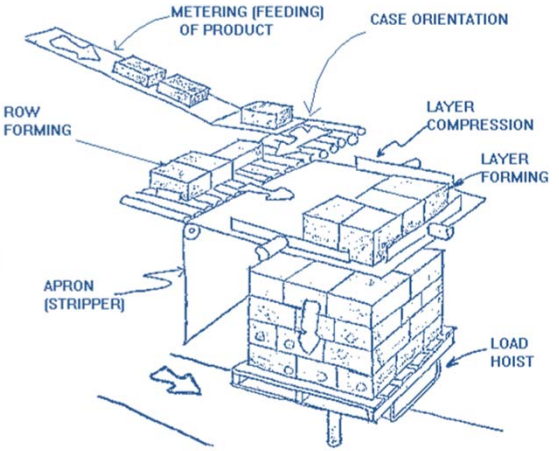
Pallet

Manual palletizing

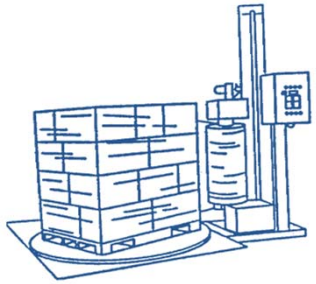


Carton

Stripper plate palletizer



Shrink-wrapper



Characteristics of Good Layouts

1. Room for future expansion at site
2. Orient to minimize road frontage
3. Separate truck and employee/vistor access
4. Flexible/modular design
5. Cafeteria big enough for shift-wide meetings
6. Low-bay offices, high-bay manufacturing with mezzanines
7. Lots of windows, no cubicles