Lecture 03
Equipments in Warehouse:

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Outline

source: General references [BH09, Mul94, Fra02, **?**]

Benefits of equipment

- Reduce cost (labor + space)
  - enhance space utilization (rack → vertical dimension, denser safer storage)
  - allow for more efficient order-picking (WMS → zone/wave picking)
- Enhance responsiveness (speed + cycle time)
  - Increase throughput (sorter → automated sorting & transfer)
- Maintain qualities of products & operations
  - provide efficient ways for identification (e.g., bar code, RF terminal)
  - provide safe & secure material handling (e.g., man-on reach truck)
  - establish & maintain a controlled environment (e.g., access control)

Concept of unitizing equipment

- **Idea:** standardizing SKUs → easy to move & collect
- **Where:** supplier site, receiving & shipping area
- **Issues:** installation cost, volume, size & shape (7Eleven tote, Lotus cool box)
- **Example:** pallet, wrapping machine

Pallet & co

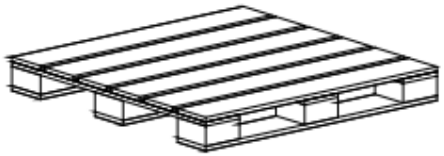
- **Idea:** creating unit load by std platform
- **Issues:** circulation, size, form

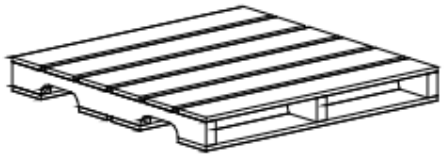
Comparison of pallet materials

source: https://www.palltechpallets.co.uk

Material	Durability	Repairable	Env. Impact	Application
Wood	med	yes	recyclable	common
Pressed Wood	med	yes	recyclable	printing, tiber
Fiberboard	low	no	recyclable	paper, garment
Plastic	high	no	closed loop	cement, automotive
Metal	high	depends	closed loop	grocery, food, military

Shape of Pallet





Block Pallet

Stringer Pallet

Standard Pallets

ISO pallets 1000 mm × 1200 mm

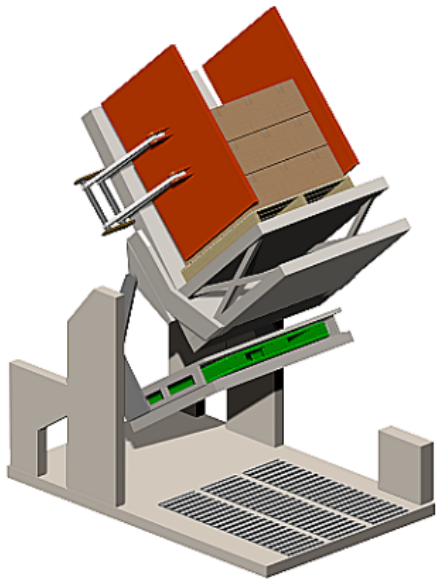
US pallet 40 in × 48 in (1016 mm × 1219 mm) or 42 in × 48 in

Euro pallet 800 mm × 600 mm & 800 mm × 1200 mm

Other pallets

Other Industrial Package

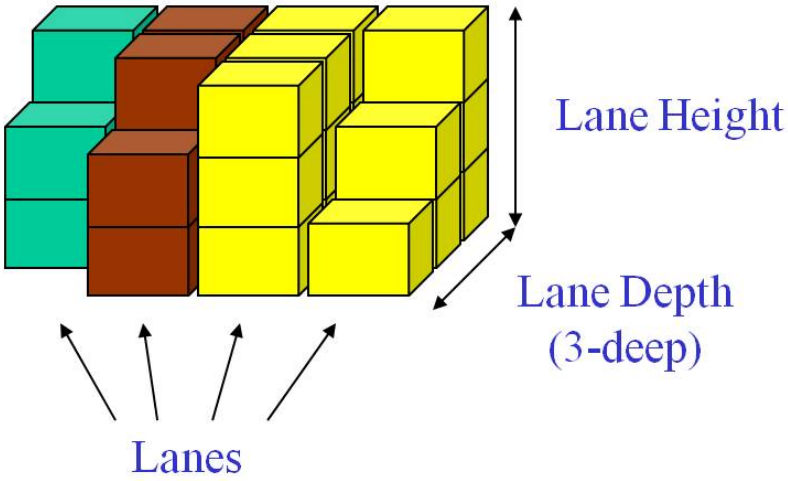
Other type of unit load



Storage & retrieval equipment

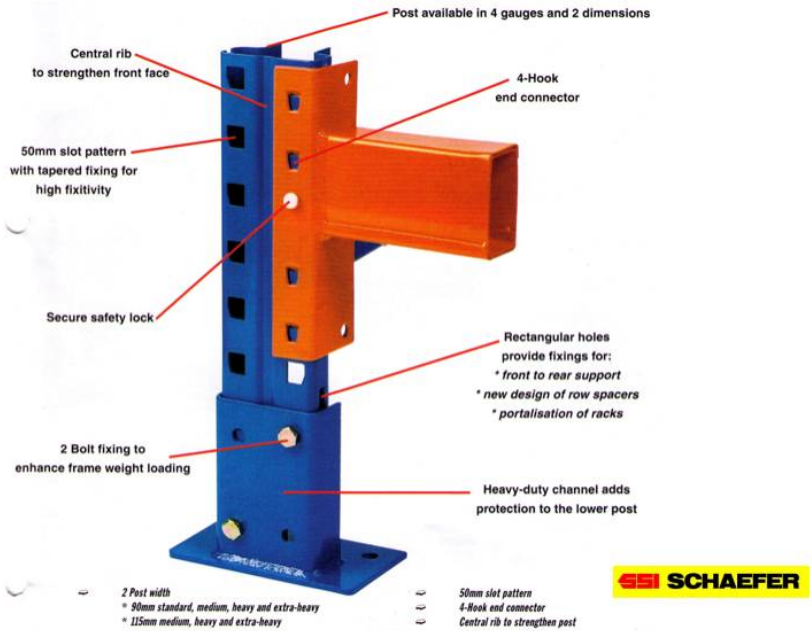
- **Idea:** cubic space saving & efficient retrieving
- **Where:** storage & picking area
- **Issue:** standardization, FIFO, safety, ergonomic
- **Example:** floor stack, selective rack (single deep & double deep), carrousel

Floor stack: No equipment

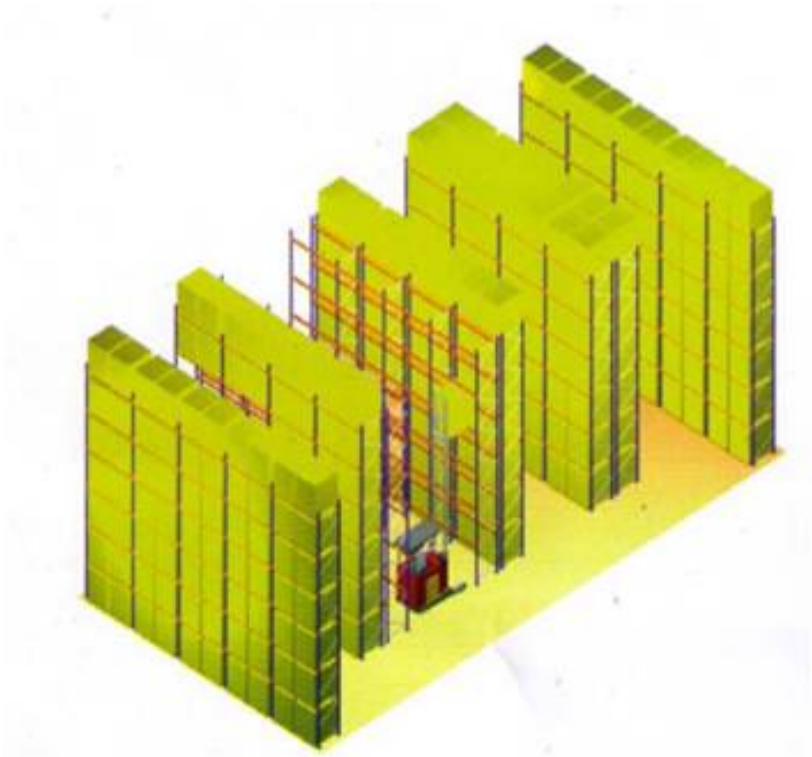


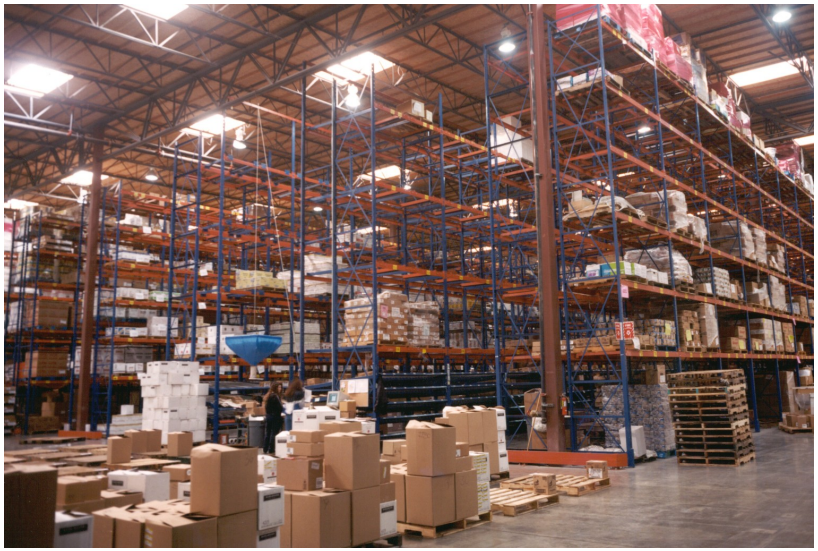
- **Idea:** stack pallets up-height
- **Pro:** zero investment, multiple pallets per SKU, high inventory over
- **Con:** honeycombing problem, stability
- **Issue:** stack-ability, stack height, aisle width

Industrial rack



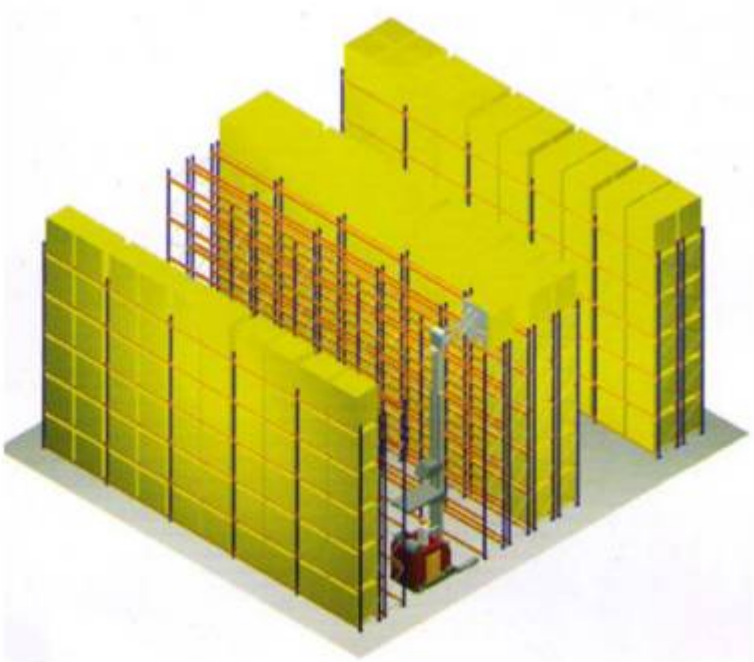
Single-deep rack





- **Idea:** a pallet rack that has a **single** storage space
- **Pro:** each pallet is independently accessible
- **Con:** too many aisles $\rightarrow$ inefficient space utilization

Double-deep rack



- **Idea:** a pallet rack that has a **double** storage space
- **Important:** Each lane dedicated to one SKU (one pallet or two pallets)
- **Pro:** Less aisle space required (upto 50% savings in aisle space)
- **Con:** More work and/or specialized equipment for retrieving

Drive-in & drive-through rack

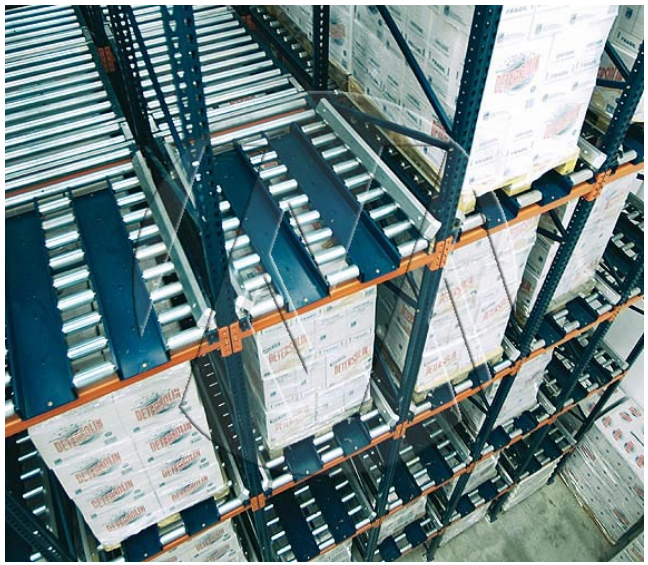
- **Idea:** forklift can drive in the structure
- **Important:** $\exists$ two aisles $\rightarrow$ drive-through, $\exists$ inclined rollers $\rightarrow$ push-back
- **Pro:** maximize space utilization
- **Con:** accidents, inefficient of vertical dimension

Comparison of unit-load equipments

	Block storage	Selective	Double deep
Installed (USD/unit load)	–	150	150
Footprint	–	large	medium
Storage density	high	low	medium
Throughput	high	high	medium
Space use	very good	fair	good
Load accessibility	poor	excellent	fair
Rotation of loads	LIFO	FIFO	LIFO
Number of aisles	few	many	medium
Unit loads deep/opening	8-10	1	2
Utilization factor	60%	85%	80%
Probability of damage	high	low	low
Security	poor	good	good

source: Malmborg, C. *et al.* 1998 [PMP+98]

Pallet flow rack



- **Idea:** a pallet rack that **always** brings next pallet
- **Important:** separate picking & put-away
- **Pro:** high pick density, FIFO
- **Con:** space utilization, high cost

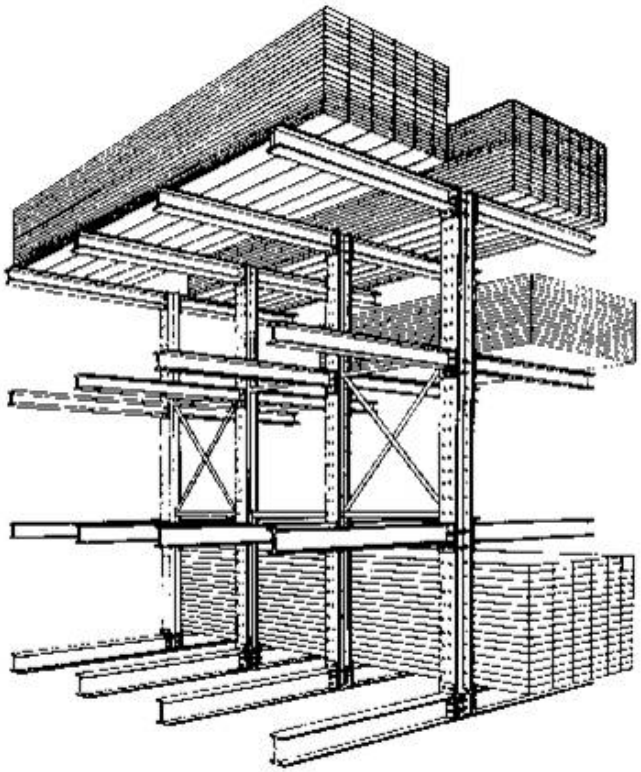
Gravity flow rack

- **Idea:** a rack that **always** brings next case/carton (200+ picks/hr)
- **Pro:** high pick density, FIFO
- **Con:** space utilization, high cost

Bin shelve

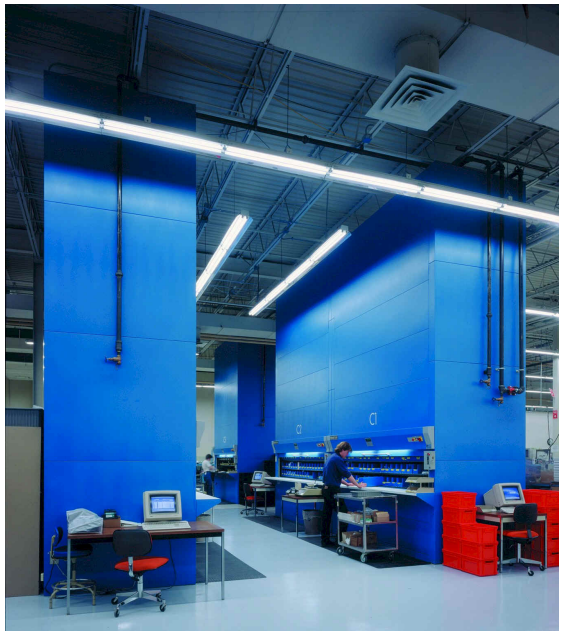
- **Idea:** storing cabinet for case/carton
- **Pro:** cheap,
- **Con:** single access, ID, low pick density, LIFO

Cantilever rack



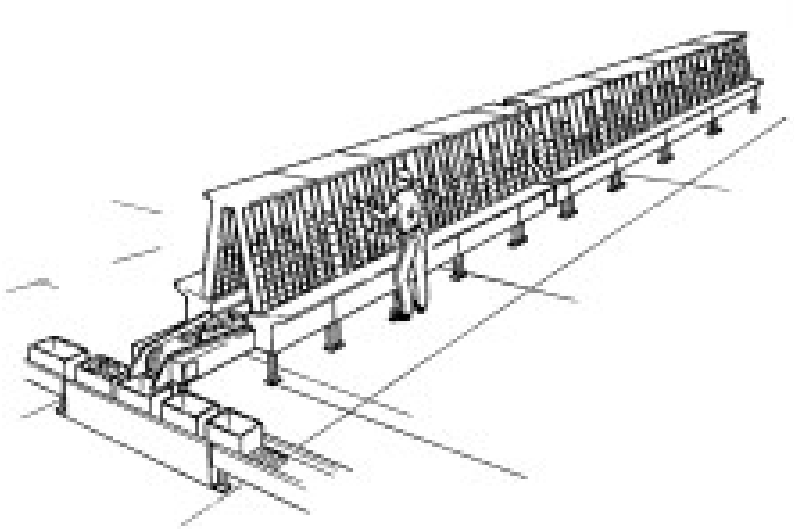
- **Idea:** structure with protruding beams to support items
- **Pro:** suitable for irregular/long shaped product
- **Con:** strength, balancing, pallet >> carton/piece

Carousels



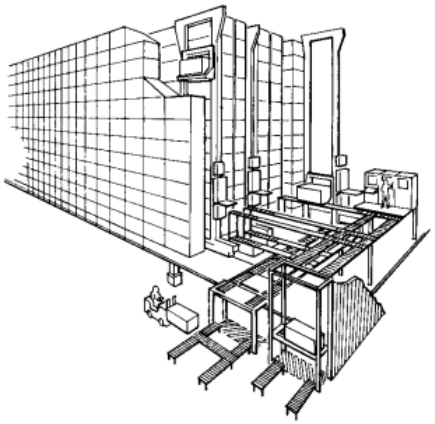
- **Idea:** automatic storage/retriving equipment (100-200 pick/hr)
- **Pro:** no searching, security
- **Con:** single access

A-frame

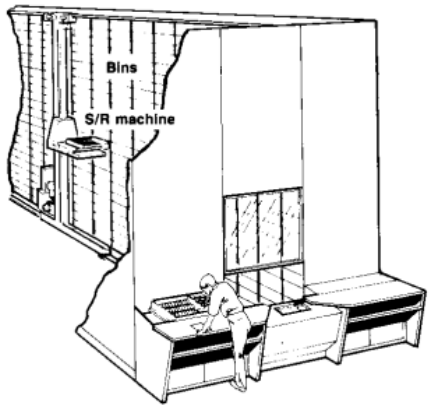


- **Idea:** combine picking, storing & packing with automation (300+ pick/hr)
- **Pro:** high pick density for small & similar SKUs ready pack
- **Con:** double handling, filling machine

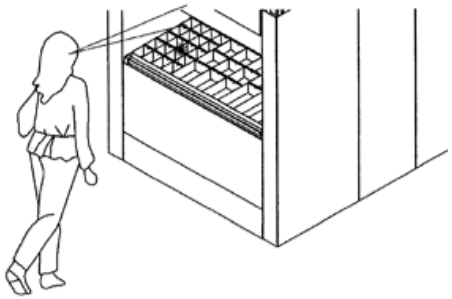
Other Automatic Storage Equipment



Unitload ASRS



Miniload ASRS

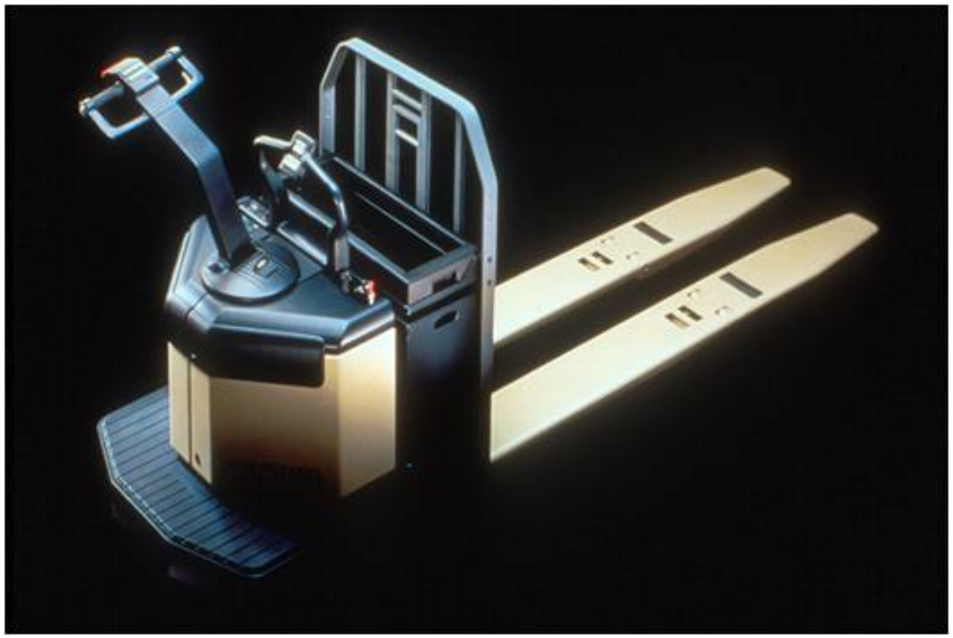


Vertical Shutter

- **Idea:** combine put-away, picking, storing
- **Pro:** high hight, little labor
- **Con:** investment, may double handling

Small storage item equipments

Material Handling Equipment



- **Idea:** moving items/SKUs
- **Where:** everywhere
- **Issue:** reach, automation, space footprint, congestion
- **Type:** Manual, Conveyor, Sorter, Crane, AGV, Industrial trucks
- **Example:** hand truck, forklift, conveyor

Counter balance forklift truck

- **Idea:** unit-load mover equipped with motor & hydriodic
- **Pro:** very useful
- **Con:** wide turn $\rightarrow$ wide aisle

Manual Equipment

Dolly

Hand Pallet Jack

Lift Cart

- **Idea:** manual equipment for moving pallet or tote (no driving cab)
- **Pro:** small, cheap
- **Con:** more manual, fixed height (may not apply for block pallet)

Industrial Trucks

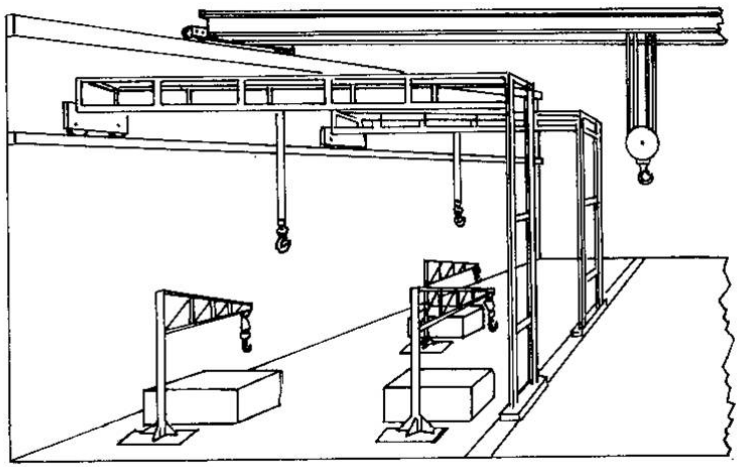
Swing Mast

Reach Truck

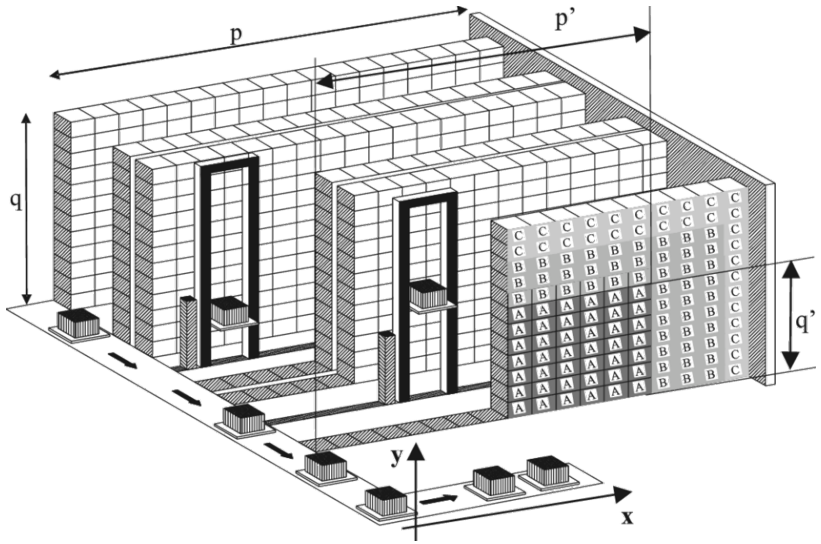
VNA truck

- **Idea:** moving pallet from A $\rightarrow$ B with power
- **Type:** turret, footprint, drivable, # pallets
- **Pro:** save time & labor
- **Con:** price, storage equipment

Crane



bridge crane



stacker crane in AS/RS

- **Idea:** moving items overhead
- **Pro:** flexible shape/size
- **Con:** restricted area, congestion with others

Others MHE: Rail

Tow Line

AGV

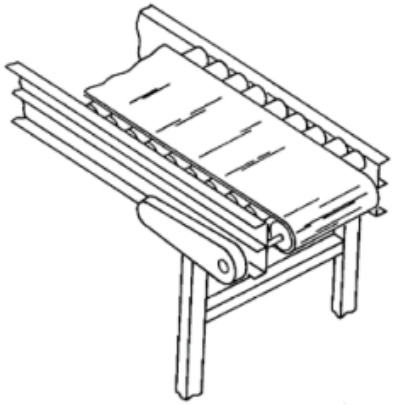
RGV

- **Idea:** moving items on fixed paths usually as loop
- **Pro:** eliminate worker
- **Con:** restricted area, investment

Conveyor

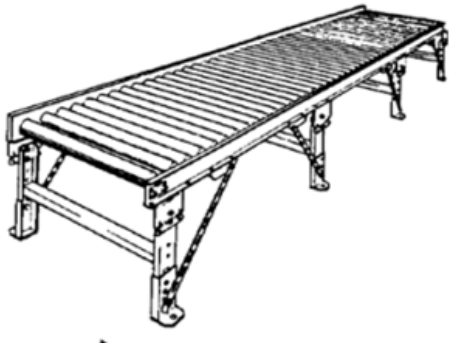
- **What:** automatic moving 'regular' shape pallet
- **Pro:** free labor
- **Con:** large moving huge std. size, fixed paths

Variation of Conveyors

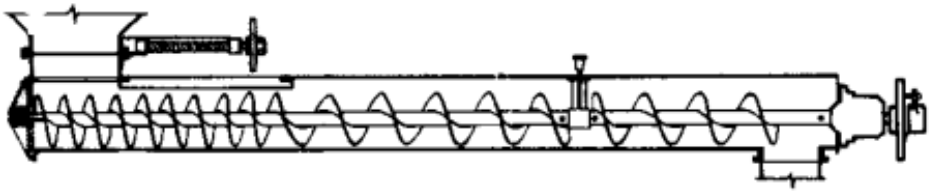


belt

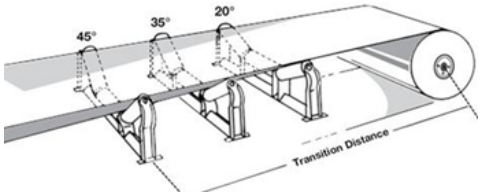
chain



gravity



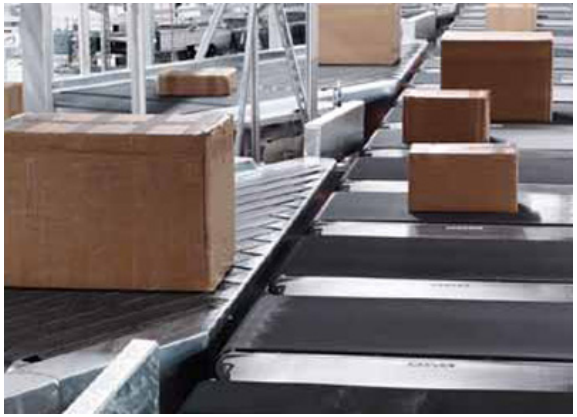
screw



troughted

- **Selection:** materials, slope, price, weight

Sorter



cross belt

tilt tray

sliding shoe

- **Idea:** automatically distribute product without picking
- **Type:** weight, dimension, speed & throughput, chute
- **Pro:** accuracy, slave
- **Con:** price, installation, handling

Space requirement for popular equipments

No.	Design				Specification		
	Storage ($/pallet)	Handling ($/unit)	Pallet Depth	Pallet Height	Slot Width	Aisle Width	Avg. Utiliz.
1	Floor ($0)	Forklift ($22k)	6	3	1.35	3.6	0.30
2	Drive-In ($150)	Reach ($28k)	6	5	1.35	3.6	0.90
3	Double Deep ($55)	Deep Reach ($35k)	2	5	1.25	3.0	0.75
4	Push-Back ($155)	Reach ($28k)	4	5	1.25	2.7	0.85
5	Selective ($50)	Reach ($28k)	1	5	1.25	2.7	0.80

Questions

- Calculate area requirements for each option if a particular warehouse, on average, needs 3000 pallet positions
- Propose a layout if the width and height of a storage area of this warehouse are 36m. and 20m.

source: Napolitano, M. *et al.* 2003 [NG94].

Positioning equipment

- **Idea:** making loading & unloading easier
- **Where:** receiving & shipping
- **Issue:** weight, layout (blind spot)
- **Example:** dock door, dock leveler, staging area

Dock doors

palletizer

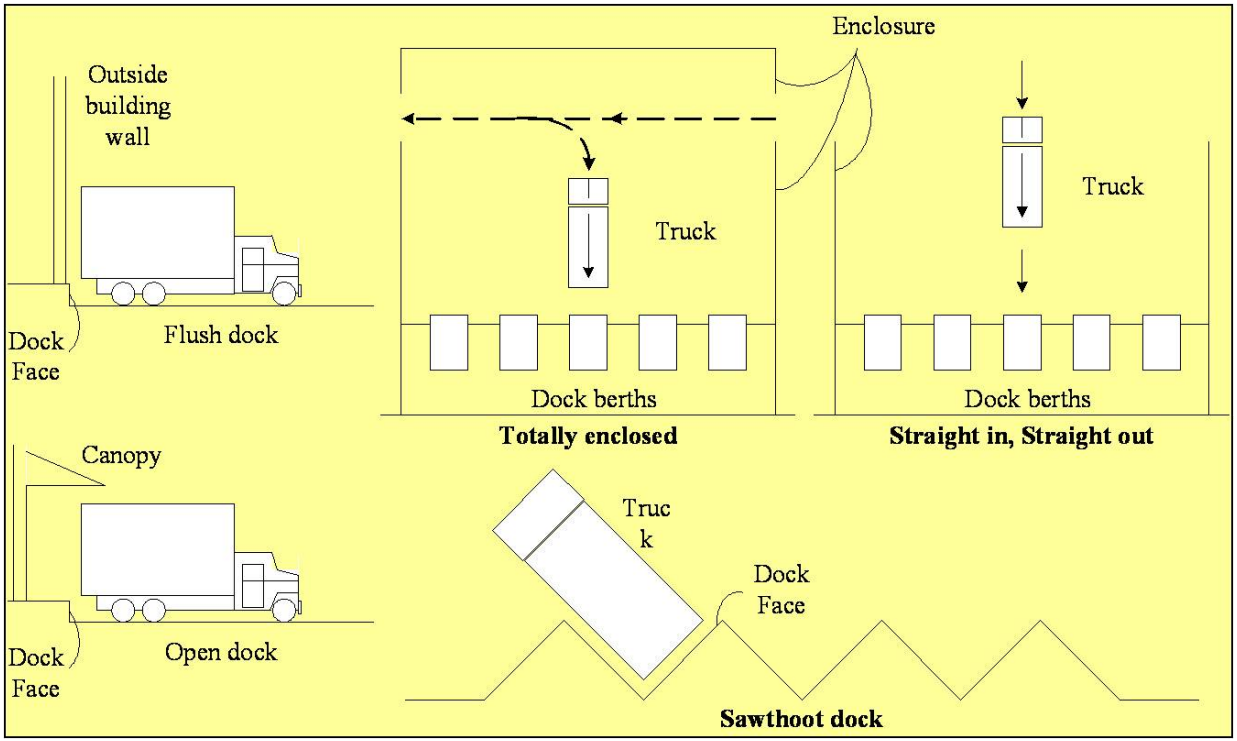
dock leveler

dock door

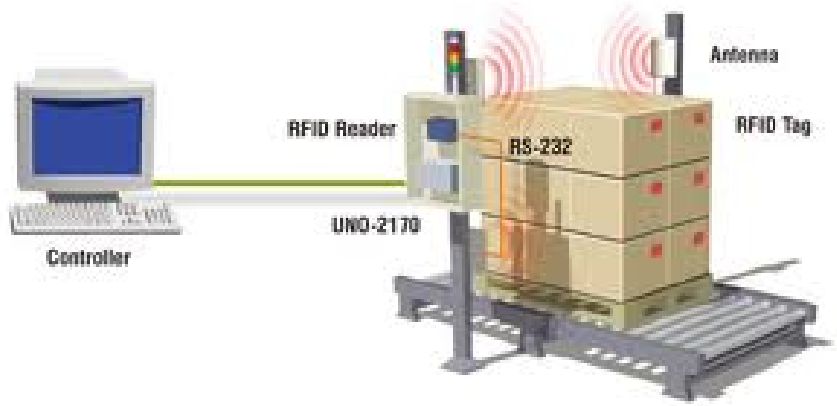
manipulator

stair

Dock area

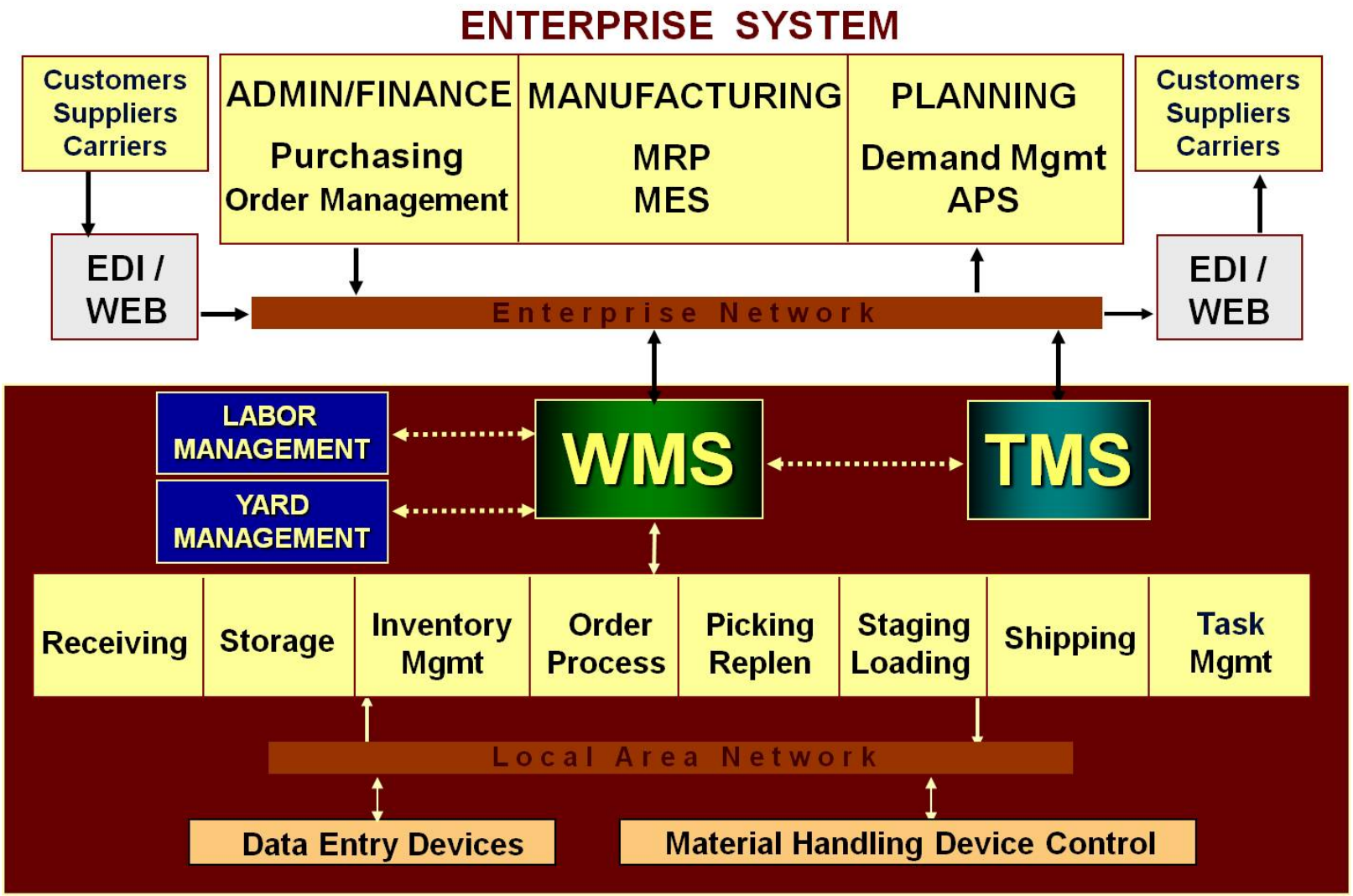

Outside building wall
Dock Face
Flush dock
Canopy
Dock Face
Open dock
Enclosure
Truck
Dock berths
Totally enclosed
Truck
Dock berths
Straight in, Straight out
Truc k
Dock Face
Sawthoot dock

Identification equipment



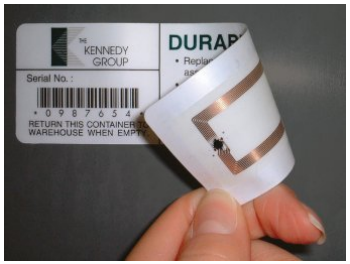
- **Idea:** speeding receiving & shipping
- **Where:** receiving & shipping
- **Issue:** integration with system
- **Example:** RFID, bar code reader, magnet

ERP/WMS/TMS



source: Brett Peters. "Collect-Industry Council on Material Handling Education"

Bar code scanner & RF terminal



Equipments selection

- **Finance:** IRR, payback period, b/c ratio, terms (rent/loan/lease & lead time)
- **Product, itself:**
  - **Physical:** material stage, std. dimension, weight
  - **condition:** temperature, shaded, traceability, moisture, sterilizing
  - **possible defect:** fragile, bend/compress/stack/roll-able
  - **hazard:** flammable, oxidizable, smell, corrosive,
- **System:** requirement (TH, CT, policy, scale-ability, priority), applicable to workers and system
- **Material:** physical appearance & property, quantity
- **Restriction:** area, power availability, door size, compliment to other MHE
- **Maintenance:** spare part, training program, SLA
- **Other:** prone to accident, customer, industry standard, technology

Useful information

Material Handling

- **Material Handling Taxonomy:** http://www.mhia.org/industrygroups/cicmhe/resources/mhe_tax.htm
- **Material Handling Pictures:** https://www.cirrelt.ca/mhmultimediabank/

Warehouse Tours

- **Interactive Tour:** http://www.roodbergen.com/warehouse/
- **Warehouse Science:** http://www2.isye.gatech.edu/~jjb/wh/sites/sites.html

COVID-19 and MHE

Opportunity

- **Investment:** labor shortage/ less crowded / higher wage / lack of 2^{nd} line mgt $\rightarrow$ better ROI
- **Business:** online+omni+onlive channels/ idea sandbox + catalyst /less market for fresh $\rightarrow$ development

Threats & Risks

- **Fluctuation:** bullwhip effect/ future trend (ever-fast changing industry)/ (peak VS off-peak)
- **Maintenance:** cost of PPE/ overseas MRO & part/

Problems

1. Why does a **single-deep rack** accommodate FIFO & FEFO policy, but not **double deep rack**?
2. Why floor stack is more suitable for a unit load fast-moving item than double-deep rack?
3. Compare **similarities** & **differences** of the following equipments
   - *selective rack & cantilever rack*
   - *drive-in rack & drive-through rack*

Summary:

- Equipment helps to reduce storage required, to improve efficiency, to protect condition of products
- Main types of equipment are:
  - **Unitload:** forming larger unit for easy handling or storage, e.g., pallet, tote
  - **Storage:** providing storage and address, e.g., rack, bin shelf
  - **Handling:** providing speed or scale to travel, e.g., forklift,
  - **Positioning:** assisting with activity, e.g., dock, arm,
  - **Communication:** providing info how to work, e.g. WMS, barcode,

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