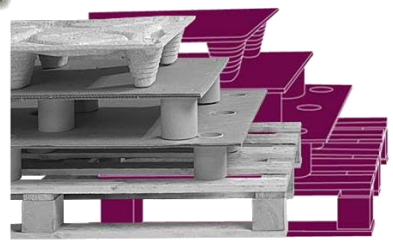
PALLET STORAGE AND RETRIEVAL SYSTEM

The material in this chapter will focus on pallet load storage and retrieval operations in warehouse. This handling unit is very often present in warehousing processes

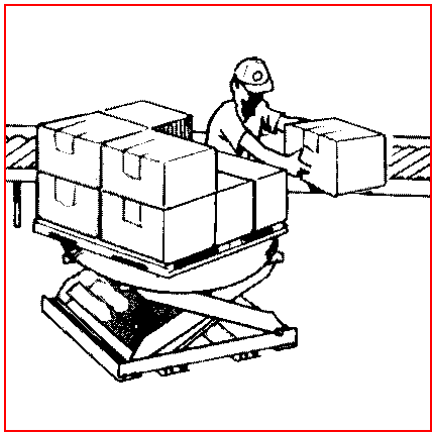
BUT, WHEN WE ARE TALKING ABOUT PALLET WHAT DOES IT MEAN?

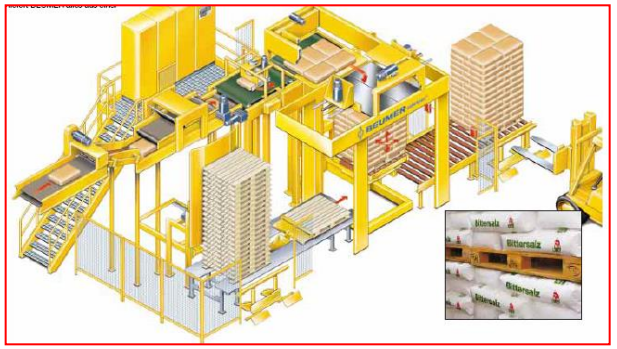
Usually, it is something like that

A lot of different models are developed and materials used



Different materials, sizes, shapes,… *and something new*





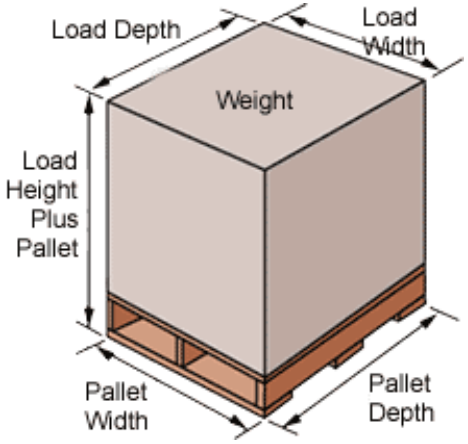
Different palletizing systems are developed

The material in this chapter will focus on pallet load storage and retrieval operations in warehouse. This handling unit is very often present in warehousing processes

PALLET STORAGE SYSTEMS

The most popular pallet storage systems are

Block stacking
Stacking frames
Single-deep selective pallet rack
Double-deep pallet rack
Drive-in rack
Drive-thru
Pallet-flow rack
Push-back rack
Mobile racks



Also, it could be found *deep-line racks* as well as some special constructions

Block stacking

Typically loads stacked on top of each other and stored on the floor in storage lanes, 2 to 10 loads deep. Stacks may range a height depending a lot of factors (safe limits, weight, pallet conditions…)

Typical question is concerned on line depth

First – question of the lane

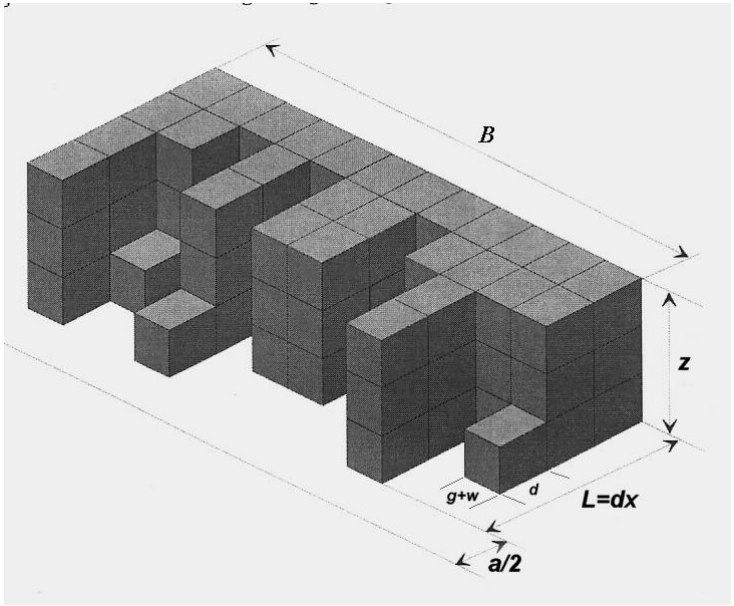
Let w, d are standard pallet width and depth
Lane is x pallets deep
g – gap between adjacent lines
a – aisle width,

then footprint of the lane (dedicated for a single SKU) is

(g+w)(d·x+a/2)

We have to store N pallets where $N = \sum_{i=1}^{n} q_i$

n – different items to be stored



In floor storage SKU_i is stored with $\mathbf{z_i \cdot x}$ pallets per lane and occupies $\mathbf{[q_i / (z_i \cdot x)]}$ lines. Assuming that average about half of each SKU i is present in the warehouse, there are lines occupied. To eliminate (minimize) rounding max. error, we assume that line occupied for item i could be expresses as

$[q_i / (2 \cdot z_i \cdot x)] + 1/2$

Multiplying by the footprint of a lane gives average floor area S occupied by whole population of SKUs:

$$\sum_{i=1}^{n} \left(\frac{q_i}{2 \cdot z_i \cdot x_i} + \frac{1}{2} \right) \cdot (g + w) \cdot \left(d \cdot x + \frac{a}{2} \right)$$

The result then follows setting the derivate of average floor space S to zero and solving for optimal line depth x:

$$S = \sum_{i=1}^{n} \left(\frac{q_i}{2 \cdot z_i \cdot x} + \frac{1}{2} \right) \cdot (g + w) \cdot \left(d \cdot x + \frac{a}{2} \right)$$

$$S = (g + w) \cdot \sum_{i=1}^{n} \left(\frac{q_i}{2 \cdot z_i} + \frac{d \cdot x}{2} + \frac{a \cdot q_i}{4 \cdot z_i \cdot x} + \frac{a}{4} \right)$$

$$\frac{dS}{dx} = (g + w) \cdot \sum_{i=1}^{n} \left(\frac{d}{2} - \frac{a \cdot q_i}{4 \cdot z_i \cdot x^2} \right) = 0,$$

follows:

$$d \cdot n = \frac{a}{2 \cdot x^2} \sum_{i=1}^{n} \frac{q_i}{z_i},$$

$$L^*(x) = \sqrt{\frac{a}{2 \cdot d \cdot n} \sum_{i=1}^{n} \frac{q_i}{z_i}}$$

Example:

Aisle a = 4m,

Pallet (w · d) =1,2 · 0,8 m

n = 3

SKU_i	q_i	z_i
A	50	3
B	40	4
C	36	2

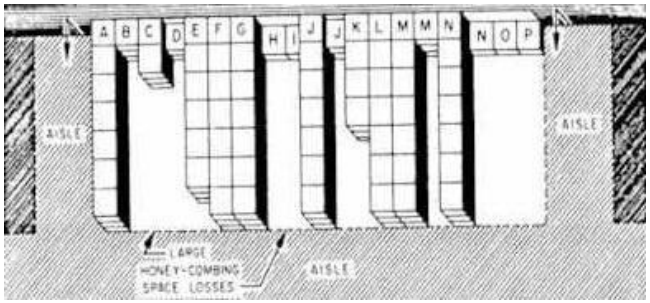
$$L^* = \sqrt{\frac{4}{2 \cdot 0{,}8 \cdot 3} \cdot \left(\frac{50}{3} + \frac{40}{4} + \frac{36}{2} \right)} = 0{,}91 \cdot 6{,}68 = 6{,}06 \rightarrow 6 \text{(pallets}$$

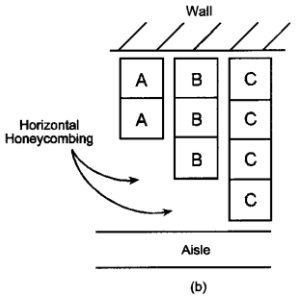
Of course, in practice, d has to be corrected (typically adding at least 0,1 m)

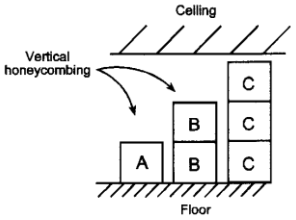
This system support FILO discipline, when inventory turns in large increments

Concerning limitations, generated with loads removed from a storage lane, a space loss phenomenon referred to as ***honeycombing*** *occurs.* That's the reason that line depth must be carefully determined.

The investment in a block system is low, near infinite flexibility for floor space configuration



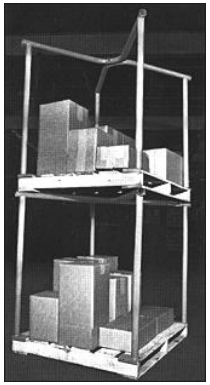


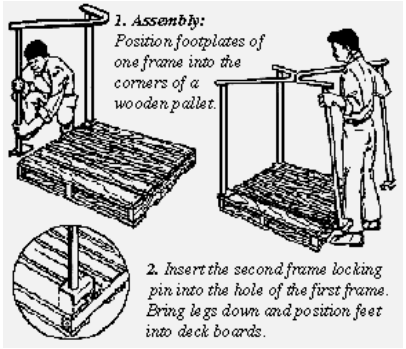


Pallet stacking frames

Stacking frames are commonly used when loads are not stackable and other racking alternatives are not justifiable. They are useful to increase storage density as normally open floor-space.

A single stacking frame costs $100 - $300



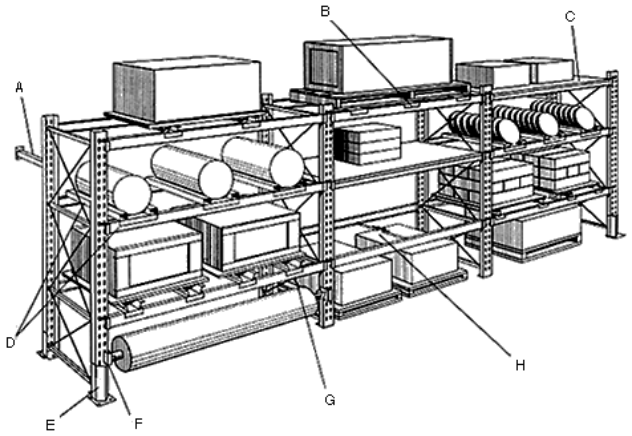


Single deep (selective) pallet rack

They are simple metal construction providing immediate (pick-face) access to each unit (without honeycombing) 100% FIFO enabled . Stacking height is not limited by stackability, (it could be up to 40 m), depending on material handling system involved.

Typical price of rack position is $40 - $50. Major disadvantage is amount of space devoted to aisles.

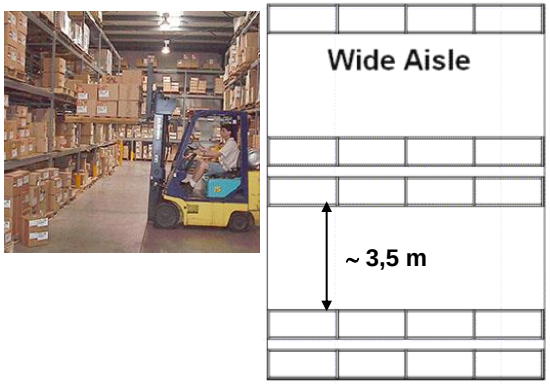
Most storage systems benefit from the use of at least some selective pallet rack for SKUs whose storage requirements is less then 3 to 5 pallet loads.

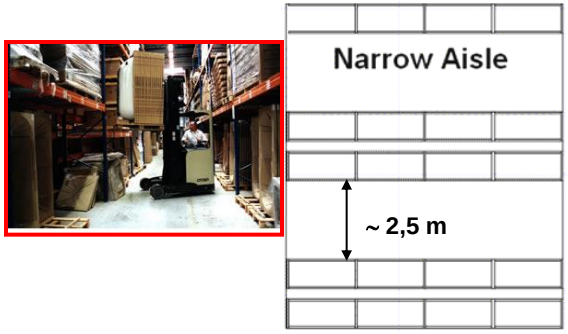


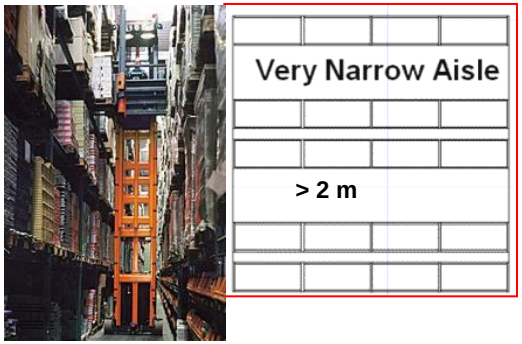
Pallet Rack Accessories
for Maximum Versatility

Aisle width is very important. There are many technical solutions in fork-lift techniques

Here is one comparison





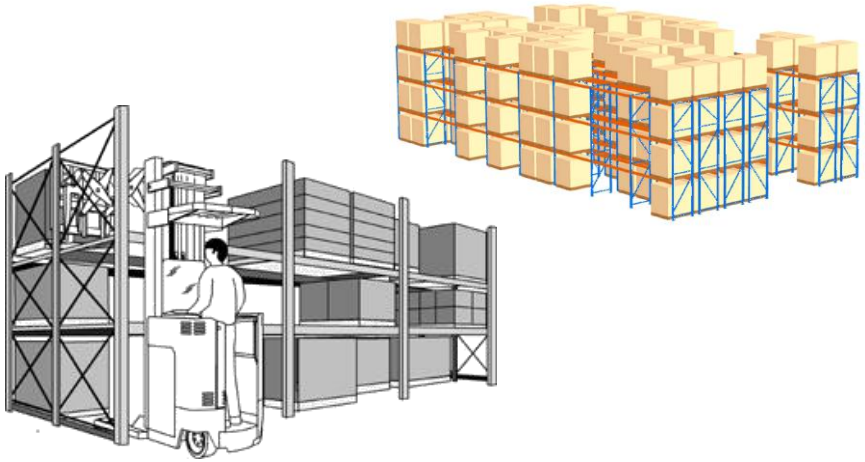


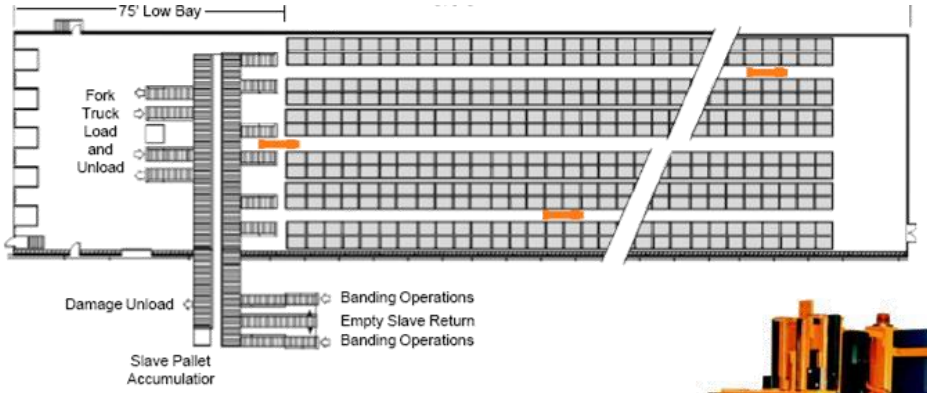
Vehicle Type	Space Utilizatoin	Productivity	Cost	Flexibility
Standard Wide Aisle Forklift	Baseline		$	
Narrow Aisle Reach	+20% to +25%		$ $	
Narrow Aisle Double Deep Reach	-20% to +60%		$ $	
VNA Turret	+40% to +50%		$ $ $ $ $	
VNA Swing Mast or Bendi	+35% to +45%		$ $ $	

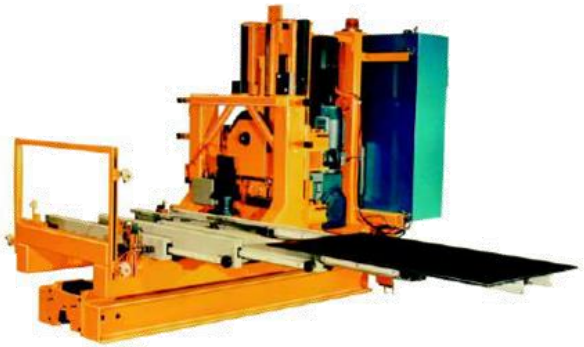
Double deep pallet rack

The advantage of two deep pallet rack is that fewer aisles are needed (50% aisle savings achieved versus single deep selective rack. But, here is utilization les due to honeycombing.

This type of rack is used when the storage requirement for SKU is >5 pallets, when product is received and picked frequently in multiples of 2 pallets.







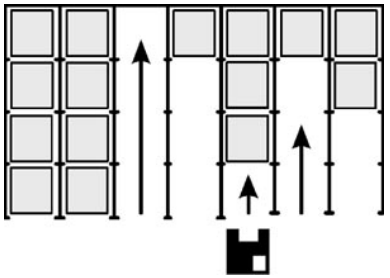
Double deep shuttle provides high density storage using fewer aisles.

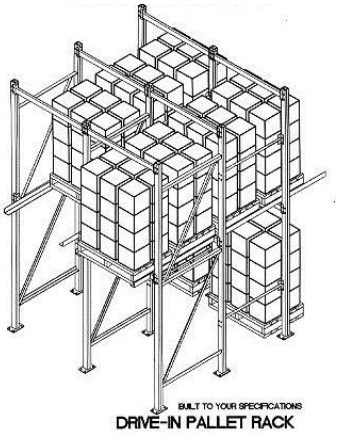
Drive in rack

Drive in racks extend the reduction of aisle space begun with double deep pallet rack by providing storage lanes to 10 load deep and 3 – 5 loads high; construction enables a lift truck to drive into the rack several pallet positions and store/retrieve a pallet.

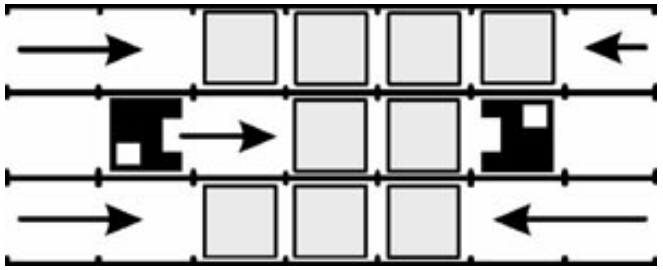
Disadvantages are a reduction of lift truck travel speed and honeycombing losses; LIFO

Drive in rack is best used for slow to medium velocity SKUs with 20 or more pallets



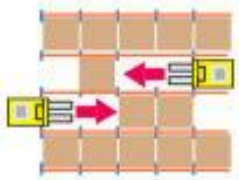


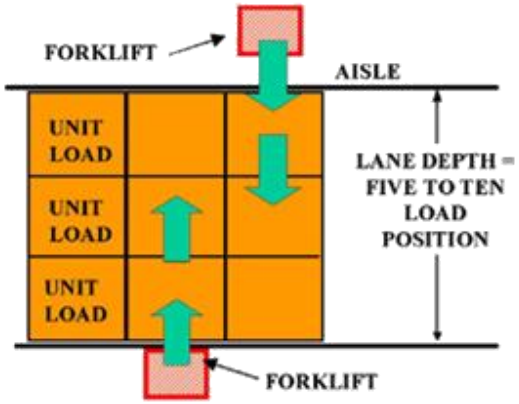
Drive thru rack



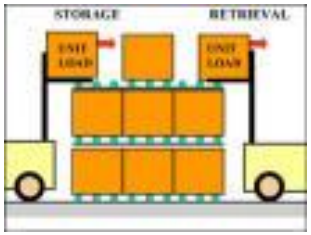
Drive thru rack are similarly drive in rack that is ***accessible from both sides of the rack***. It is for staging loads in a flow thru fashion where a pallet is loaded at one end and retrieved at the other end.

FIFO is also achieved.





Pallet flow rack



In pallet flow rack loads are conveyed (FIFO) on different types of conveyors, form one end of storage lane to the other. As a load is picked, the next load (if any) advances to pick face.

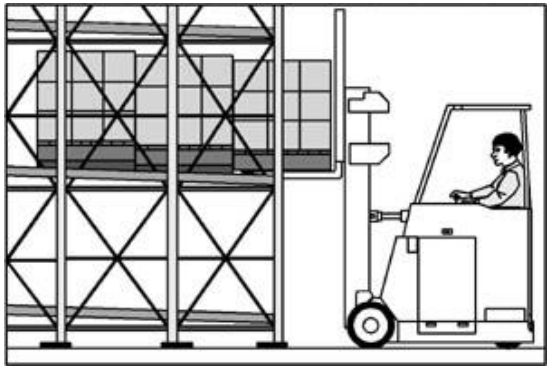
The main purpose of pallet flow rack is to provide high throughput pallet storage and retrieval and good space utilization.

Price is the major disadvantage: $200 - $300 per storage position.

Push back rack

This type provides LIFO 2 to 5 pallets deep line. During storing, force of putaway vehicle pushes the other loads in the lane back to create room for the additional load. As a load is removed from the front of a storage lane, the weight of remaining automatically advances remaining loads to the rack face.

Push back racks are appropriate for medium to fast moving SKUs. Cost is in the range of $150 per pallet position.

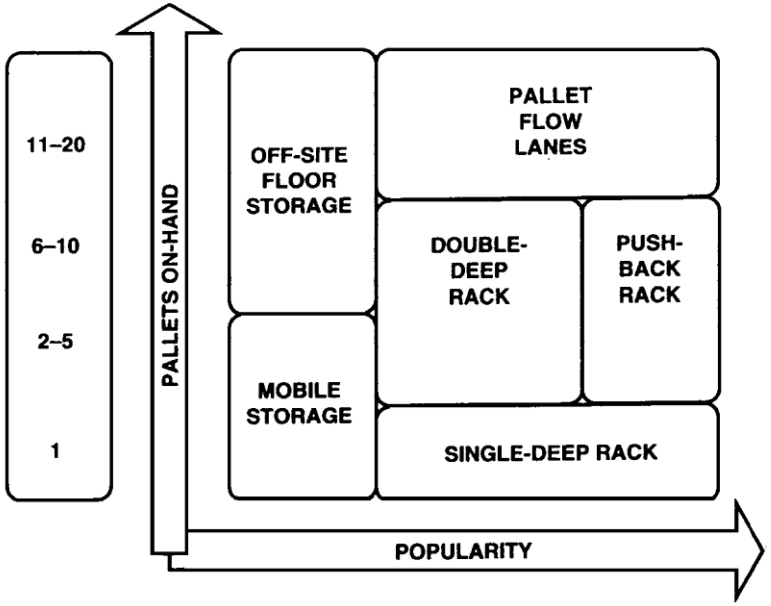


Mobile rack

Essentially, they are single-deep pallet racks on wheels and tracks permitting entire row of racks to move away from adjacent rack rows. As result, les then 10% OF floor space is devoted to aisles and the storage density is the highest. But productivity of pallet retrieval is lowest. So, they are acceptable where space is expensive, with slow moving SCUs. The costs are typically in range of $250 per pallet position.

Pallet storage system selection

Figure is designed to assist in storage system configuration. The example is taken from particular case and cannot be generalized because the preference regions vary widely as a function of the cost and availability of labor and space.



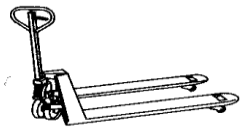
PALLET STORAGE/RETRIEVAL SYSTEM

The most popular pallet S/R systems are based on:

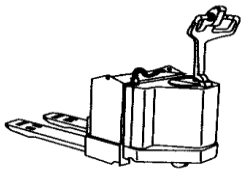
- **Walkie trucks**
- **Counterbalance lift truck**
- **Straddle trucks**
- **Straddle reach trucks**
- **Sideloader trucks**
- **Hybrid trucks**
- **Automated storage and retrieval (AS/RS) systems**

Walkie trucks

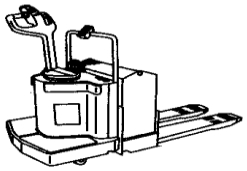
Walkie trucks enables a pallet to be transported on a shorter distances, and some types enables a pallet to be lifted and stacked. They are typically appropriate where short distances, low vertical storage height and low cost solutions and low throughput are desired. Some are motorized and designed for higher stacking (walkie stackers)



Pallet truck
Pallet jack



Motorized hand truck
Walkie low lift



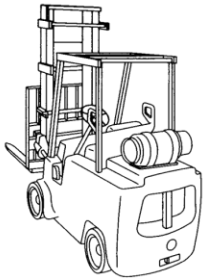
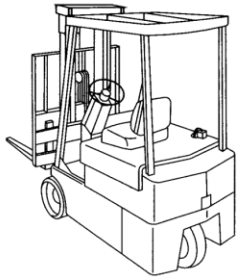
Motorized hand/rider
Walkie low lift rider

Motorized walkie stacker

Walkie stacker manually powered

Counterbalanced lift trucks

They can be gas, oil or battery powered. Besides forks, other attachments may be used. Lifting height is typically below 7 – 7,5 m and capacity up to 50 t. They are used ordinary for selective pallet racks, push back but they are used as well for putaway/retrieve operations as for truck load/unload operations. Flexibility, coupled with relative low cost make them for benchmark for all pallet retrieval vehicles.
The major drawback is wide turning radius and wide aisles (with 1 t capacity around 3,5 m).






Straddle trucks

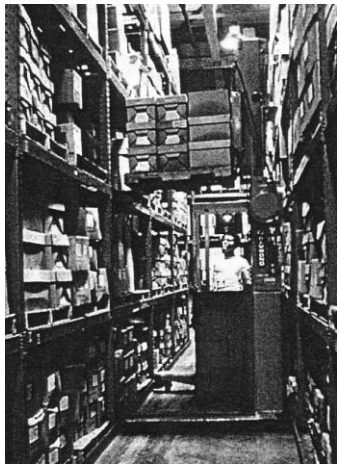
This truck provides load and vehicle stability using outriggers to straddle the pallet load, instead a counterbalanced weight, resulting with aisle with 2,5 – 3 m. It is necessary to support the floor level load on rack beams.

Straddle reach trucks

They are Developed from conventional straddle trucks by shortening the outriggers and providing reach capability with two type of mechanisms (fork and mast reach).
So they do not need to be driven under the floor load level to enable storage position. Also, double deep reach truck is available.

Sideloading trucks

A sideloading truck loads and unloads rack from one side, thus eliminating the need to turn in the aisle to access storage positions. Either mast moves on a set of tracks transversely or the fork project from a fixed mast on a pantograph.
The major drawback is the need to enter the correct end of the aisle to access a particular location, thus adding routing complexity.



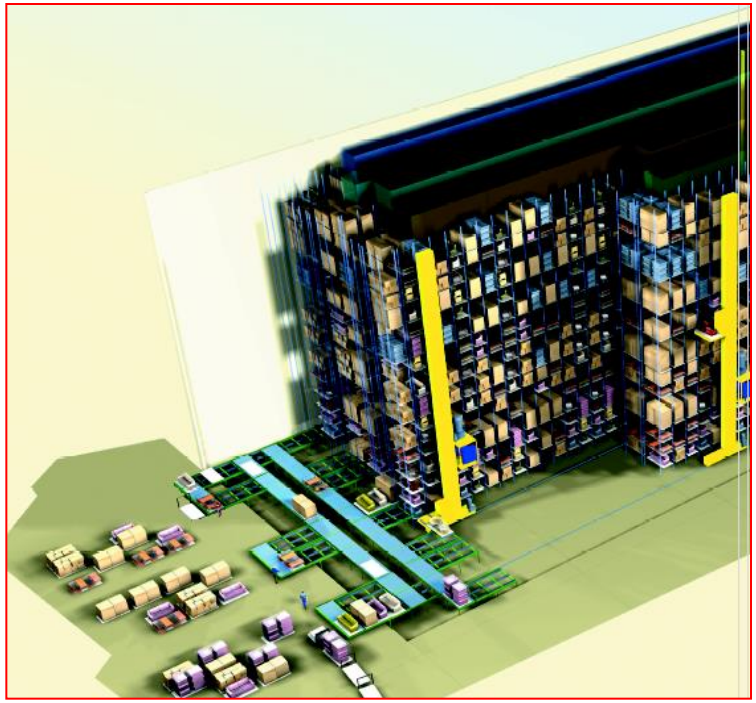
Turret trucks

Turret trucks (swingmast or swingreach models) do not require the vehicle to make a turn within the aisle to store or retrieve pallet. Load is lifted by forks that swing on the mast, a mast that swings from the vehicle, or a shuttle fork mechanism.

AS/RS Automated storage/retrieval system

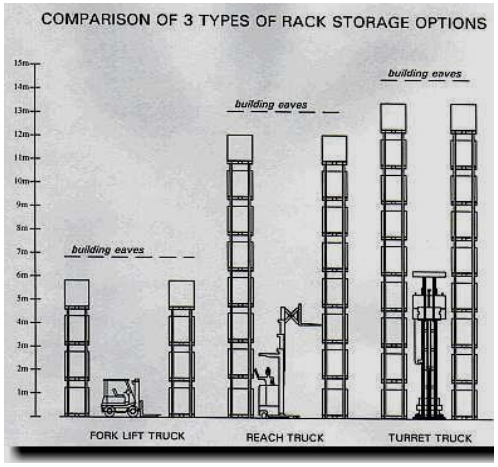
AS/RS consists on integrated that implement storage/warehousing elements (storage medium, transport mechanism and controls) with various levels of automation for fast and accurate random storage of products, with high productivity. This is based on simultaneously vertical and horizontal travel of S/R machine.
Racks are high up 30m or more, S/R machine operates in narrow aisle. It is connected with receiving/shipping points by various techniques.

Some of possible configuration alternatives are:
- **Double deep storage with single load width aisle**
- **Double deep storage with double load width aisle**
- **Deep lane storage with single load width aisle**



Storage racks comparison

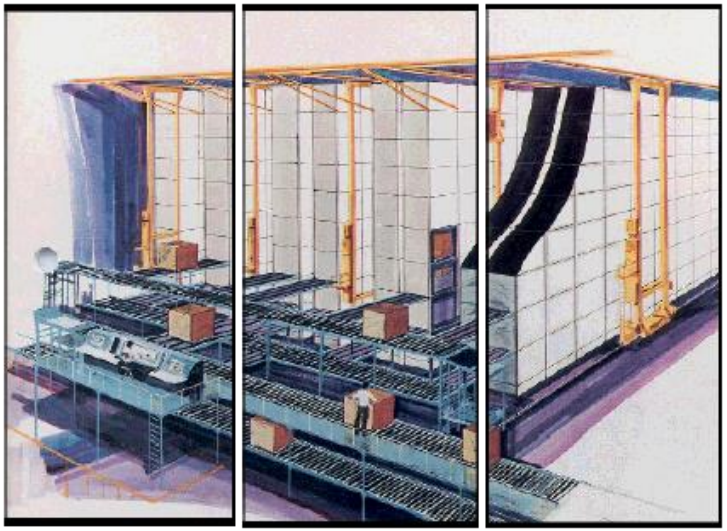
Type of Rack	Storage Pattern	All Loads Accessible	FIFO Retrieval	Principal Advantage	Principal Disadvantage
Standard	single deep	yes	yes	-	↓ cube util.
Narrow Aisle	single deep	yes	yes	↑ cube util.	↓ truck cost
Deep Reach	> 1 deep	no	no	↑ cube util.	↑ truck cost
Drive In	> 1 deep	no	no	↑ cube util.	↑ honeycomb loss potential
Drive Thru	> 1 deep	no	yes	↑ cube util.	↑ honeycomb loss potential
Flow Thru	> 1 deep	no	yes	↑ cube util.	↑ rack cost
Push Back	> 1 deep	no	no	↑ cube util.	↑ rack cost
Sliding Racks	single deep	yes	yes	↑ cube util.	↑ rack cost + T S/R time

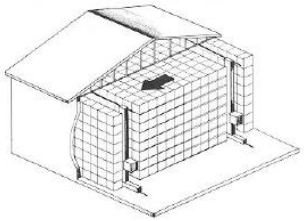


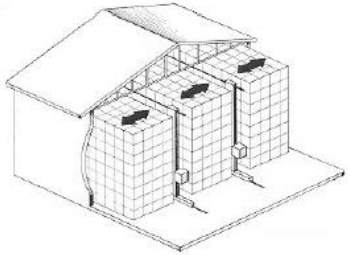
Pallet retrieval system comparison *(typical data)*

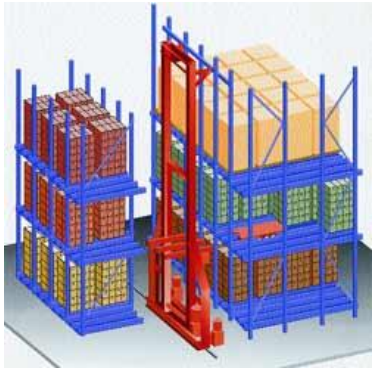
	Counter - balance	Straddle	Straddle Reach	Side loader	Turret	AS/RS
Vehicle cost	$30,000	$35,000	$40,000	$75,000	$95,000	$200,000
Lift height Capacity m	7	6,5	10	10	12	30
Aisle width m	3,5	2,5-3	2-2,5	1,5-2	1,5-2	1.5
Weight capacity t	3	2,5	2,5	3	2	3
Lift speed m/min	25	18	15	15	23	60
Travel Speed /min	170	140	150	130	150	210

Automated Storage/Retrieval System









Storage/retrieval machines use a transport shuttle to place unit loads in storage lanes that are one to seven positions deep

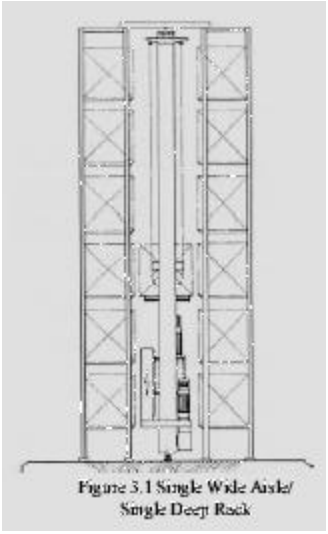


Figure 3.1 Single Wide Aisle/ Single Deep Rack

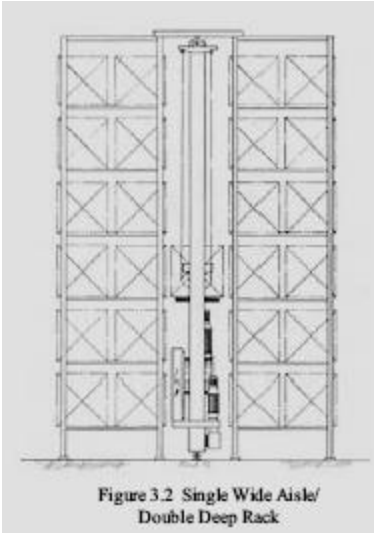


Figure 3.2 Single Wide Aisle/ Double Deep Rack

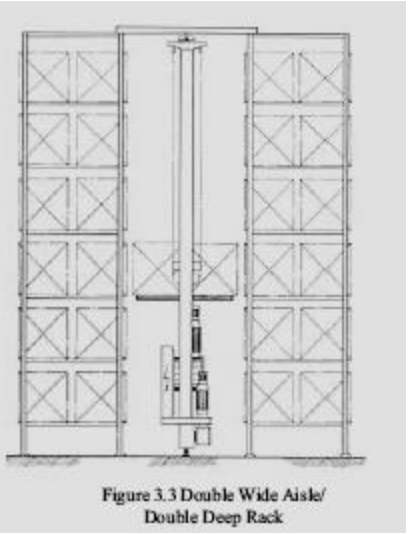
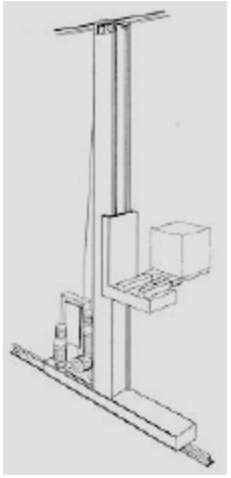
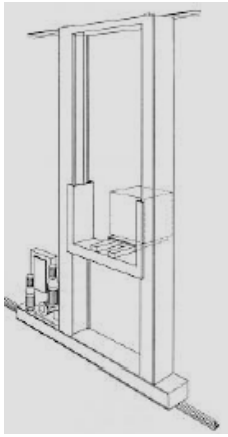


Figure 3.3 Double Wide Aisle/ Double Deep Rack





ALTERNATIVE BULDING CONSTRUCTIONS FOR PALLET RACK WHs