Storage Space Planning in Warehouse

The maximum and average quantities of unit load stored in warehouse are directly related to the method of controlling inventory and inventory control objectives.

Re-order point = Safety Stock + "demand over lead-time"

Maximum quantity to be stored = Safety Stock + Order Quantity

$$\text{Average quantity to be stored} = \text{Safety Stock} + \frac{\text{Order Quantity}}{2}$$

The two storage location methods that represent extreme points of view are randomized storage and dedicated storage.

- Randomized storage is used when an individual stock keeping unit can be stored in any any available storage location.

⇒ When an inbound load arrives for storage, the closest available slot is designated as the storage location. Retreivals are performed on FIFO basis.

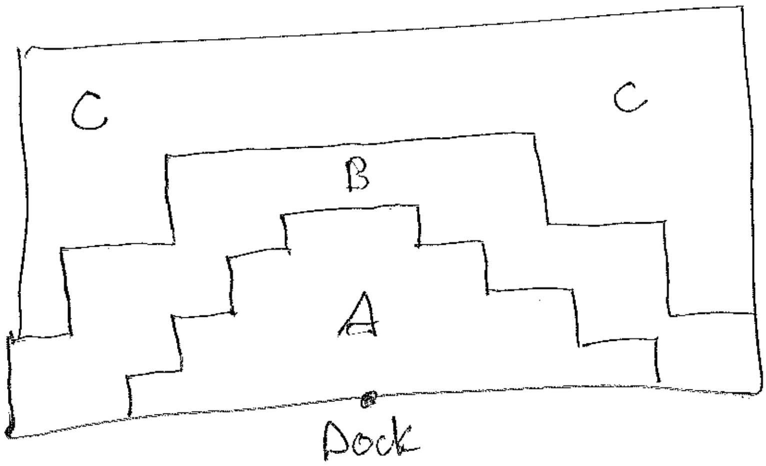
- Dedicated storage is used when an individual stock keeping unit is assigned to a specific storage location or set of locations. The term fixed slot is used to describe dedicated storage.

Two variations:

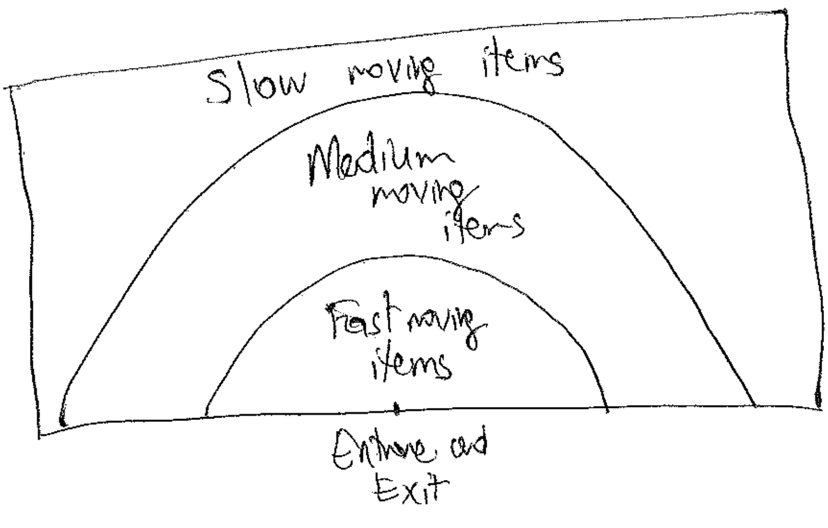
- storage of items in part number sequence,
- determine the storage location based on its level of activity and inventory level.

Over on example: Suppose three classes of products:

A items represent $\sim$80% of the input/output activity
B items represent $\sim$15% of the " "
C items represent $\sim$5% of the " "



Optimum dedicated storage layout



Material storage by popularity

STORAGE MODELS:

Unit load storage alternatives:

- Block stacking,
- Deep lane storage,
- Single-deep selective pallet rack,
- Double-deep selective pallet rack.

Block stacking: It involves the storage of unit loads in stacks within storage rows. It is frequently used when large quantities of a few products are to be stored and the product is stackable to some reasonable height without load crushing.

Block stacking is typically used to achieve a high space utilization at a low investment cost.

Note that; during the storage and retrieval cycle of a product lot, vacancies can occur in a storage row. To achieve FIFO, lot rotation, these vacant storage positions can not be used for storage of other products. The space losses resulting from unusable storage positions are referred to as "honeycomb loss".

Block stacking suffers from both vertical and horizontal honeycomb loss.

The design of the block stacking storage system is characterized by:

- the depth of the storage row, (x),
- the number of storage rows required for a given product lot, (y), and
- the height of the stack (z),

where the decision variables x, y ~~and~~ must be integer valued...

$$S_{BS} = \eta (W + c)(xL + 0.5A)$$

- S_{BS} → average amount of floor space required with block stacking and no safety
- η → average number of storage rows required over the life of a storage lot, with block stacking
- W → width of unit load
- c → side-to-side clearence between unit loads and between a unit load and a vertical rack member
- x → depth of a storage row or storage lane, in unit loads
- L → Length or depth of a unit load
- A → width of the storage aisle

Assuming $I_K = Q + 1 - K$ (uniform withdrawal)

$$\eta = \frac{y\left[2Q - xyz + xz\right]}{2Q}$$

Q → size of storage lot, in unit loads

Substituting this

$$S_{BS} = y(W+c)(xL + 0.5A)\frac{\left[2Q - xyz + xz\right]}{2Q}$$

S_{BS} is not a convex function, in order to obtain its minimum it is necessary to enumerate over x.

Example:

Assume $X=2$ and $Z=3$

Period	Inventory level
1	15
2	14
3	13
4	12
5	11
6	10
7	9
8	8
9	7
10	6
11	5
12	4
13	3
14	2
15	1

# of storage rows required	Periods	# of periods
3	1, 2, 3	3
2	4, 5, 6, 7, 8, 9	6
1	10, 11, 12, 13, 14, 15	6

$$\eta = 3\cdot\left(\frac{3}{15}\right) + 2\left(\frac{6}{15}\right) + 1\left(\frac{6}{15}\right)$$

$$= \frac{27}{15} = \underline{\underline{1.8}} \quad \#$$

$$\eta = \frac{y\left[2Q - Xyz + Xz\right]}{2Q} = \frac{3\left[2\cdot 15 - 18 + 6\right]}{30} = \frac{54}{30} \quad \#$$

Continuous approximation: For large values of Q

using $Q = XyZ$

$$S_{BC}^{C} = (W+C)(XL + 0.5A)\frac{(Q + XZ)}{2XZ}$$

take derivative with respect to X, and set equal to zero

$$X_{BC}^{C} = \sqrt{\frac{AQ}{2LZ}}$$

"Continuous approximation to the optimum value of X"

Example:

Suppose $Q = 200$

$A = 12'$

$L = 4'$

$z = 4$

$$X^{C}_{BS} = \sqrt{\frac{\overset{3}{\cancel{12}} * \overset{100}{\cancel{200}}}{\cancel{2} * 4 * \cancel{4}}} = \sqrt{75} = 8.66$$ ✡

the optimum value of x would be either 8 or 9.

For what range of values of Q will $X^{C}_{BS} = 25$ $(24.5 \leq x \leq 25.5)$

⇓

$(1600 \leq Q \leq 1734)$

Safety stock: safety stock (s)

$$\eta = \frac{y\left[2(Q+s) - xyz + xz\right]}{2(Q+s)}$$

$$S_{BSSS} = \frac{y(W+c)(xL+0.5A)\left[2(Q+s) - xyz + xz\right]}{2(Q+s)}$$

$$S^{C}_{BSSS} = \frac{Q(W+c)(xL+0.5A)(Q+2s+xz)}{2(Q+s)xz}$$

$$X^{C}_{BSSS} = \sqrt{\frac{A(Q+2s)}{2Lz}}$$

- Deep lane storage is very similar to block stacking, except every unit load is individually supported
- The single-deep and double-deep pallet racks can be considered special cases of deep lane storage with X = 2 and X = 1, respectively.