Storage Systems Analysis

END4650 – Material Handling Systems

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Storage Systems – Material Types

Types of materials typically stored in a manufacturing firm

Type	*Description*
1. Raw materials	Raw stock to be processed (e.g. bar stock, sheet metal, plastic molding compound)
2. Purchased parts	Parts from vendors to be processed or assembled (e.g. castings, purchased components)
3. Work-in-process	Partially completed parts between processing operations or parts waiting assembly
4. Finished product	Completed product ready for shipment
5. Rework and scrap	Parts that are out of specification, either to be reworked or scrapped

Product

Storage Systems – Material Types

Types of materials typically stored in a manufacturing firm

Type	*Description*	
6. Refuse	Chips, swarfs, oils, other waste products left over after processing; these materials must be disposed of, sometimes using special precautions	Process
7. Tooling	Cutting tools, jigs, fixtures, molds, dies, welding wire, and other tooling used in manufacturing and assembly; supplies such as helmets, gloves, etc., are usually included	Process
8. Spare parts	Parts needed for maintenance and repair of factory equipment	Process
9. Office supplies	Paper, paper forms, writing instruments, and other items used in support of plant office	Support
10. Plant records	Records on product, equipment, and personnel	Support

Storage Sys

WIP Inventory

Storage Systems – System Performance

There are 4 KPI for a storage system:

1. Storage Capacity**:** can be measured in two ways:

- the total volumetric space available
- the total number of storage compartments available

2. Storage Density**:**

- the volumetric space *available* for actual storage relative to the *total* volumetric space in the storage facility.
- In many warehouses, aisle space and wasted overhead space account for *more volume* than the volume available for actual storage of materials

Storage Systems – System Performance

***3. Accesibility*:**

- refers to the capability to access any desired item or load stored
- In the design of a storage system, trade-offs must be made between
    - storage density, *and*
    - accesibility.

***4. System Throughput*:**

- defined as the hourly rate at which the storage system
    - receives and puts loads into storage and/or
    - retrieves and delivers loads to the output station
- must be designed for the maximum throughput

Storage Systems – System Performance

- System throughput is limited by the time to perform a storage or retrieval (S/R) transaction.
- A typical storage and retrieval transactions consist of the following elements

- *Storage transaction elements*
- (1) pick up load at input station
- (2) travel to storage location
- (3) place load into storage location
- (4) travel back to input station

- *Retrieval transaction elements*
- (1) travel to storage location
- (2) pick item from storage location
- (3) travel to ouput station
- (4) unload at output station

Storage Systems – System Performance

- Throughput can sometimes be increased by
  - combining storage and retrieval transactions in one cycle,
  - thus reducing travel time;
  - this is called a ***dual command cycle***.
- When either a storage or a retrieval transaction alone is performed in the cycle,
  - it is called a ***single command cycle***.

Storage Systems – System Performance

- Two more KPI for AS/RS
- ***Utilization***:

$$\frac{S - R\ Operations\ time}{Available\ time}$$

- ***Availability***:

$$\frac{Capable\ of\ Operating\ Time}{Normally\ scheduled\ shift\ hours}$$

Storage Systems – Location Strategies

- Each item type stored in a warehouse is known as a stock-keeping-unit (SKU).
- The SKU uniquely identifies that item type.
- Two Basic Strategies are
  - Randomized Storage
  - Dedicated Storage

Storage Systems – Location Strategies

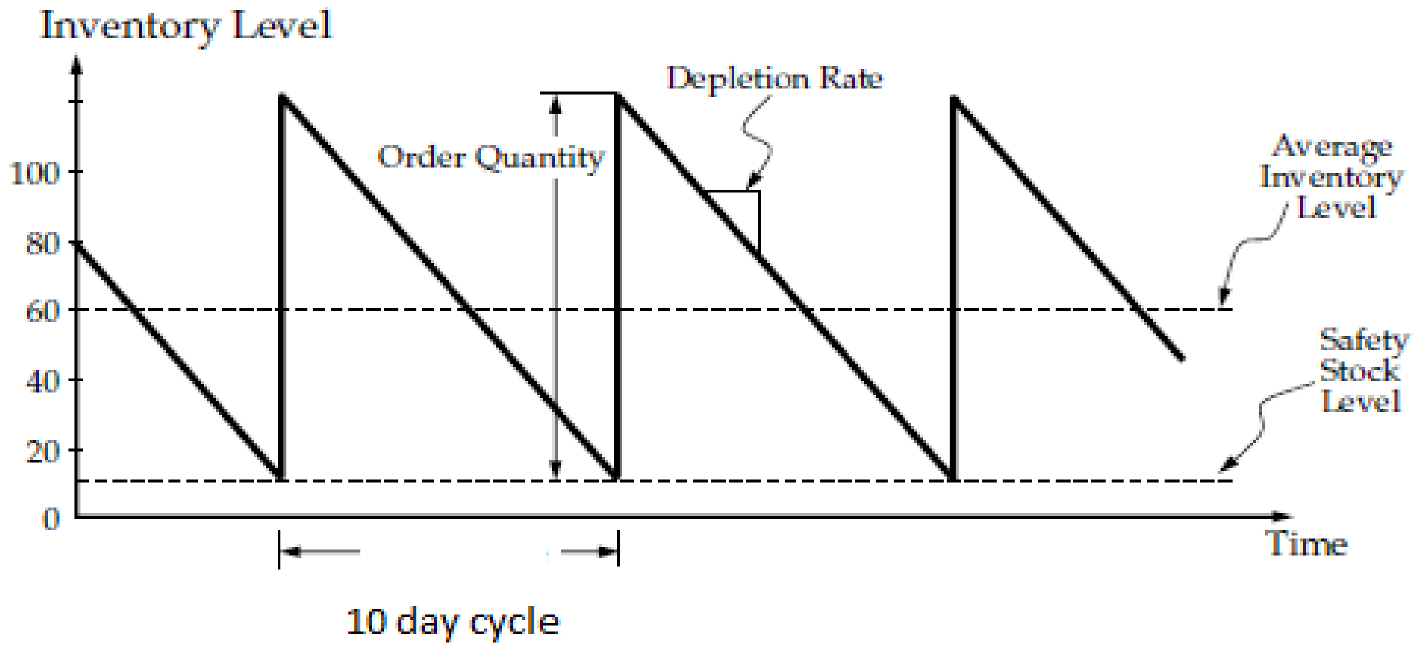
- **Randomized Storage:**
  - items are stored in any available (nearest available) location
  - The stock is retrieved from storage according to a FIFO policy
    - So that the longest staying items are used to make up the order
- **Dedicated Storage:**
  - SKUs are assigned to specific locations that are reserved
  - The number of storage locations for each SKU must be sufficient to accomodate its maximum inventory level.
- Less space for randomized
- Higher throughput rates for dedicated storage

Storage Systems – Location Strategies

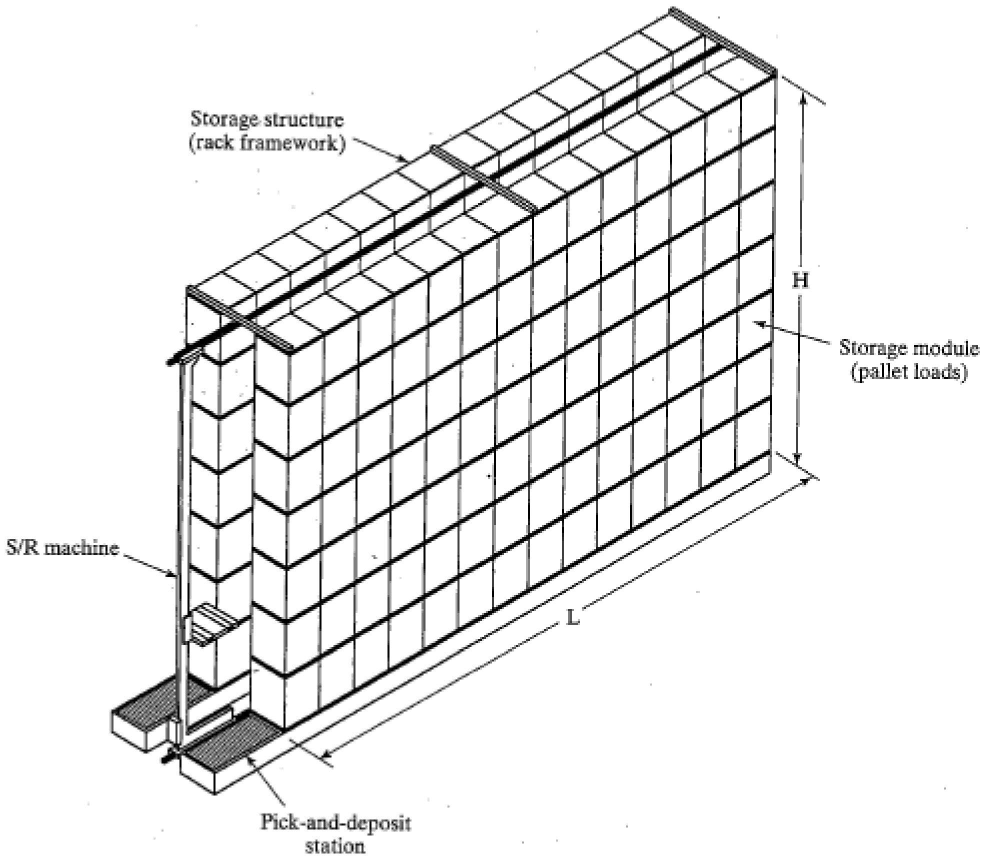
- **Example**
- 10 SKUs
- avg order quantity= 100 cartons
- avr depletion rate=10 cartons/day
- safety stock level = 10 cartons
- Each carton requires one storage
- Each SKU has an inventory cycle of 10 days.
- Since there are 10 SKUS, management has scheduled incoming orders so that a different SKU arrives each day.
- Determine the number of storage locations required in the system under two alternative strategies

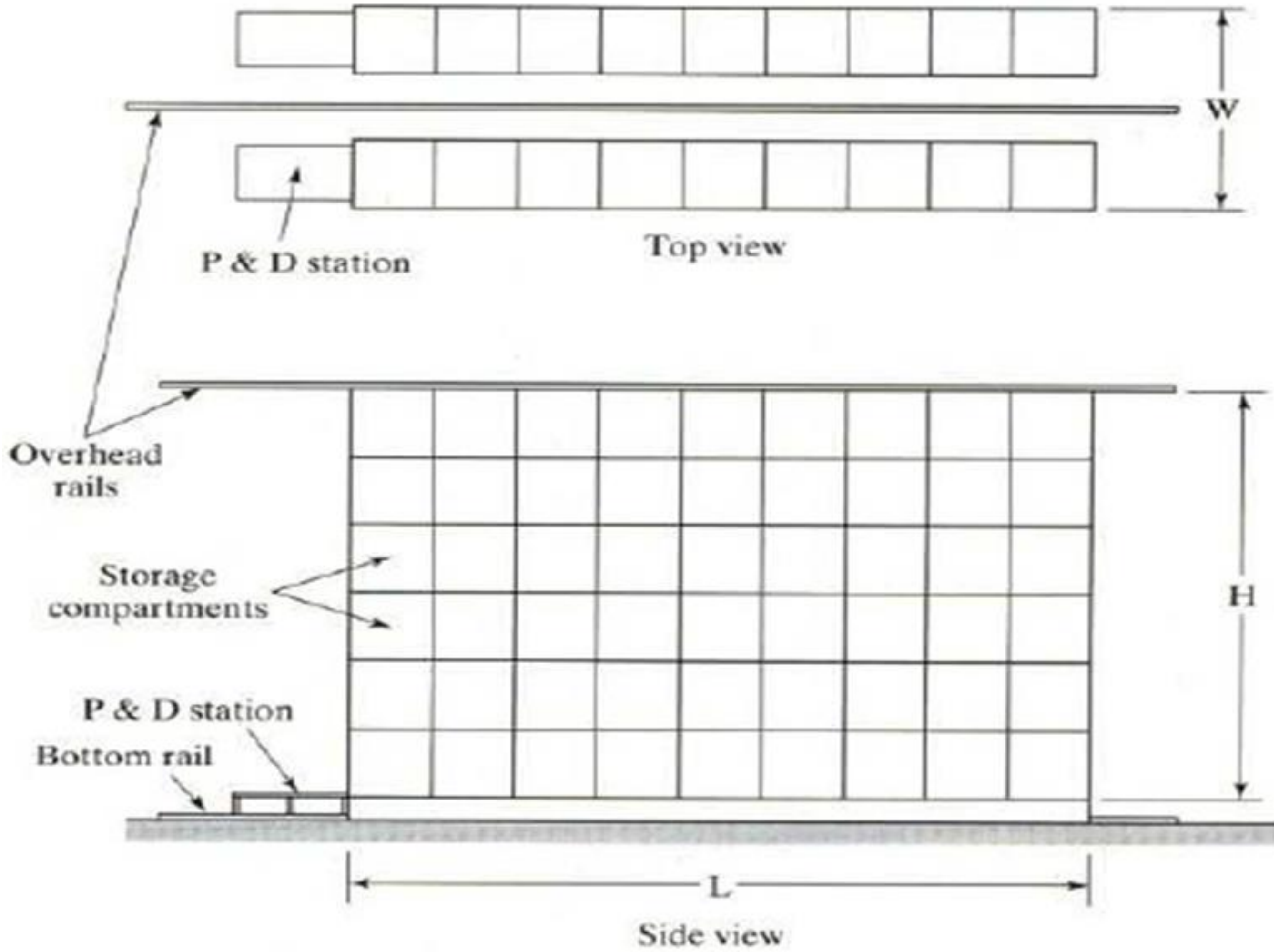
Storage Systems – Location Strategies

- **Solution:**
- The max inv level = 10+100
- Min inventory level = 10
- Average inv level = 60
- **Randomized Solution: (an estimate)**
  - 10SKU x 60 = 600 locations
- **Dedicated Solution**
  - 10SKU x 110 = 1100 locations



Storage Systems – Unit Load AS/RS





Storage capacity per aisle:

$$\text{Capacity} = 2n_y n_z$$

n_y : number of units along the length of aisle

n_z : number of units along the height of aisle

Dimensions:

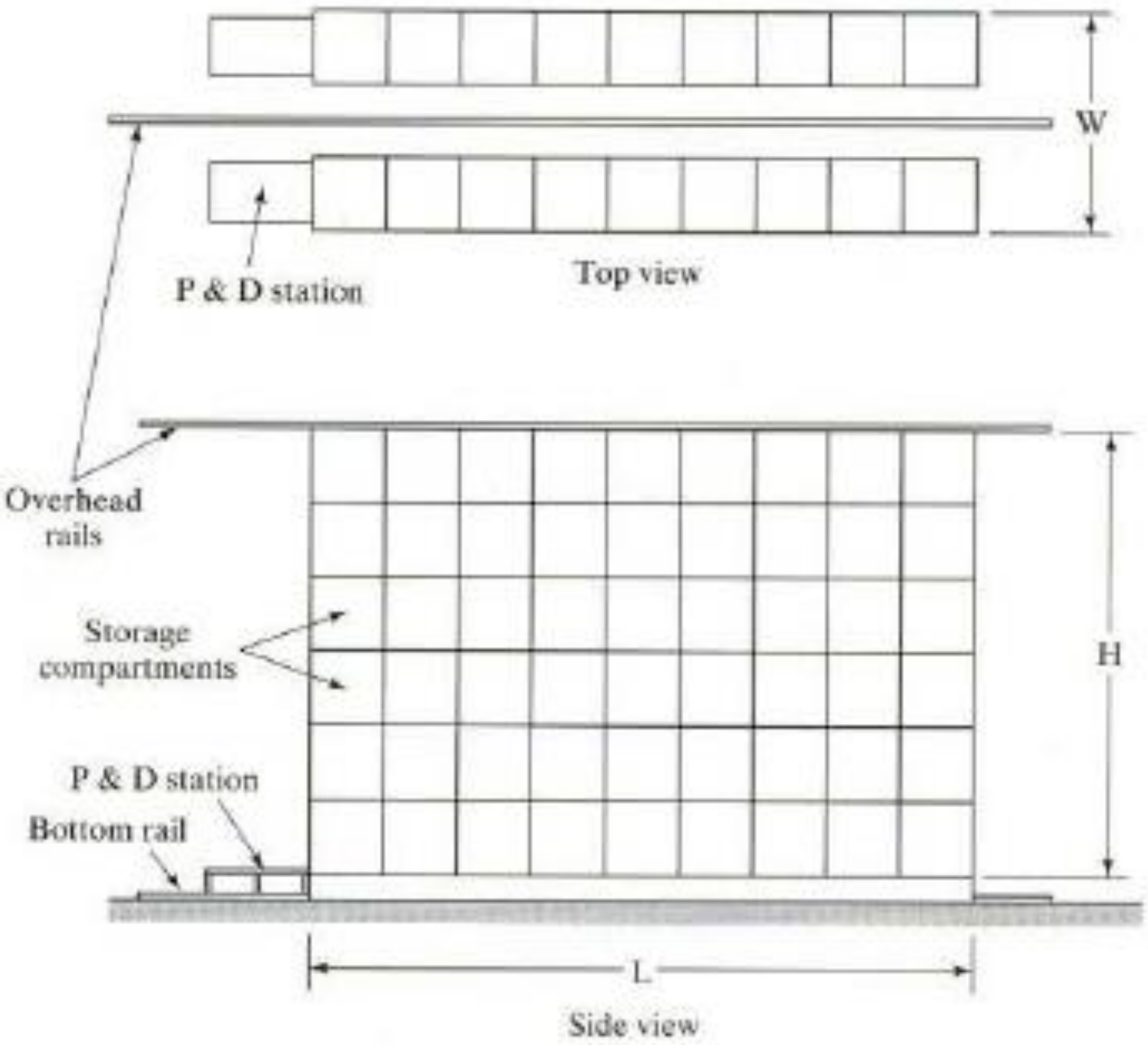
$$W = 3(x + a)$$

$$L = n_y(y + b)$$

$$H = n_z(z + c)$$

x, y, z : dimensions of the unit load

a, b, c : allowances



Unit Load AS/RS

- **Example:** Each aisle of **a four-aisle** AS/RS is to contain
  - 60 storage compartments in the length direction and
  - 12 compartments vertically.
  - All storage compartments will be the same size to accomodate standard size pallets of dimensions:
    - x = 42 in, y = 48 in. and height of a unit load z = 36 in.
  - Using the allowances a = 6 in, b = 8 in, and c = 10 in, determine:

a) The number of unit loads can be stored in the AS/RS.

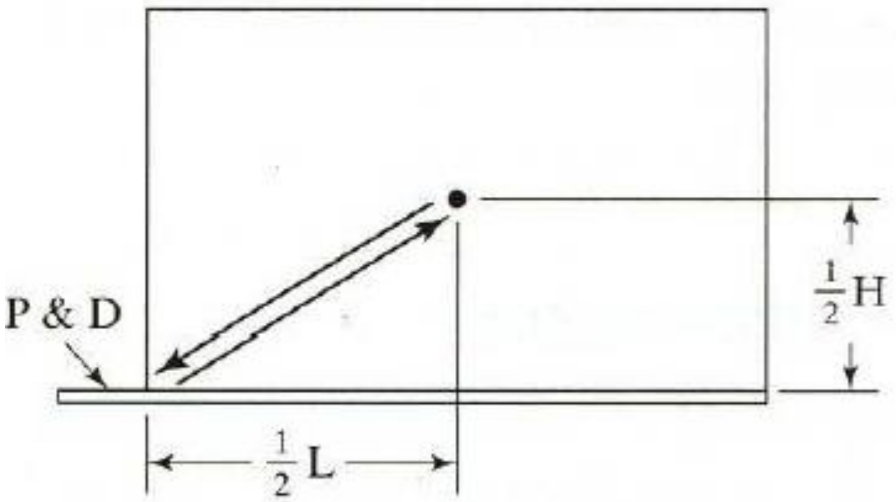
b) The width, length, and height of the AS/RS.

c) If the total width of the system is required to be about one fifth of the length find a design (*ny* and *nz*) that has at least the same capacity of the above design.

Unit Load AS/RS

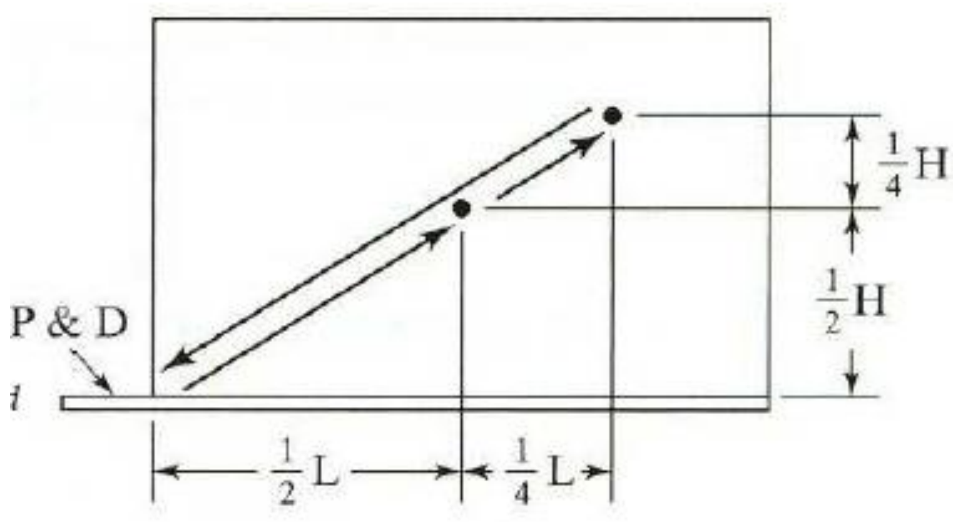
- (a)
  - Capacity = 2 x 60 x 12 = 1440 unit loads
  - AS/RS Capacity = 4 x 1440 = 5760
- (b) Dimensions
  - W = 3x(42 + 6) =144 in
  - Overall width is 4x(144) = 576
  - L = H=?
- (c) ??

AS/RS Throughput



- Travel Trajectory – Single Command Cycle
- T_s = *single* command cycle time
- T_{pd} = pick up and deposit time (min)
- L = length of the AS/RS rack structure(m)
- H = height of the AS/RS rack structure(m)
- v_y = velocity of the S/R machine along the length (m/min)
- v_z = velocity of the S/R machine in the vertical direction (m/min)
- $T_s = 2\max\left\{\frac{0.5L}{v_y}, \frac{0.5H}{v_z}\right\} + 2T_{pd} = \max\left\{\frac{L}{v_y}, \frac{H}{v_z}\right\} + 2T_{pd}$

AS/RS Throughput



- Travel Trajectory – Dual Command Cycle
- T_d = *dual* command cycle time
- T_{pd} = pick up and deposit time (min)
- L = length of the AS/RS rack structure(m)
- H = height of the AS/RS rack structure(m)
- v_y = velocity of the S/R machine along the length (m/min)
- v_z = velocity of the S/R machine in the vertical direction (m/min)
- $T_d = 2\max\left\{\frac{0.75L}{v_y}, \frac{0.75H}{v_z}\right\} + 4T_{pd} = \max\left\{\frac{1.5L}{v_y}, \frac{1.5H}{v_z}\right\} + 4T_{pd}$

AS/RS Throughput

- R_s = number of single command cycles per hour.
- R_d = number of dual command cycles per hour
- U = Utilization
  - $R_s T_s + R_d T_d = 60\ U$ (Utilization)
- R_c = Total Hourly Cycle Rate:
  - $R_c = R_s + R_d$ (Total hourly cycle rate)
- R_t =Throughput: Total rate of transactions per hour
  - $R_t = R_s + 2R_d$

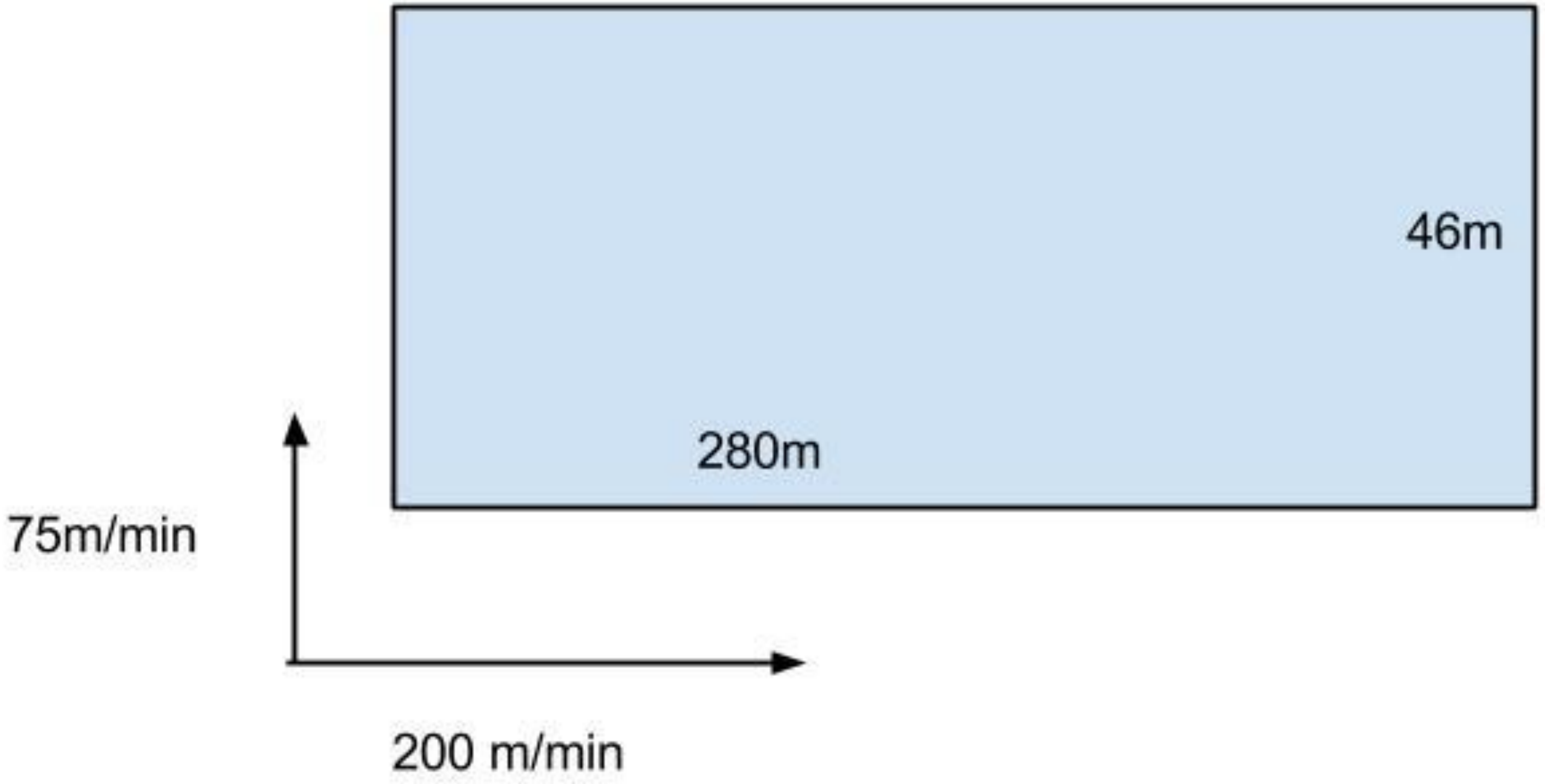
AS/RS Throughput – Example

- **Example:**
- Consider the AS/RS from previous Example 11.2, in which an S/R machine is used for each aisle.
  - Length:280 m   Height: 46 m.
  - horizontal speed: 200 m/min   vertical speed: 75 m/min
- The S/R machine requires 20 sec to accomplish a P&D operation.
- Find:

  a) the single command and dual command cycle times per aisle, and

  b) throughput per aisle under the assumptions that

  - storage system **utilization** is 90%
  - the number of single command and dual command cycles are **equal**.



20 sec for each P&D operation

$$R_{cs} = R_{cd}$$

$U = 0.9$

AS/RS Throughput

- **Solution**:

(a)single and dual command cycle times

- $T_s = \max\left(\frac{280}{200}, \frac{46}{75}\right) + 2\left(\frac{20}{60}\right) = 2.066 \text{ mins/cycle}$
- $T_d = \max\left(\frac{1.5\times280}{200}, \frac{1.5\times46}{75}\right) + 4\left(\frac{20}{60}\right) = 3.432 \text{ min}s\text{/cycle}$

AS/RS Throughput

b) First find the hourly rates for single and dual cycles (

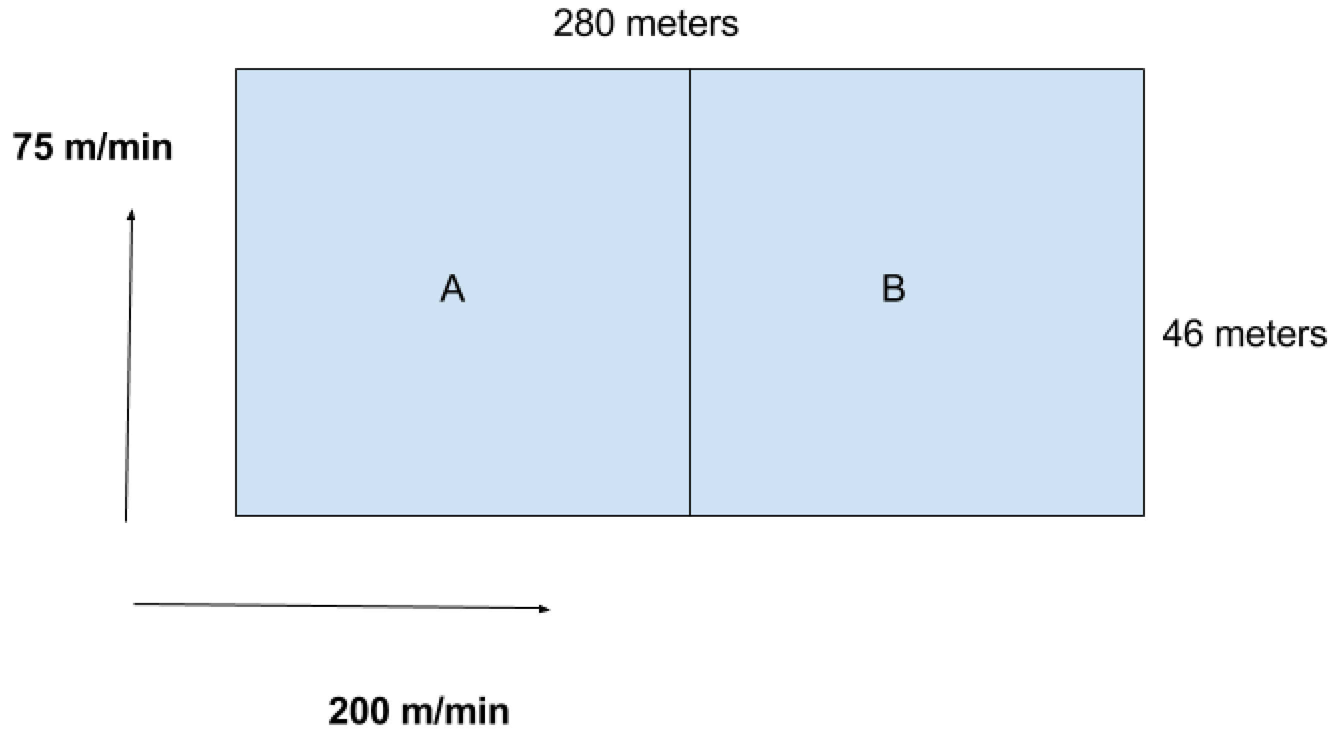
- 2.066 R_s + 3.432 R_d = (60)(0.90) = 54.0 mins
- R_s = R_d from the problem statement, hence we have
  - $R_s = R_d = 9.82$
- Total rate
  - $R_c = R_s + R_d = 19.64$
- System **throughput** = $\sum$ S/R transactions per hour
  - $R_s + 2 \times R_d = 29.46$ transactions/hr
  - With four aisle we have $R_t = 4 \times 29.46 = 117.84$

AS/RS Throughput

Example

- Assume, **class based <u>dedicated</u>** storage.
- Two classes:
  - The more active product (A) is stored in the left half of the system that is located *closest* to the I/O station
  - The less active product (B) is stored in the other (right) half
- The more active stock accounts for 75% of the transactions
- The less active stock accounts for the remaining 25%.
- Assume again that
  - the utilization 90%
  - Single CS # = Dual CS #
- Determine the **throughput** of the AS/RS based on the assumptions of MHI.

AS/RS Throughput



AS/RS Throughput

Class A:

- $T_{sA} = 2 \times \max\left(\frac{0.5 \times 140}{200}, \frac{05 \times 46}{75}\right) + 2\left(\frac{20}{60}\right) = 1.366\,\frac{\text{mins}}{\text{cycle}}$
- $T_{dA} = 2 \times \max\left(\frac{0.75 \times 140}{200}, \frac{0.75 \times 46}{75}\right) + 4\left(\frac{20}{60}\right) = 2.382\,\frac{\text{min}s}{\text{cycle}}$

AS/RS Throughput

Class A:

- $T_{sA} = 2 \times \max\left(\frac{0.5\times 140}{200}, \frac{05\times 46}{75}\right) + 2\left(\frac{20}{60}\right) = 1.366\,\frac{\text{mins}}{\text{cycle}}$
- $T_{dA} = 2 \times \max\left(\frac{0.75\times 140}{200}, \frac{0.75\times 46}{75}\right) + 4\left(\frac{20}{60}\right) = 2.382\,\frac{\text{mins}}{\text{cycle}}$

Class B:

- $T_{sB} = 2 \times \max\left(\frac{140+0.5\times 140}{200}, \frac{0.5\times 46}{75}\right) + 2\left(\frac{20}{60}\right) = 2.766\,\frac{\text{mins}}{\text{cycle}}$
- $T_{dB} = 2 \times \max\left(\frac{140+0.75\times 140}{200}, \frac{0.75\times 46}{75}\right) + 4\left(\frac{20}{60}\right) = 3.782\,\frac{\text{mins}}{\text{cycle}}$

AS/RS Throughput

- Single and Dual command cycles of each product is the same:
  - $R_{sA} = R_{dA}$ and $R_{sB} = R_{dB}$
- Product A accounts for 75% of the transactions:
  - $R_{sA} = 3\ R_{sB}$ and $R_{dA} = 3R_{dB}$
- Then we have the following
  - $R_{sA}T_{sA} + R_{dA}T_{dA} + R_{sB}T_{sB} + R_{dB}T_{dB} = (60)\ (0.90)$
  - $R_{sA}T_{sA} + R_{\boldsymbol{s}A}T_{dA} + R_{sB}T_{sB} + R_{\boldsymbol{s}B}T_{dB} = 54$
  - $3 \times R_{sB}T_{sA} + 3 \times R_{sB}T_{dA} + R_{sB}T_{sB} + R_{\boldsymbol{s}B}T_{dB} = 54$
  - $3 \times R_{sB}(1.366) + 3 \times R_{sB}(2.382) + R_{sB}(2.766) + R_{sB}(3.782) = 54$

AS/RS Throughput

- $R_{sB} = 3.035$
- $R_{sA} = 3 \times R_{sB} = 9.105$
- $R_{dB} = R_{sB} = 3.035$
- $R_{dA} = 3 \times R_{sB} = 9.105$
- The throughput is:
  - $R_t = R_{sA} + R_{sB} + 2 \times (R_{dA} + R_{dB})$ = 36.42 transactions / hour