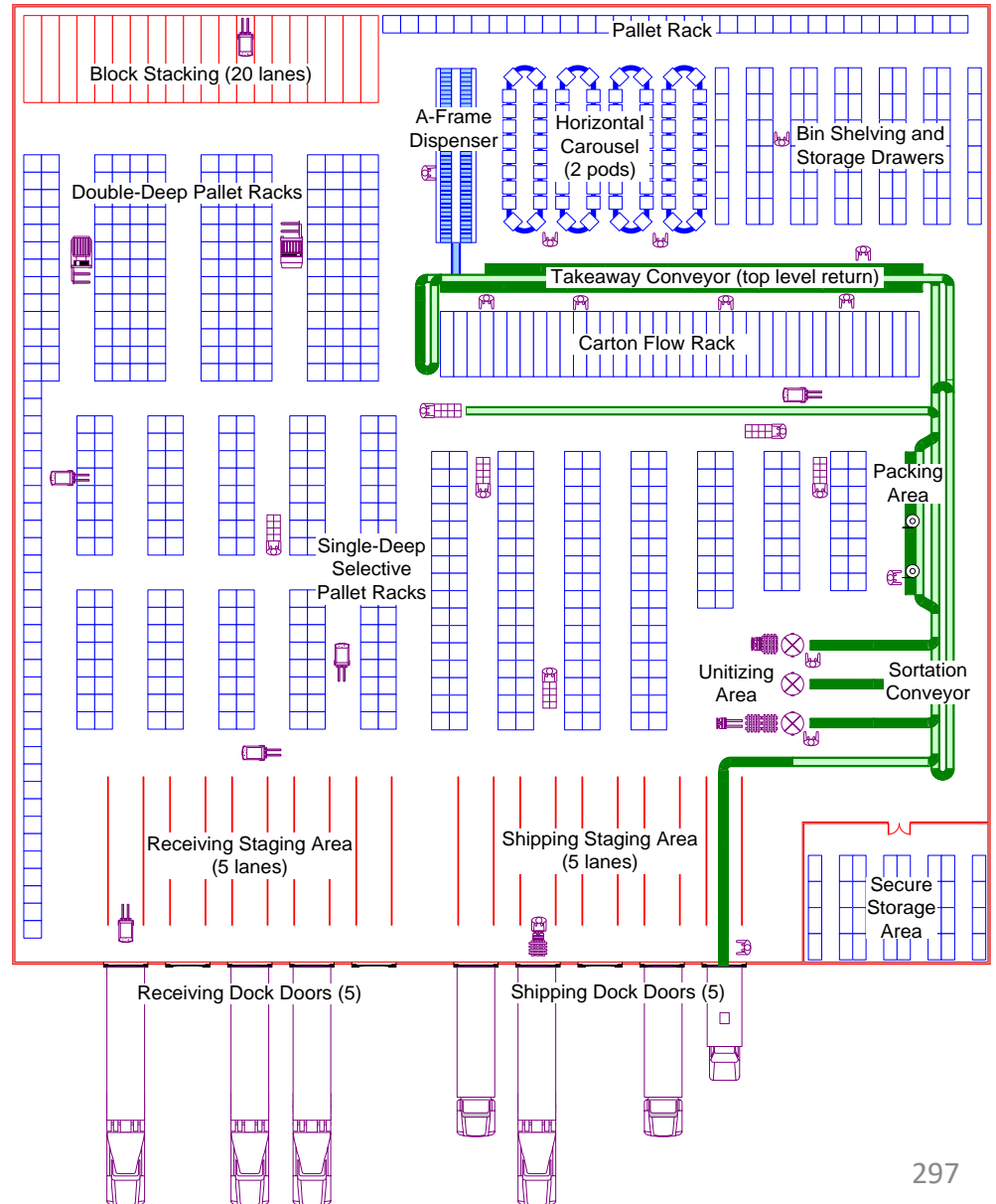
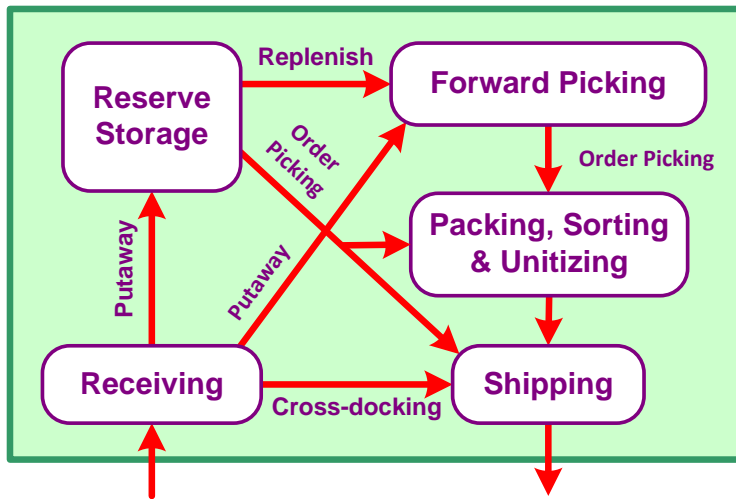
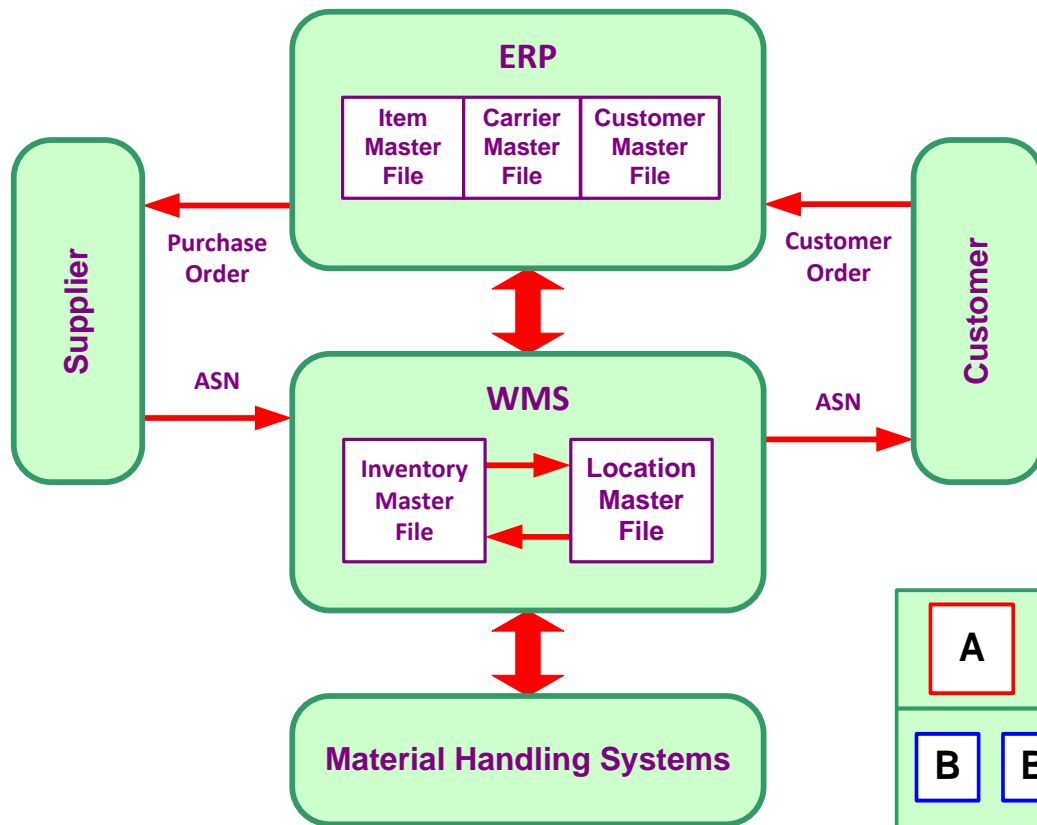


# Warehouse Operations



# Warehouse Management System

- WMS interfaces with a corporation's enterprise resource planning (ERP) and the control software of each MHS

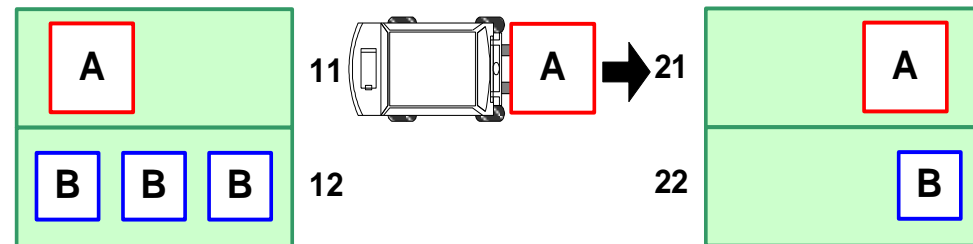


Inventory Master File

| Item | On-Hand Balance | In-Transit Qty. | Locations |
|------|-----------------|-----------------|-----------|
| A    | 2               | 1               | 11,21     |
| B    | 4               | 0               | 12,22     |

Location Master File

| Location | Item | On-Hand Balance | In-Transit Qty. |
|----------|------|-----------------|-----------------|
| 11       | A    | 1               | 0               |
| 12       | B    | 3               | 0               |
| 21       | A    | 1               | 1               |
| 22       | B    | 1               | 0               |



- Advance shipping notice (ASN) is a standard format used for communications

# Logistics-related Codes

|             | Commodity Code              | Item Code                                       | Unit Code                    |
|-------------|-----------------------------|---|------------------------------|
| Level       | Category                    | Class   | Instance                     |
| Description | Grouping of similar objects | Grouping of identical objects                   | Unique physical object       |
| Function    | Product classification      | Inventory control                               | Object tracking              |
| Names       | —                           | Item number, Part number, SKU, SKU + Lot number | Serial number, License plate |
| Codes       | UNSPSC, GPC                 | GTIN, UPC, ISBN, NDC                            | EPC, SSCC                    |

UNSPSC: United Nations Standard Products and Services Code

GPC: Global Product Catalogue

GTIN: Global Trade Item Number (includes UPC, ISBN, and NDC)

UPC: Universal Product Code

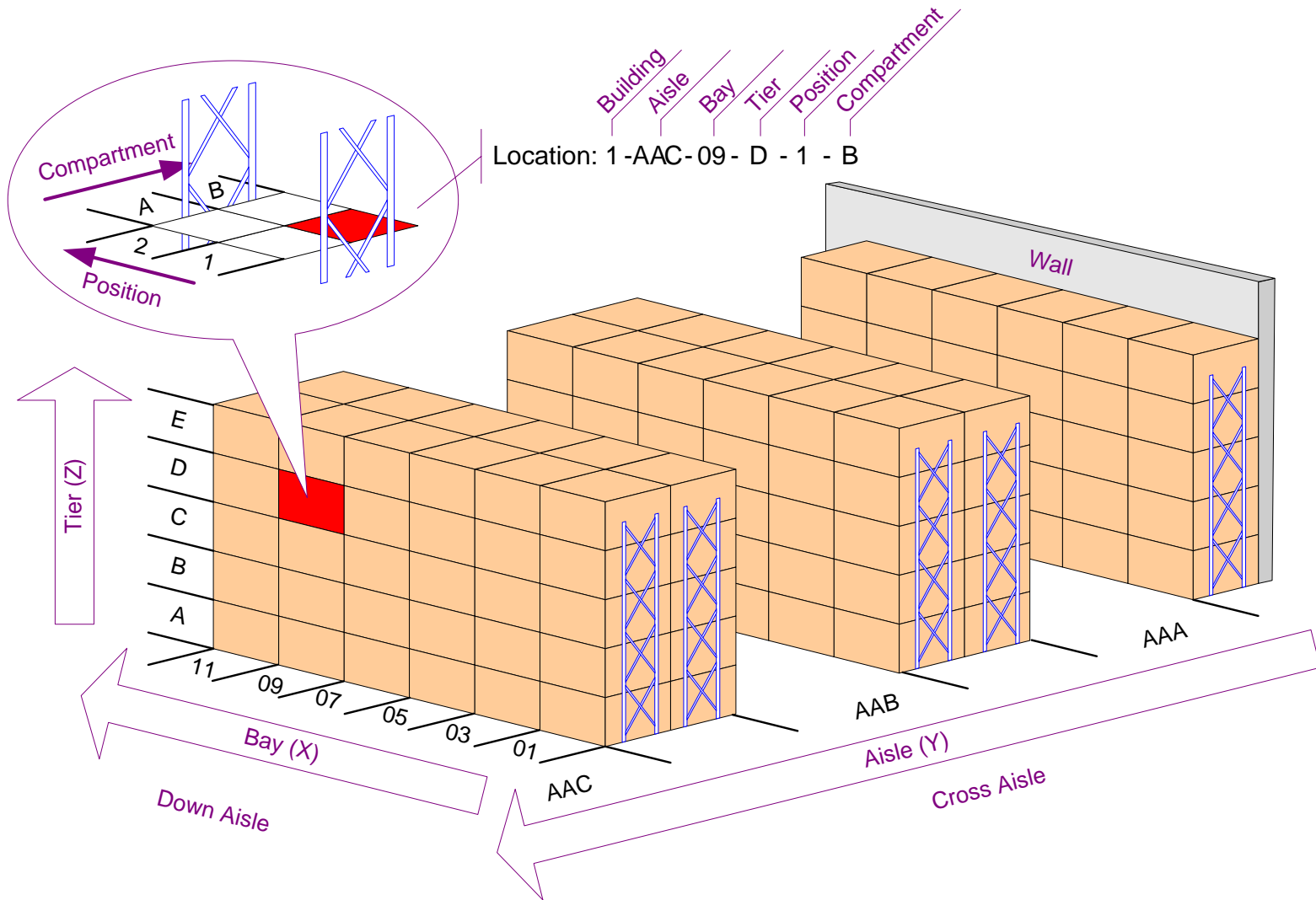
ISBN: International Standard Book Numbering

NDC: National Drug Code

EPC: Electronic Product Code (globally unique serial number for physical objects identified using RFID tags)

SSCC: Serial Shipping Container Code (globally unique serial number for identifying *movable units* (carton, pallet, trailer, etc.))

# Identifying Storage Locations



# Receiving



- Basic steps:

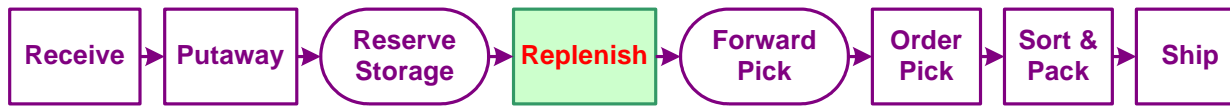
1. Unload material from trailer.
2. Identify supplier with ASN, and associate material with each moveable unit listed in ASN.
3. Assign inventory attributes to movable unit from item master file, possibly including repackaging and assigning new serial number.
4. Inspect material, possibly including holding some or all of the material for testing, and report any variances.
5. Stage units in preparation for putaway.
6. Update item balance in inventory master and assign units to a receiving area in location master.
7. Create receipt confirmation record.
8. Add units to putaway queue

# Putaway

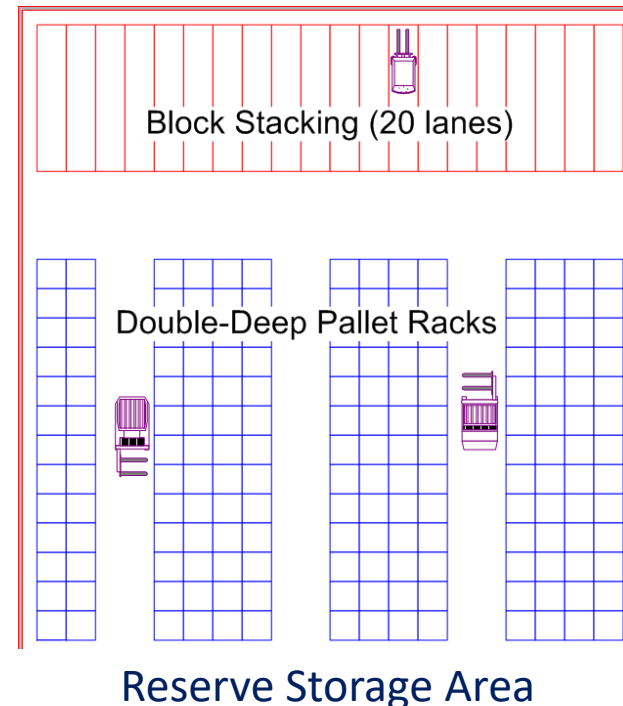


- A putaway algorithm is used in WMS to search for and validate locations where each movable unit in the putaway queue can be stored
- Inventory and location attributes used in the algorithm:
  - *Environment* (refrigerated, caged area, etc.)
  - *Container type* (pallet, case, or piece)
  - *Product processing type* (e.g., floor, conveyable, nonconveyable)
  - *Velocity* (assign to A, B, C based on throughput of item)
  - Preferred putaway zone (item should be stored in same zone as related items in order to improve picking efficiency)

# Replenishment



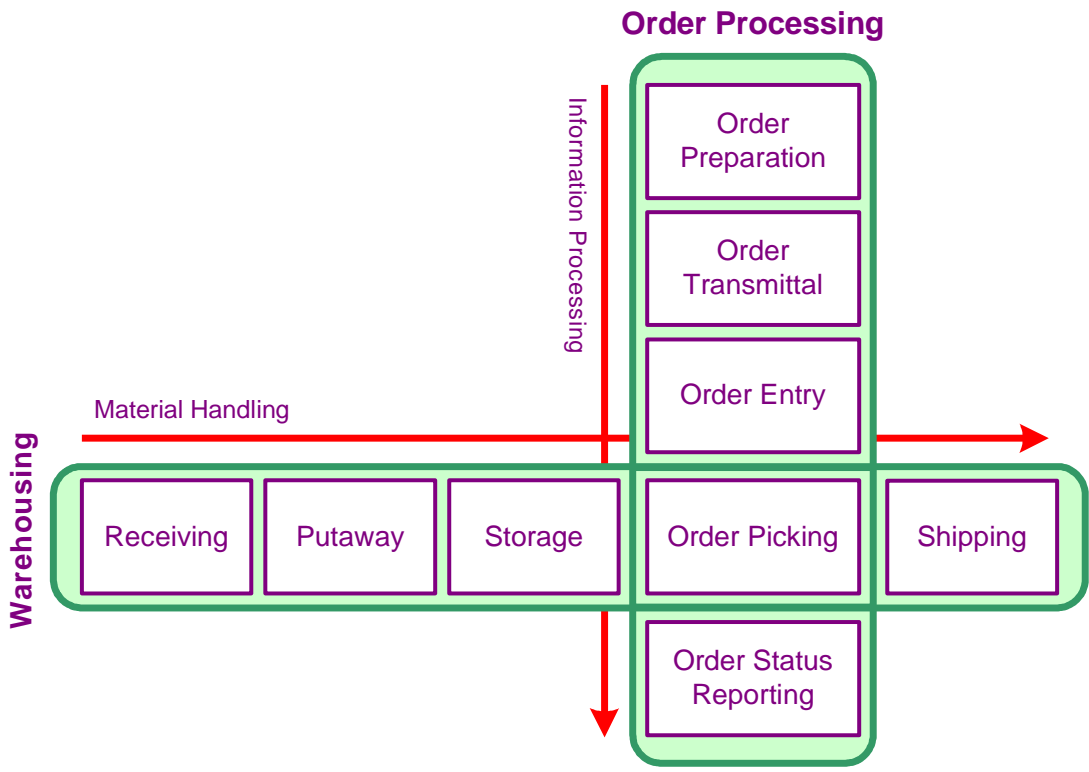
- Replenishment is the process of moving material from reserve storage to a forward picking area so that it is available to fill customer orders efficiently
- Other types of in-plant moves include:
  - Consolidation: combining several partially filled storage locations of an item into a single location
  - Reworkhousing: moving items to different storage locations to improve handling efficiency



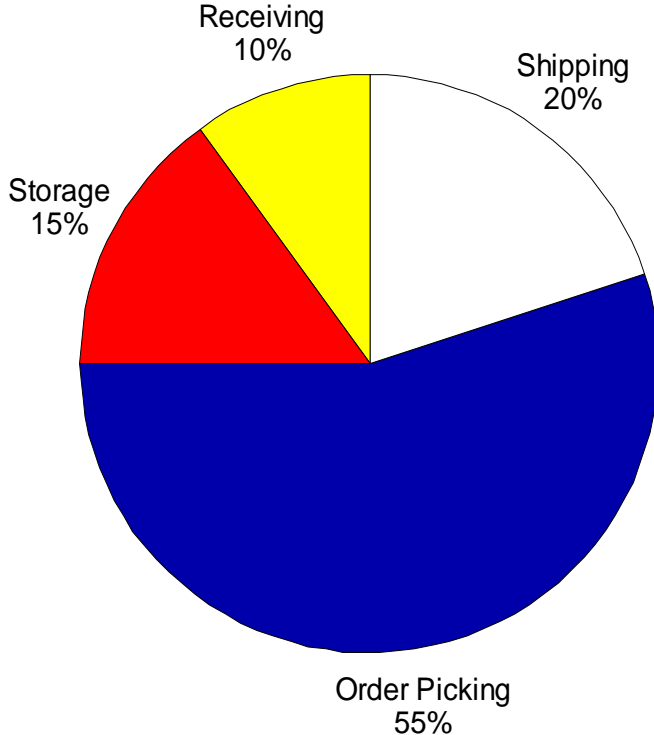
# Order Picking



- Order picking is at the intersection of warehousing and order processing



WH Operating Costs

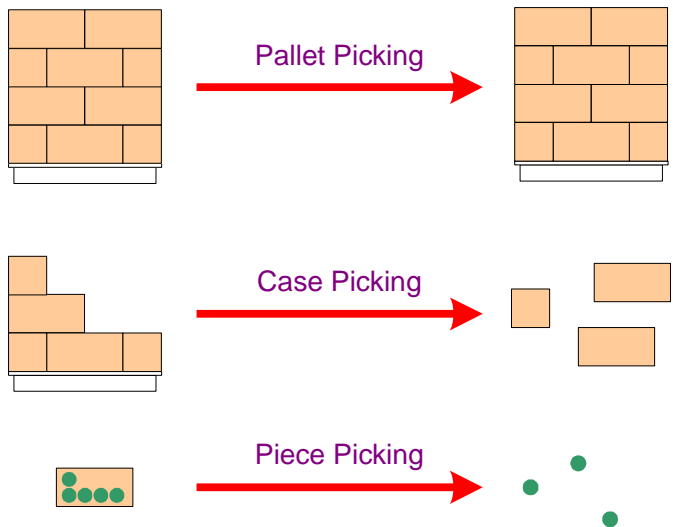




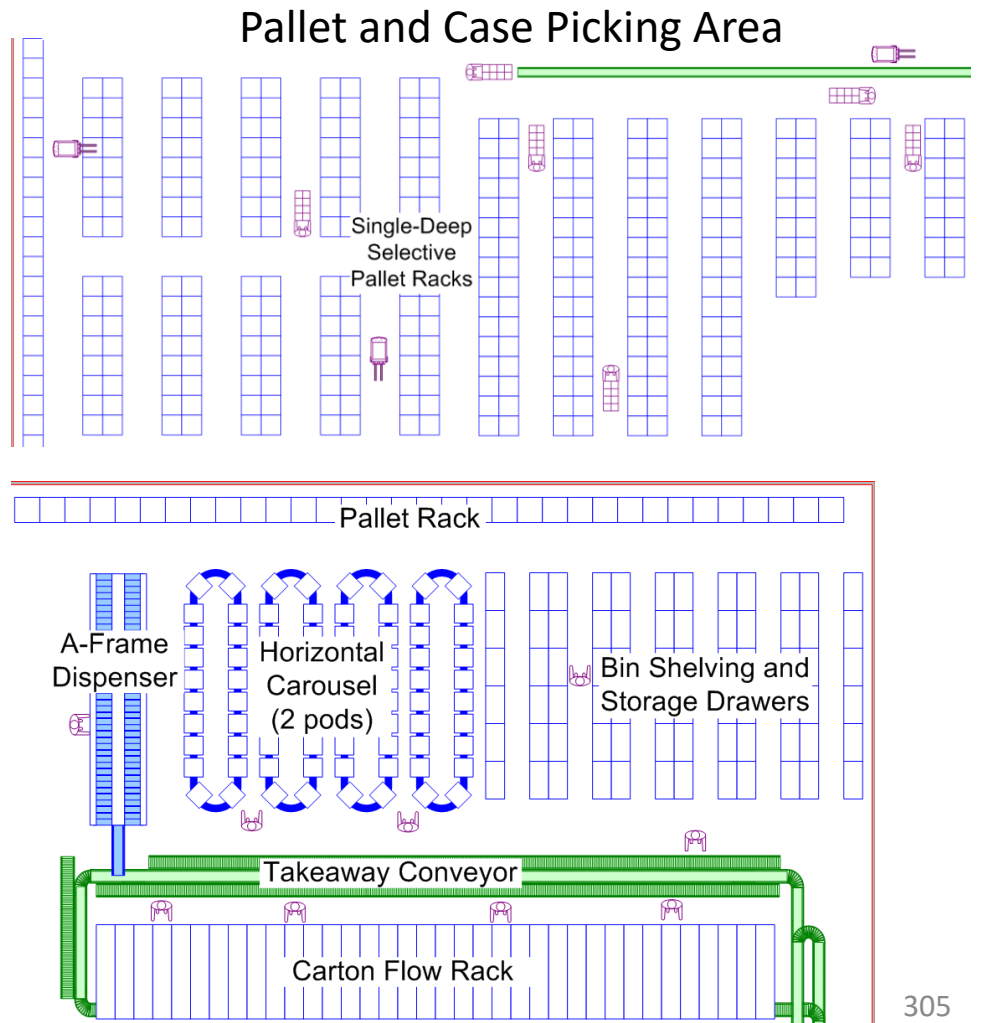
# Order Picking



## Levels of Order Picking



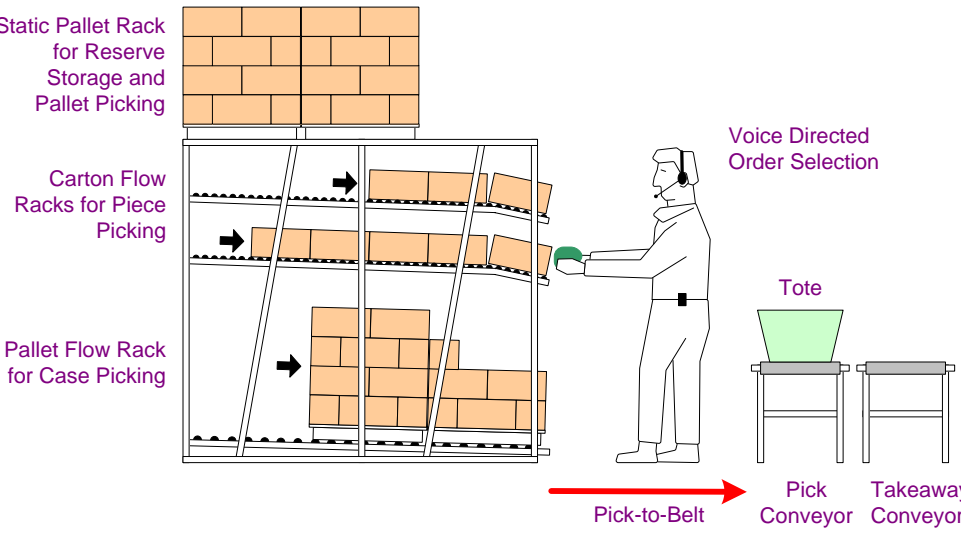
## Forward Piece Picking Area



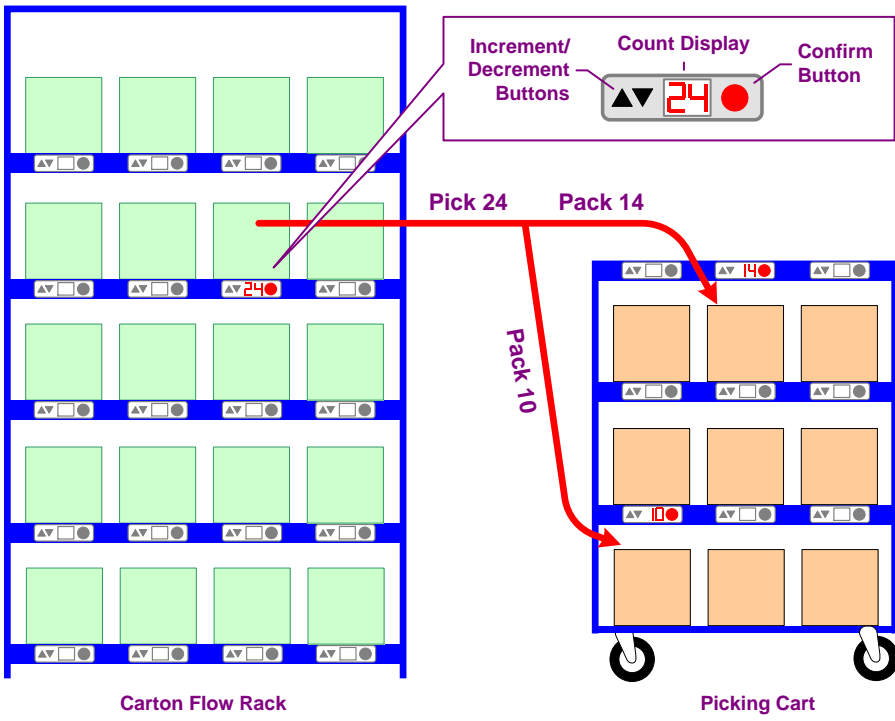
# Order Picking



## Voice-Directed Piece and Case Picking



## Pick-to-Light Piece Picking



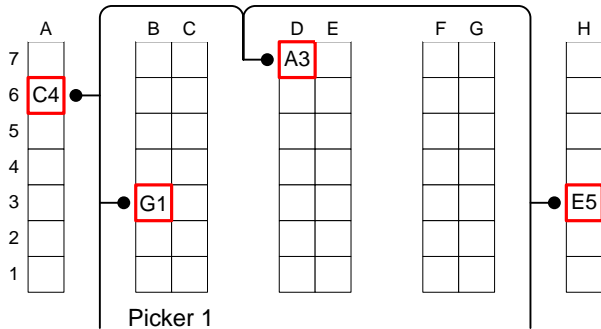
# Order Picking



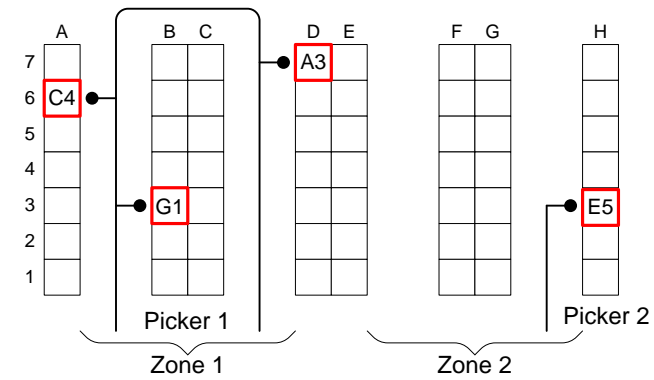
## Methods of Order Picking

| Method     | Pickers per Order | Orders per Picker |
|------------|-------------------|-------------------|
| Discrete   | Single            | Single            |
| Zone       | Multiple          | Single            |
| Batch      | Single            | Multiple          |
| Zone-Batch | Multiple          | Multiple          |

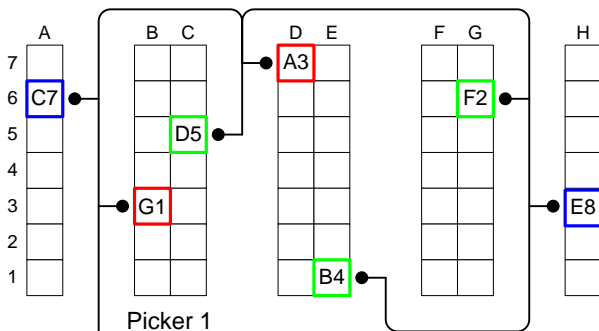
### Discrete



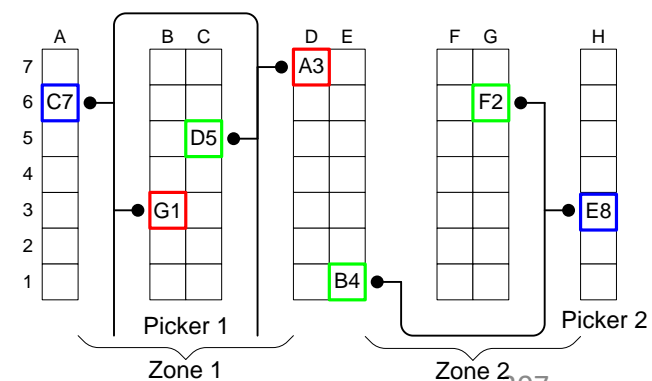
### Zone



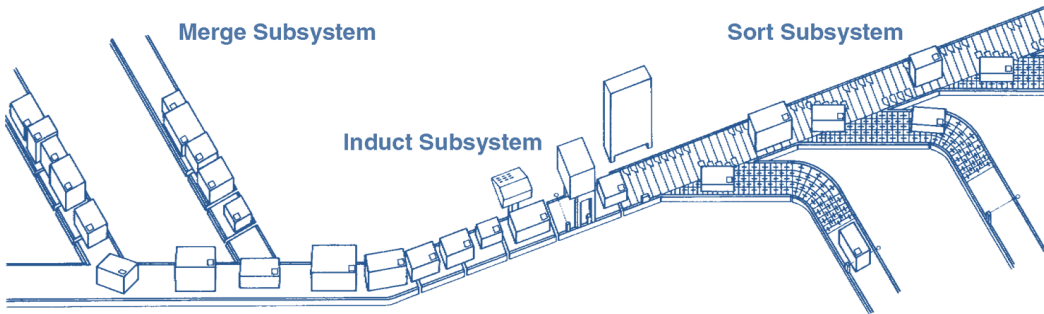
### Batch



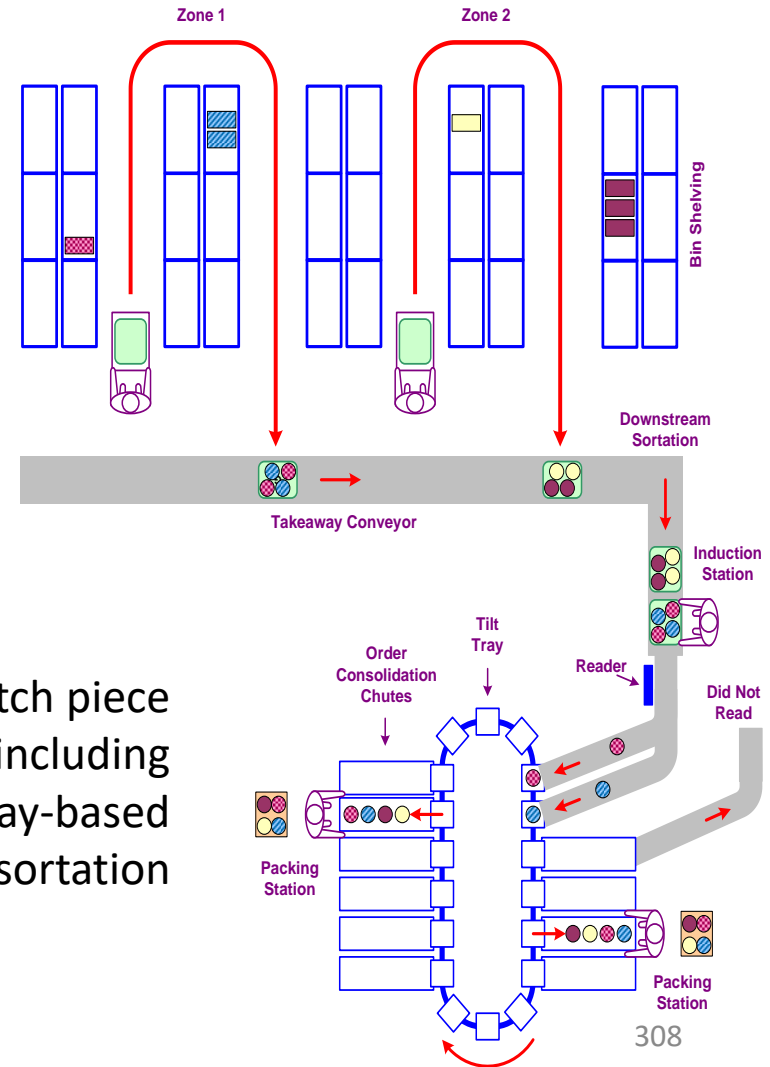
### Zone-Batch



# Sortation and Packing



Case Sortation System

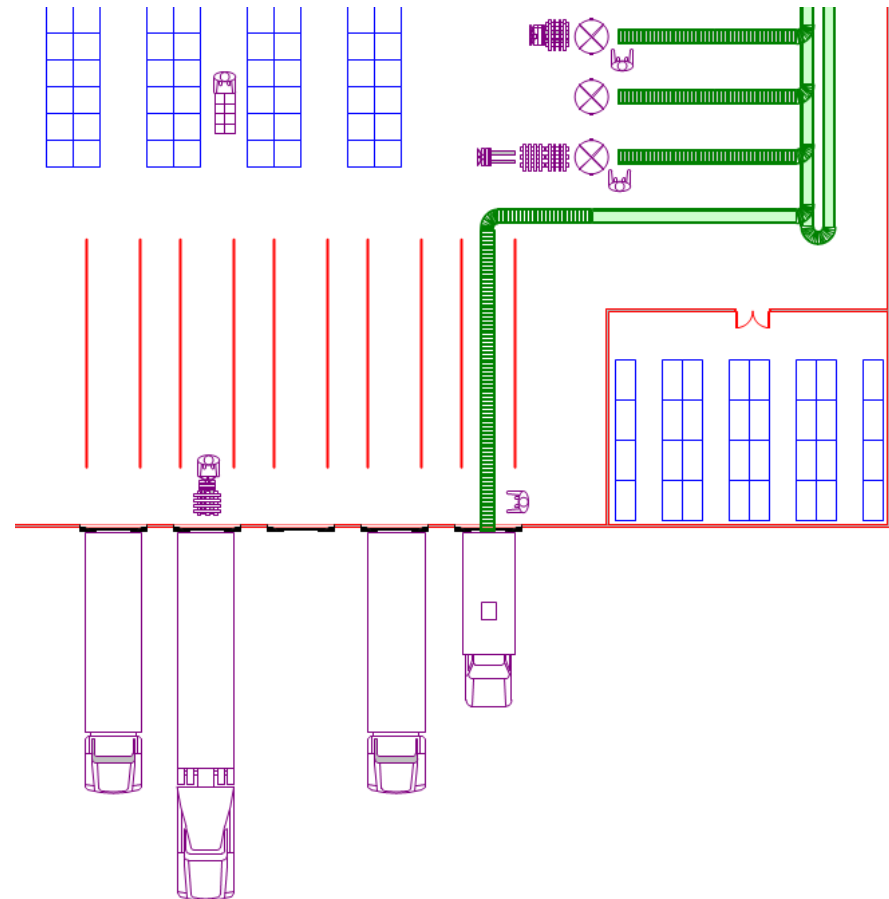


Wave zone-batch piece picking, including downstream tilt-tray-based sortation

# Shipping



- Staging, verifying, and loading orders to be transported
  - ASN for each order sent to the customer
  - Customer-specific shipping instructions retrieved from customer master file
  - Carrier selection is made using the rate schedules contained in the carrier master file



# Activity Profiling

- *Total Lines*: total number of lines for all items in all orders
- *Lines per Order*: average number of different items (lines/SKUs) in order
- *Cube per Order*: average total cubic volume of all units (pieces) in order
- *Flow per Item*: total number of S/R operations performed for item
- *Lines per Item (popularity)*: total number of lines for item in all orders
- *Cube Movement*: total unit demand of item time x cubic volume
- *Demand Correlation*: percent of orders in which both items appear

## Customer Orders

| Order: 1 |     |
|----------|-----|
| SKU      | Qty |
| A        | 5   |
| B        | 3   |
| C        | 2   |
| D        | 6   |

| Order: 2 |     |
|----------|-----|
| SKU      | Qty |
| A        | 4   |
| C        | 1   |

| Order: 3 |     |
|----------|-----|
| SKU      | Qty |
| A        | 2   |

| Order: 4 |     |
|----------|-----|
| SKU      | Qty |
| B        | 2   |

| Order: 5 |     |
|----------|-----|
| SKU      | Qty |
| C        | 1   |
| D        | 12  |
| E        | 6   |

### Item Master

| SKU | Length | Width | Depth | Cube | Weight |
|-----|--------|-------|-------|------|--------|
| A   | 5      | 3     | 2     | 30   | 1.25   |
| B   | 3      | 2     | 4     | 24   | 4.75   |
| C   | 8      | 6     | 5     | 180  | 9.65   |
| D   | 4      | 4     | 3     | 32   | 6.35   |
| E   | 6      | 4     | 5     | 120  | 8.20   |



Total Lines = 11

Lines per Order =  $11/5 = 2.2$

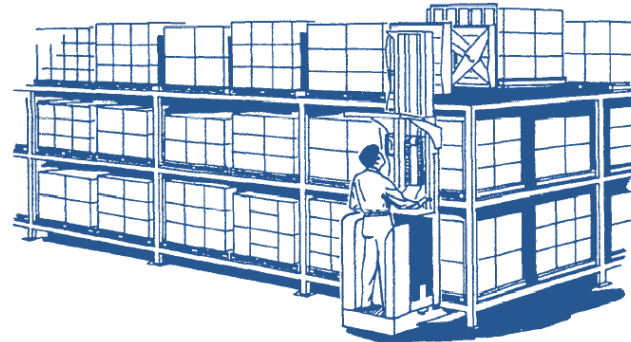
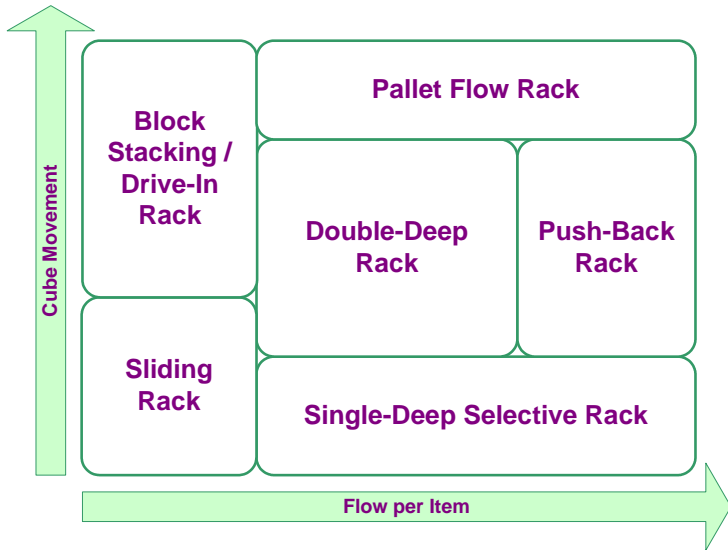
Cube per Order = 493.2

| SKU | Flow per Item | Lines per Item | Cube Movement |
|-----|---------------|----------------|---------------|
| A   | 11            | 3              | 330           |
| B   | 5             | 2              | 120           |
| C   | 4             | 3              | 720           |
| D   | 18            | 2              | 576           |
| E   | 6             | 1              | 720           |

### Demand Correlation Distribution

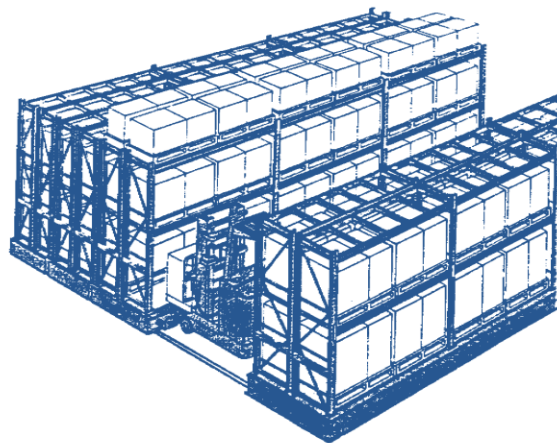
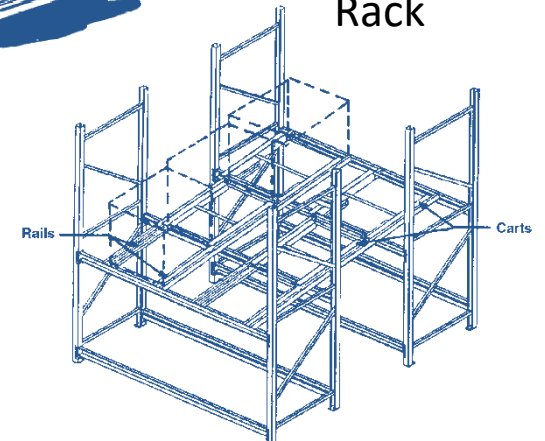
| SKU | A | B   | C   | D   | E   |
|-----|---|-----|-----|-----|-----|
| A   |   | 0.2 | 0.4 | 0.2 | 0.0 |
| B   |   |     | 0.2 | 0.2 | 0.0 |
| C   |   |     |     | 0.4 | 0.2 |
| D   |   |     |     |     | 0.2 |
| E   |   |     |     |     |     |

# Pallet Picking Equipment

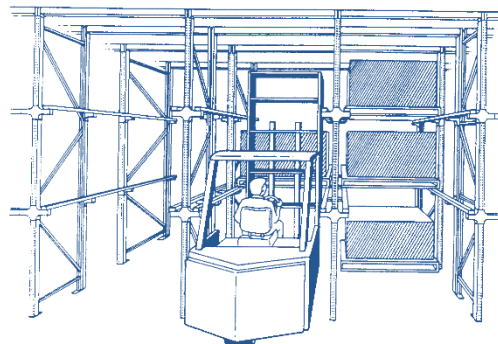


Double-Deep Rack

Push-Back Rack

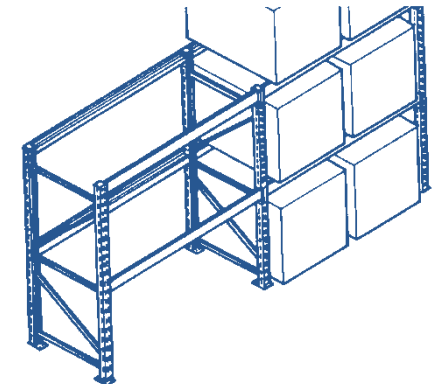


Sliding Rack

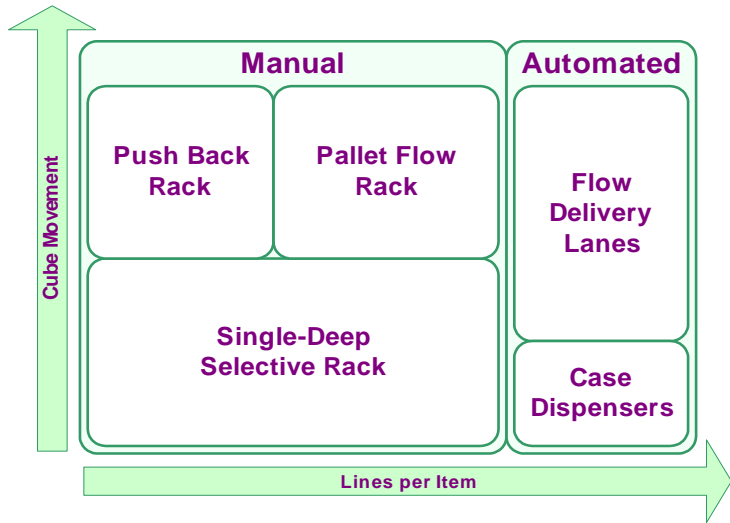


Drive-In Rack

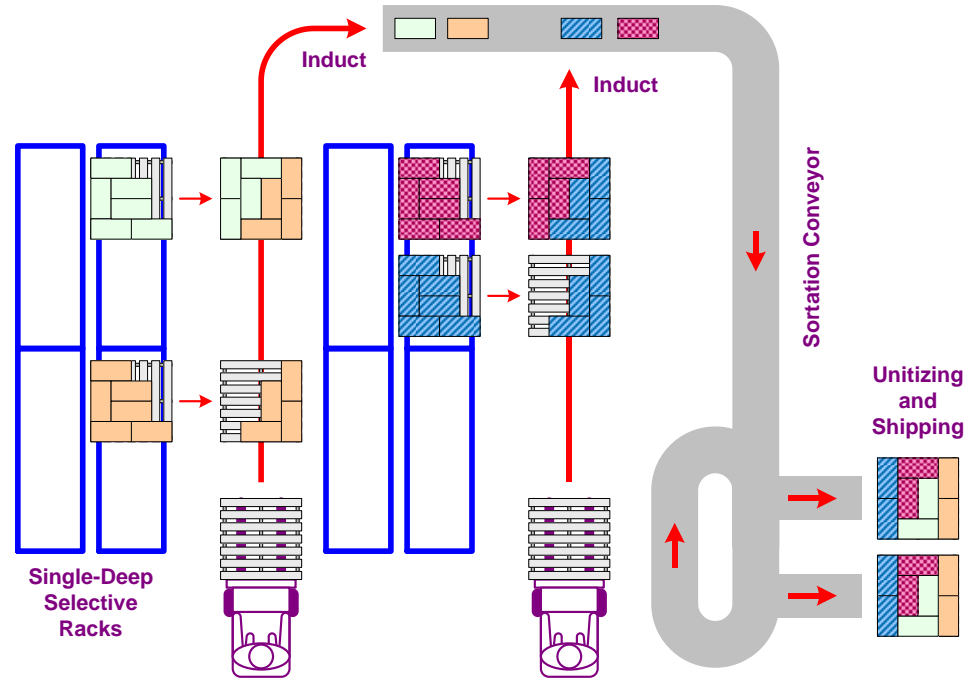
Single-Deep Selective Rack



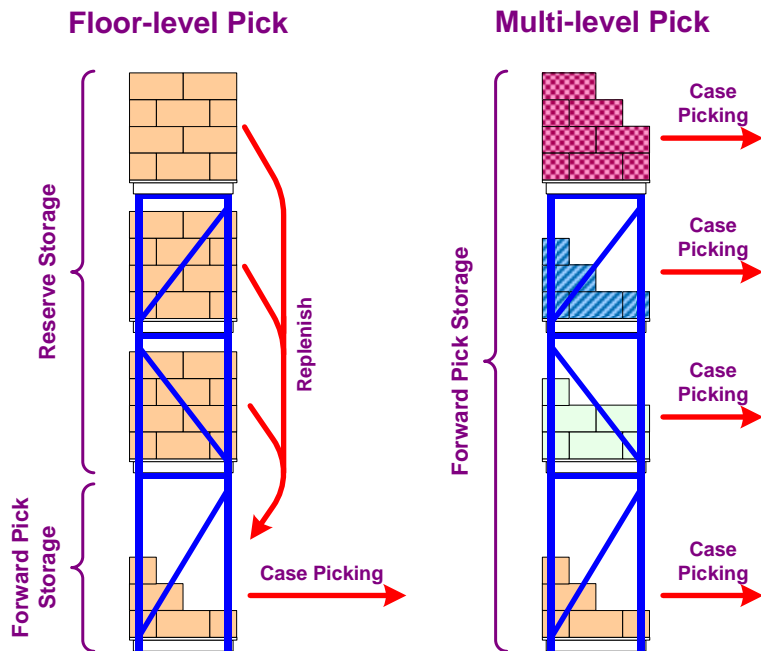
# Case Picking



## Case Picking Equipment



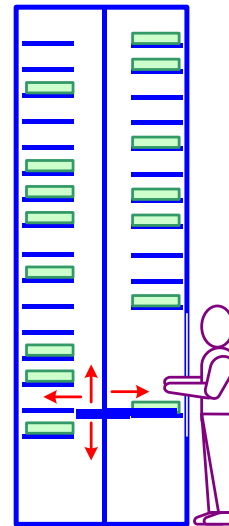
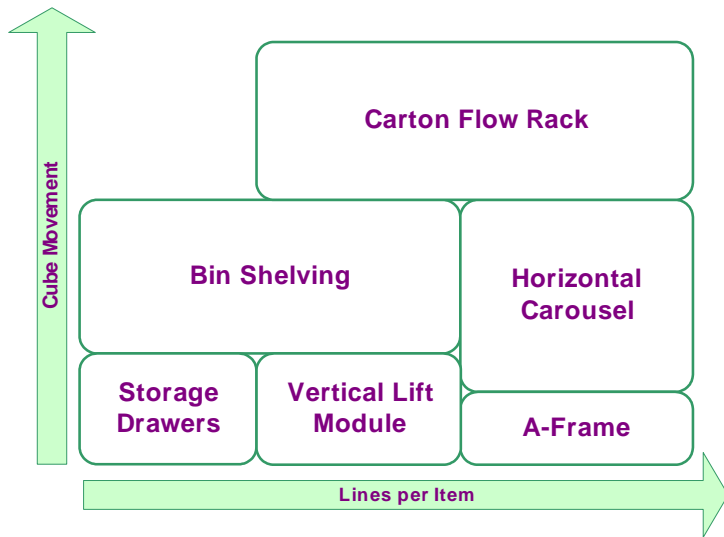
## Zone-Batch Pick to Pallet



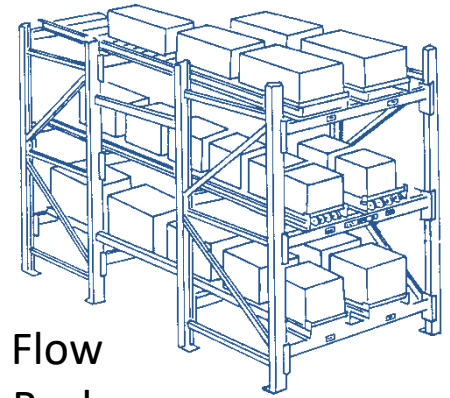
## Floor- vs. Multi-level Pick to Pallet



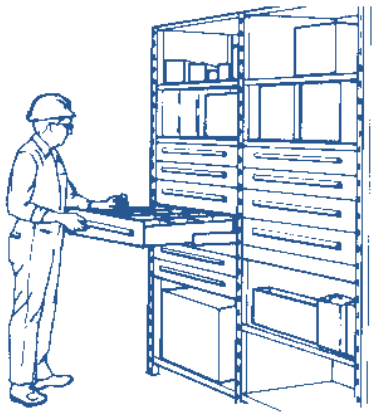
# Piece Picking Equipment



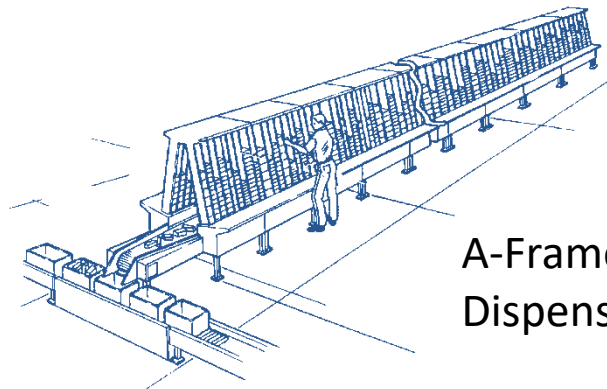
Vertical Lift Module



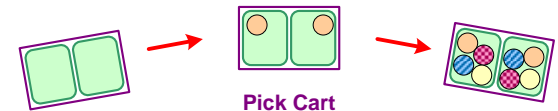
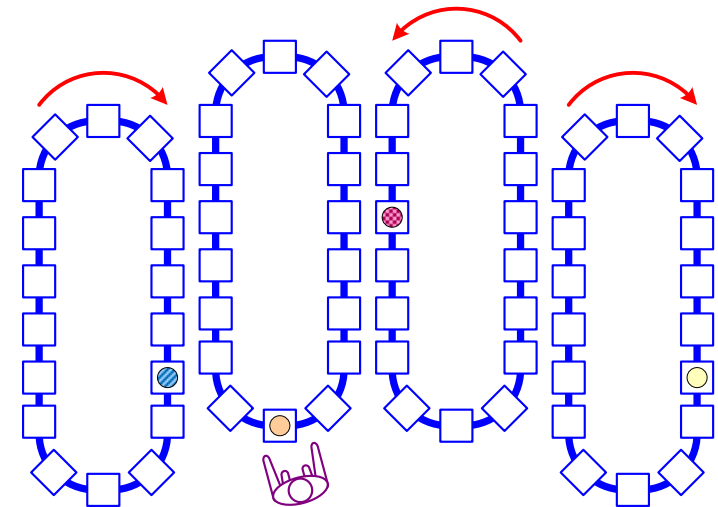
Carton Flow Rack



Drawers/Bins



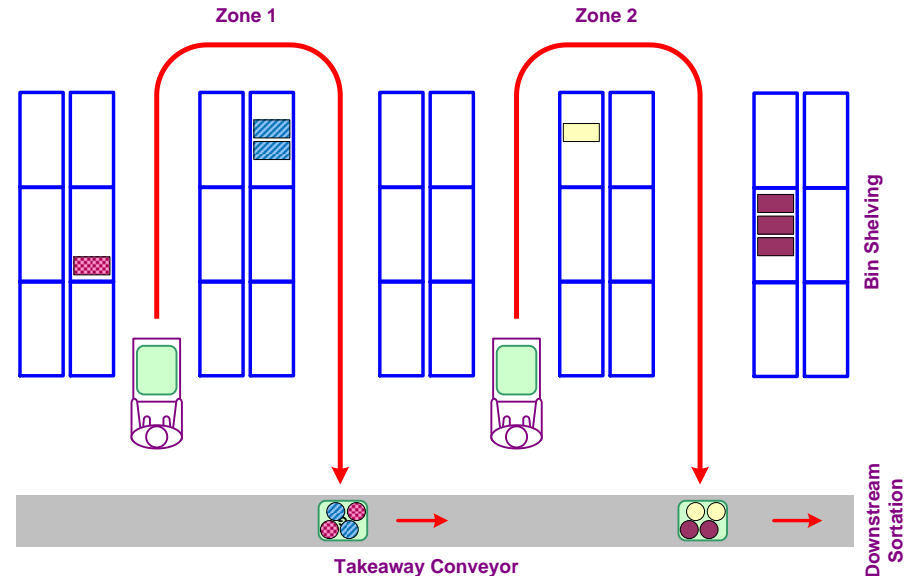
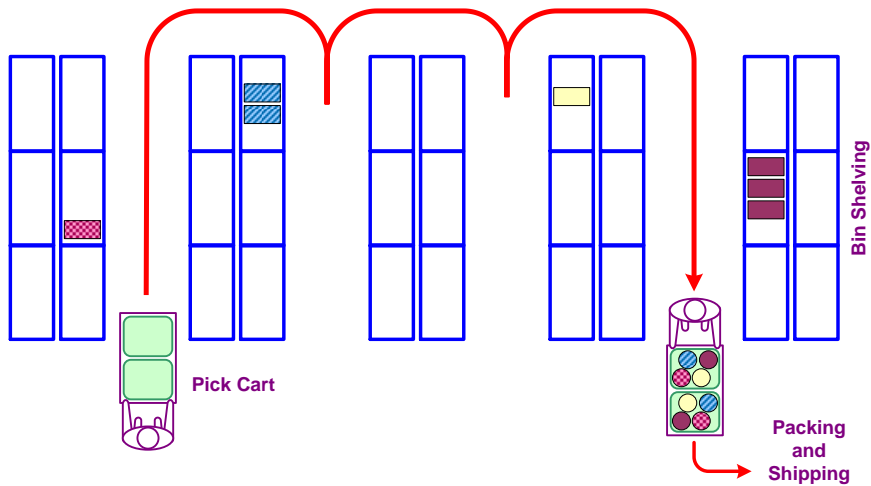
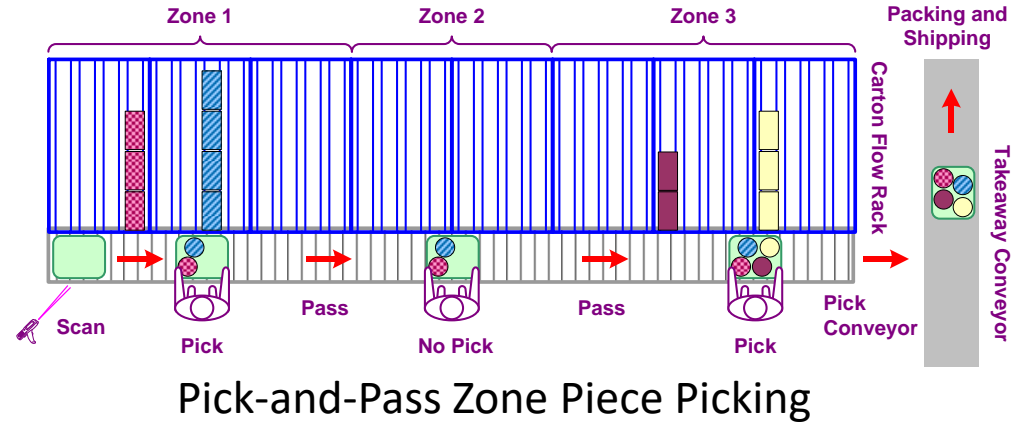
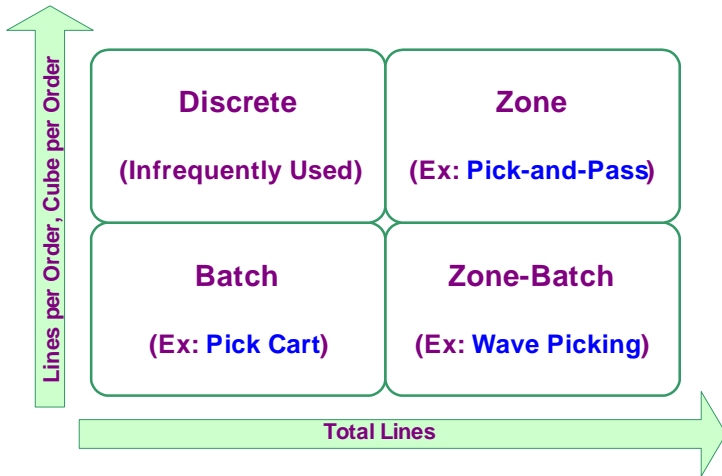
A-Frame Dispenser



Pick Cart

Carousel

# Methods of Piece Picking



# Warehouse Automation

- Historically, warehouse automation has been a craft industry, resulting highly customized, one-off, high-cost solutions
- To survive, need to
  - adapt mass-market, consumer-oriented technologies in order to realize to economies of scale
  - replace mechanical complexity with software complexity
- How much can be spent for automated equipment to replace one material handler:

$$\$45,432 \left( \frac{1 - 1.017^{-5}}{1 - 1.017^{-1}} \right) = \$45,432 (4.83) = \$219,692$$

- \$45,432: median moving machine operator annual wage + benefits
- 1.7% average real interest rate 2005-2009 (real = nominal – inflation)
- 5-year service life with no salvage (service life for Custom Software)

# KIVA Mobile-Robotic Fulfillment System

- Goods-to-man order picking and fulfillment system
- Multi-agent-based control
  - Developed by Peter Wurman, former NCSU CSC professor
- Kiva now called Amazon Robotics
  - purchased by Amazon in 2012 for \$775 million

