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CERTIFIED IN LOGISTICS,
TRANSPORTATION AND DISTRIBUTION

MODULE 4:
WAREHOUSE DISTRIBUTION/FULFILLMENT CENTER MANAGEMENT

APICS

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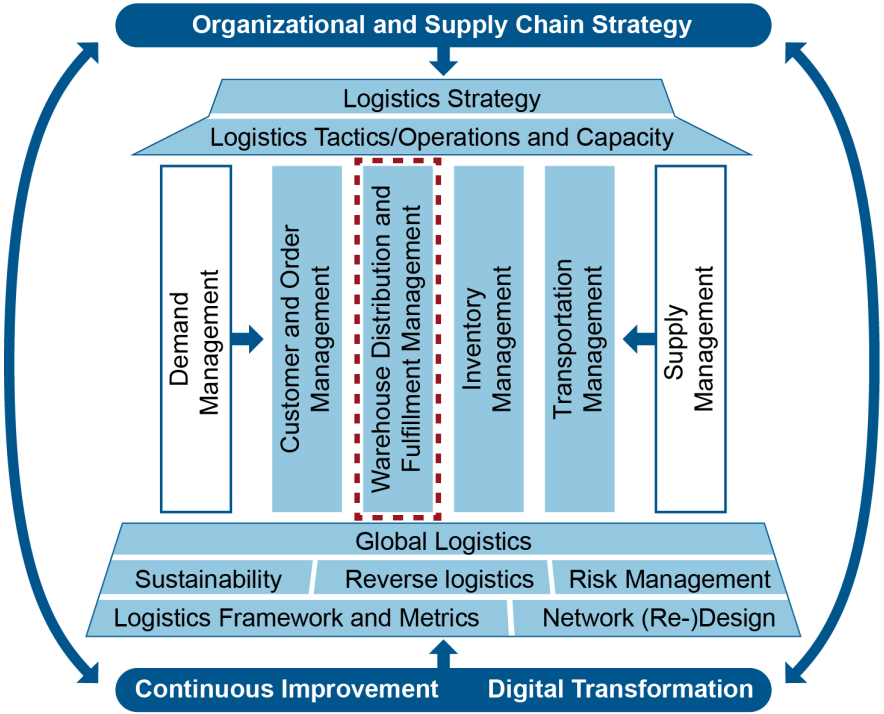
Module 4 Overview



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MODULE 4, SECTION A: IDENTIFY WAREHOUSE STRATEGY, OWNERSHIP, AND ROLES

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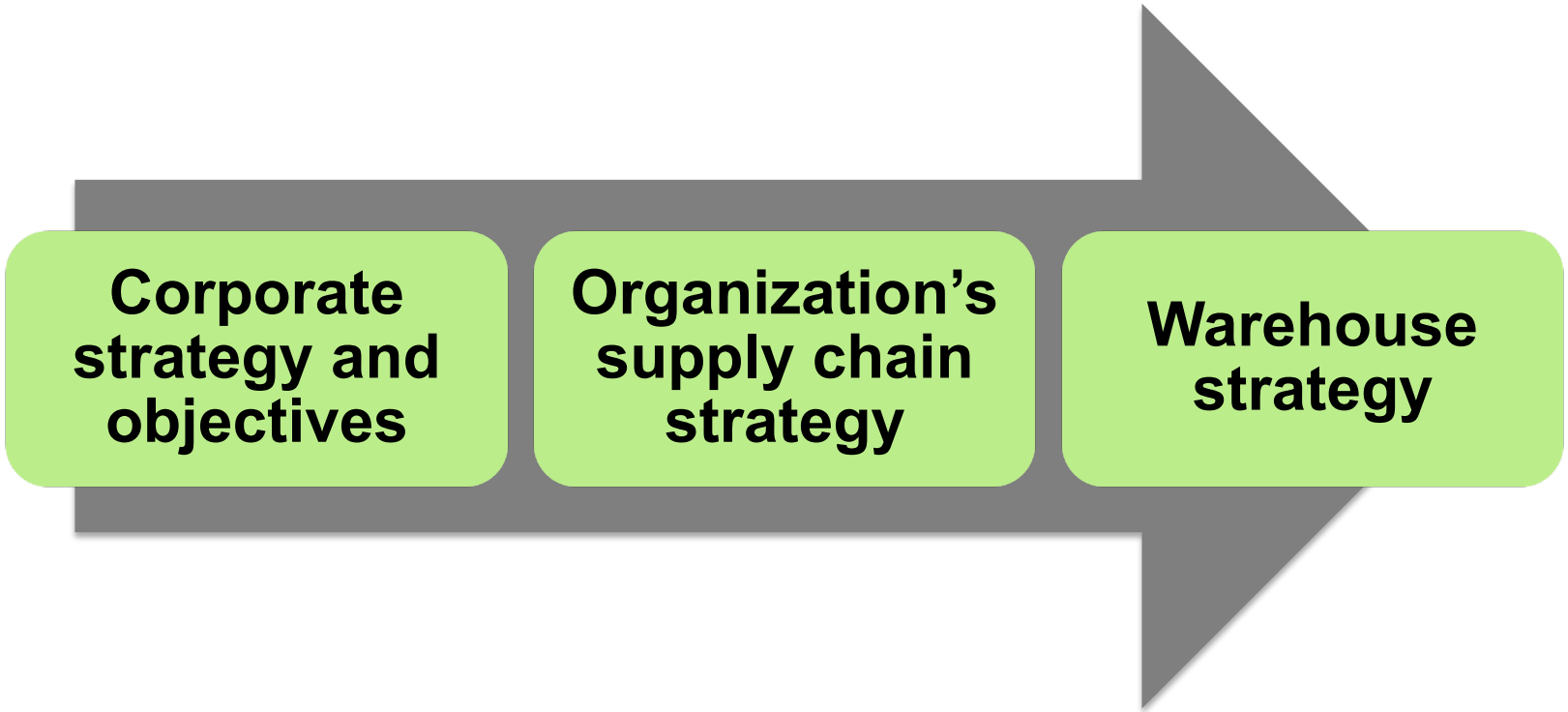
Identify, Determine, and Apply Warehouse Strategies

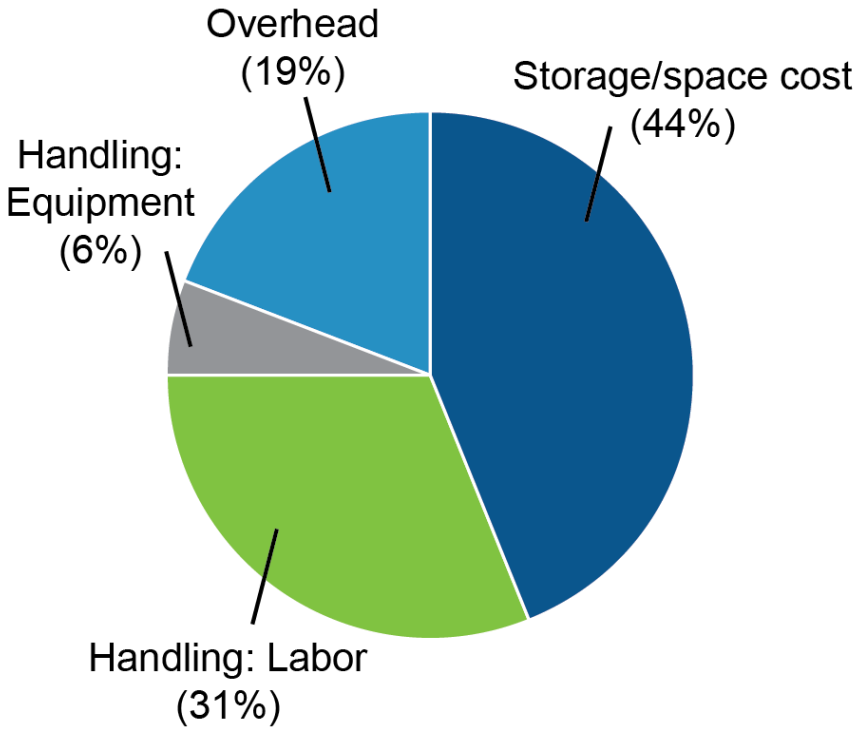
Alignment



Role of Warehousing in Business

Function	Warehousing Contribution
Meeting demand	Receive and store materials, parts, and goods and distribute them to meet internal and external demand.
Aligning supply and demand	Stock helps satisfy spikes in demand; capacity helps decouple supply and demand.
Buffering against uncertainty	Allow businesses to react to potential threats and opportunities by building protective stockpiles of materials and finished goods.
Increasing efficiencies	Grant competitive advantages: Sortation, accumulation (including consolidation), allocation (including break bulk), and assortment assembly.
Providing customer service	Meet all customer demand with quality product without error within a target time frame.

Typical Warehouse Costs: Example Breakdown



Traditional Costing

- Single overhead rate applied to all warehouse users
- Can penalize larger customers and reward smaller ones
- Can group together costs best kept separate for management and control purposes
- Can hide efficiency improvements

Activity-Based Costing (ABC)

ABC Terminology

- Direct costs
- Cost object

Activity Drivers

- Unloading
- Palletizing
- Put-away
- Order picking
- Drivers for any other operation steps…

ABC and Unused Capacity

- Some unused capacity is needed.
- Doesn't charge excess capacity to cost object.

Identify, Determine, and Apply Warehouse Strategies

Challenges/Forces Shaping the Future of Warehouses

- Global supply chains
- E-commerce and B2B
- Increased focus on excellence
- New, collaborative relationships
- New customer expectations
  - Assembly, value added
  - Returns
- Technology
- Resource constraints
- Talent requirements
- Environmental concerns
- Risk management
- Integration

Outsourcing and 3PLs

Key warehouse strategy issue: How to manage gaps between warehouse capacity and demand.

- What should be done when demand exceeds capacity?
- What should be done when capacity exceeds demand?

Identify, Determine, and Apply Warehouse Strategies

Value-Added Services

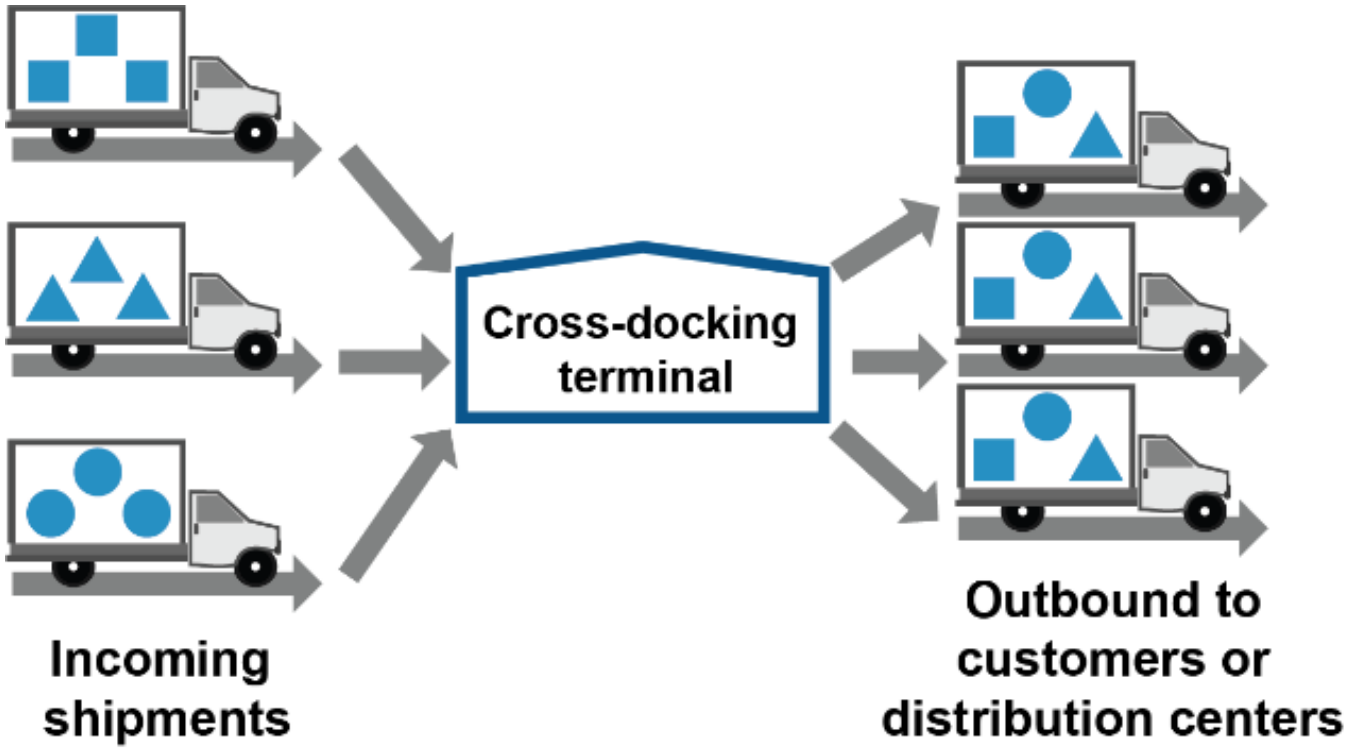
- Postponement
- JIT
- Pre-retail, pre-ticketing
- Packaging and labeling
- Kitting/dekitting
- Reverse logistics
- Inspect, repair, refurbish
- Manage supplies
- Point-of-sale (POS) materials
- Delivery/ e-fulfillment
- Information and reporting

B2B, B2C, and Cross-Docking

B2B	B2C
▪ Factory/retail shipments ▪ Economies of scale	▪ Online order fulfillment ▪ Economies of scope

Identify, Determine, and Apply Warehouse Strategies

Cross-Docking



Differentiate Between Warehouse Ownership Types

Private versus Public Warehouses

Private Warehouse pros

- Greater control over operations
- Economic advantages
- Sustainability
- Flexible asset

Private warehouse cons

- Capital expenditure may delay other priorities
- Inflexible asset
- Increased carrying costs
- Increased exposure to risks

Public warehouse pros

- Lower costs
- Increase flexibility

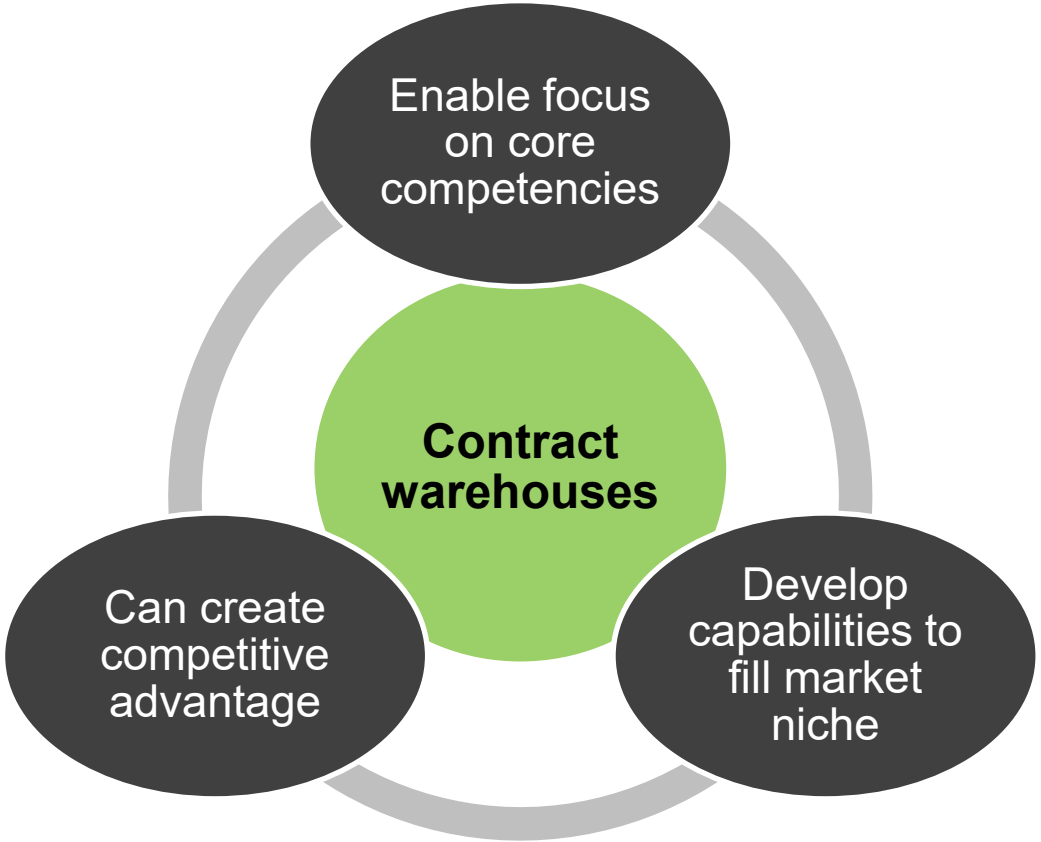
Public warehouse cons

- Less control
- Risk of availability

Differentiate Between Warehouse Ownership Types

Contract Warehouses: Owner and Client Share Costs/Risks

- US: public and contract warehouses differ
- Elsewhere: both called public
- EU: public vs. private customs warehouse



Differentiate Between Warehouse Ownership Types

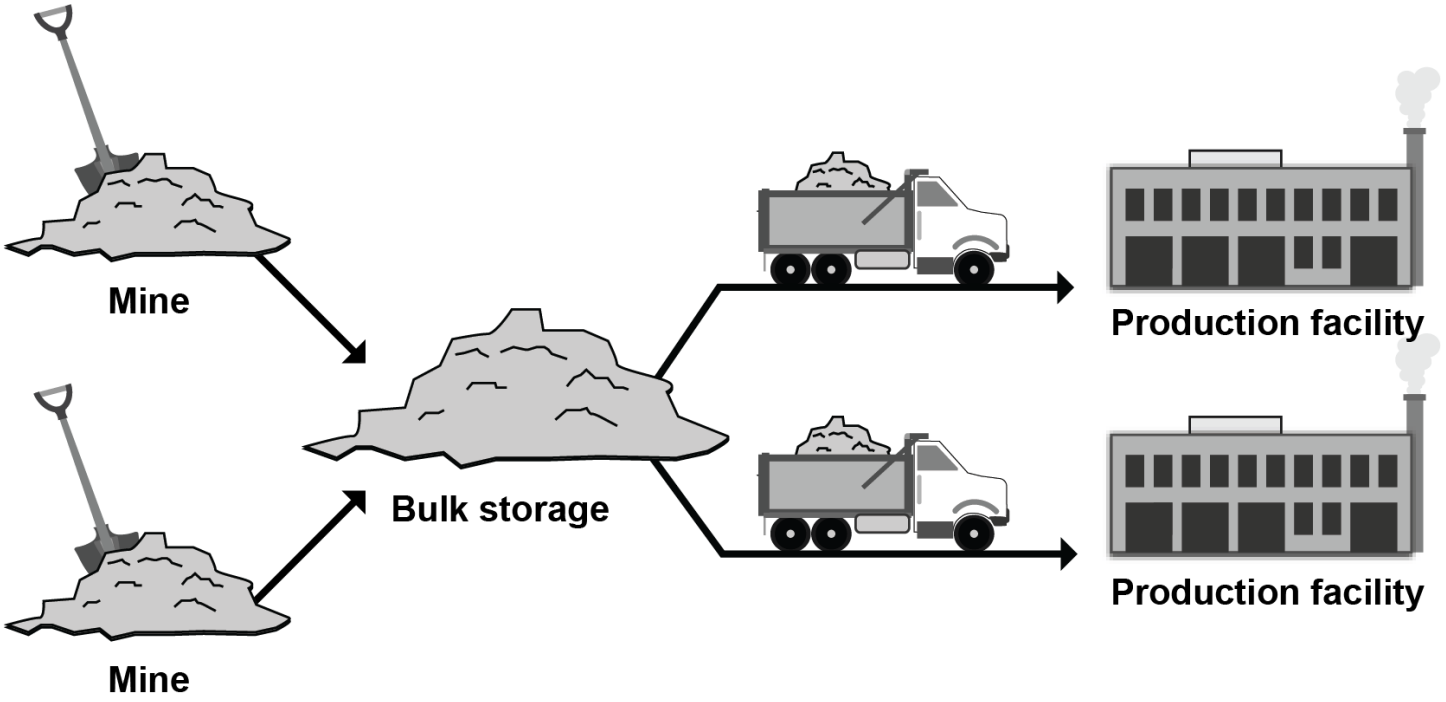
Warehouse Decision Factors

Factor	Private Warehouse	Public/Contracted Warehouse
Throughput	Higher	Lower
Demand characteristics	Stable	Fluctuating
Market density	Higher	Lower
Need for physical control	Yes	No
Security needs	Higher	Lower
Customer service requirements	Higher	Lower
Ability to meet multiple uses	Yes	No

Source: Brian J. Gibson, Ph.D., cited in *Managing Supply Chains.* Used with permission.

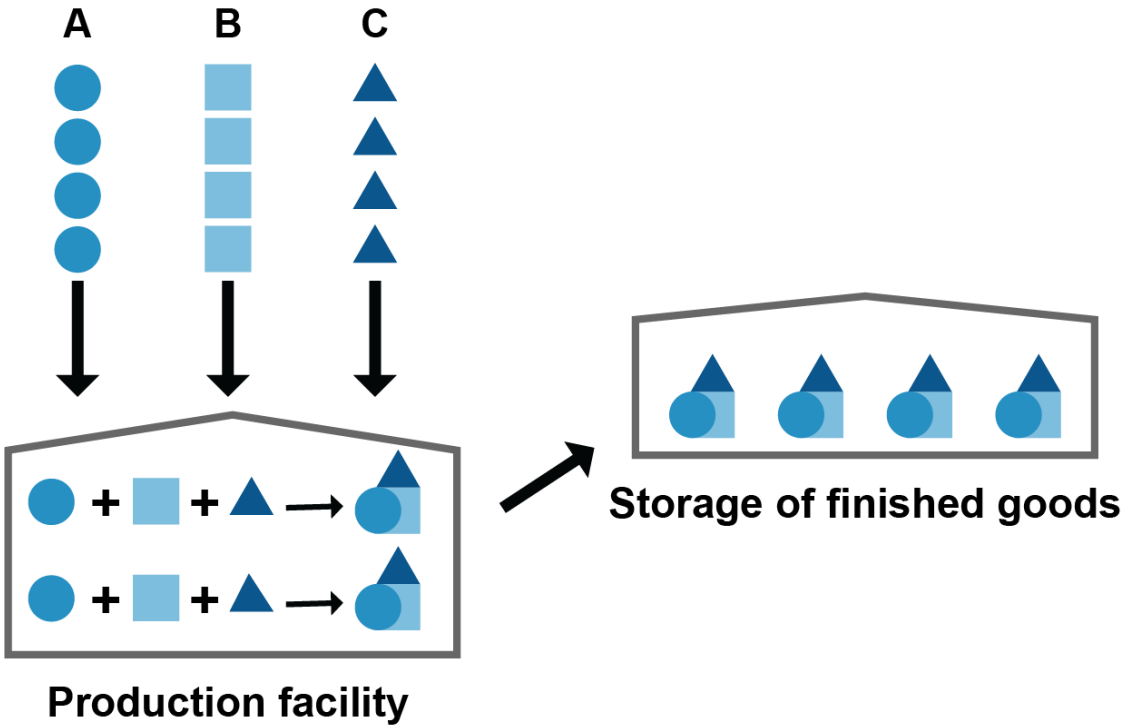
Recognize Fundamental Warehouse Services

Storing Raw Materials



Recognize Fundamental Warehouse Services

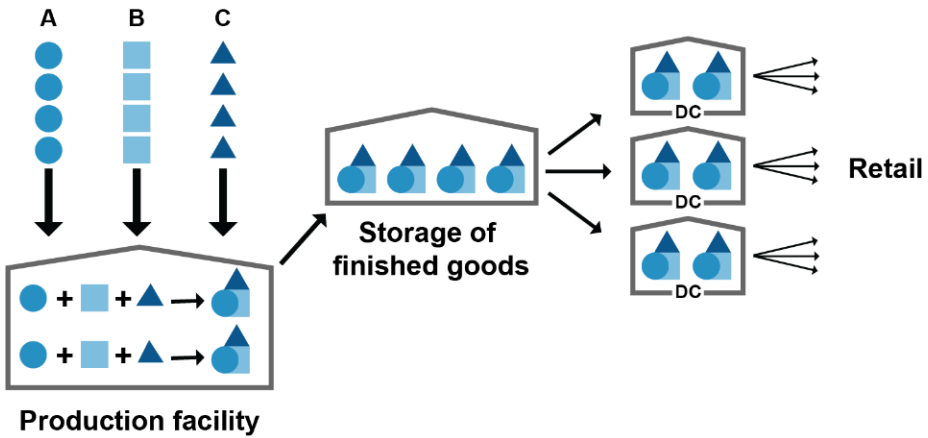
Warehousing Role at Production/Assembly Facilities



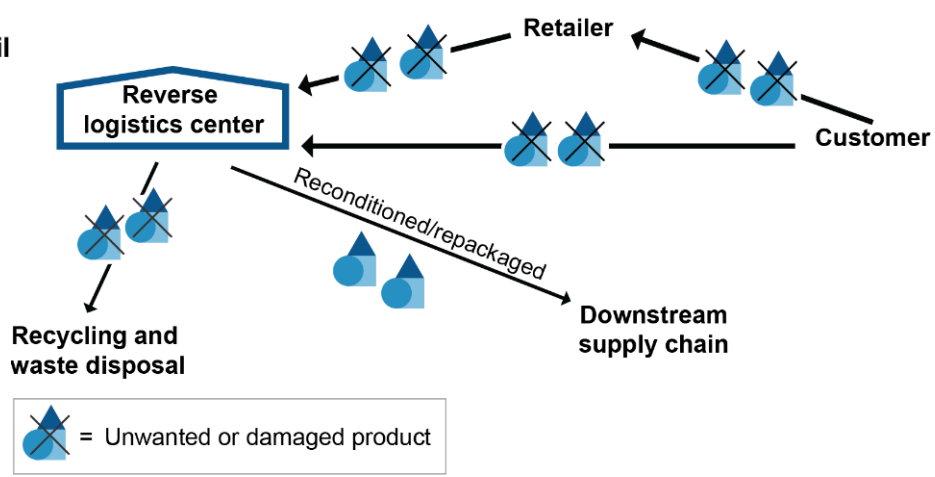
Recognize Fundamental Warehouse Services

Storing Product in Distribution Channel

Distribution Centers



Reverse Logistics Centers



Recognize Fundamental Warehouse Services

Specialized Warehouse Structures or Services

Specialized structures	• Silos, gas spheres, liquid storage, tents, inflatables, open
High compliance requirements	• Pharmaceuticals: vulnerable to contamination/degradation, highly regulated (current good manufacturing practices, cGMP)
Cold chain	• Design for inventory that would spoil at higher temperatures
Bonded (Customs)	• Delay duties and comply with other commercial policies (e.g., import license) until transfer out. Most storage: unlimited time.
Dangerous goods (hazmat)	• Design for risks posed by handling and storing dangerous goods: explosive, flammable, oxidizing, radioactive, or toxic
Automated	• High construction and equipment costs • Lower labor costs

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MODULE 4, SECTION B: FORMULATE WAREHOUSE PROCESSES AND ORDER FLOW

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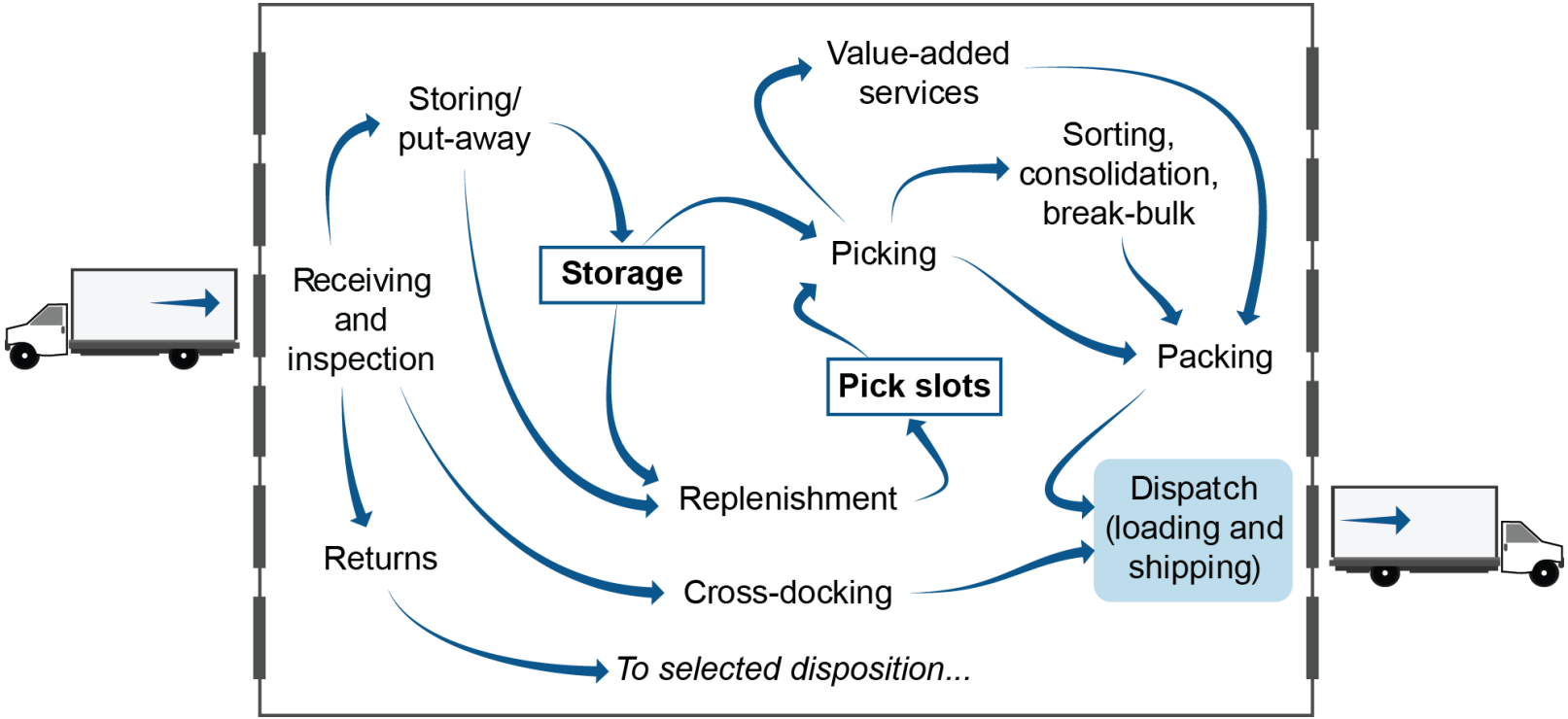
Warehouse Processes and Order Flow



Receiving, Inspection, and Returns Processing

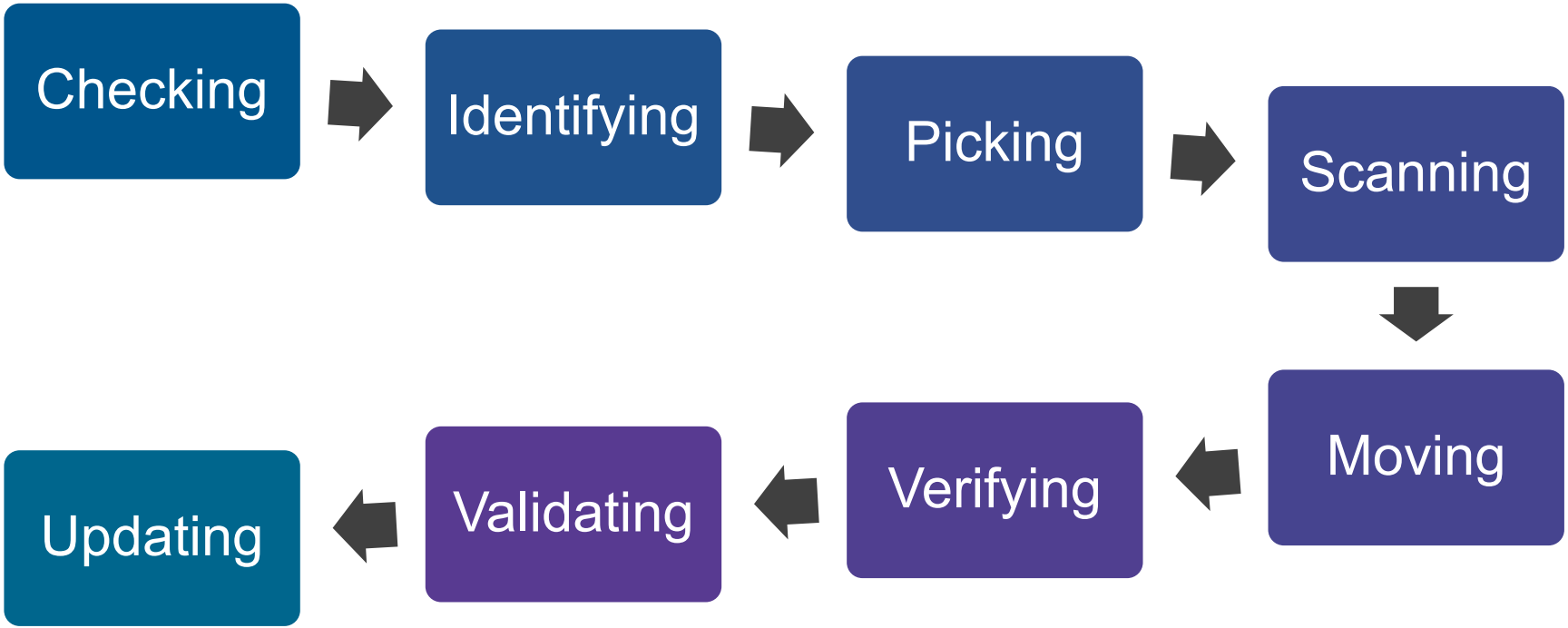
Receiving	Inspection and Quality Control	Returns Processing
▪ Coordinate and plan within the warehouse ▪ Driver role ▪ Staging, sorting, labels	▪ Basic ▪ Good faith receiving ▪ Partial inspection ▪ 100% inspection ▪ 3rd party inspection at supplier	▪ Returns consolidation center ▪ Sort into disposition categories ▪ Some items returned to inventory or pick slot

Factors Affecting Receiving Performance

Warehouse manager interacts with supplier to influence conditions that can speed up or slow down put-away.

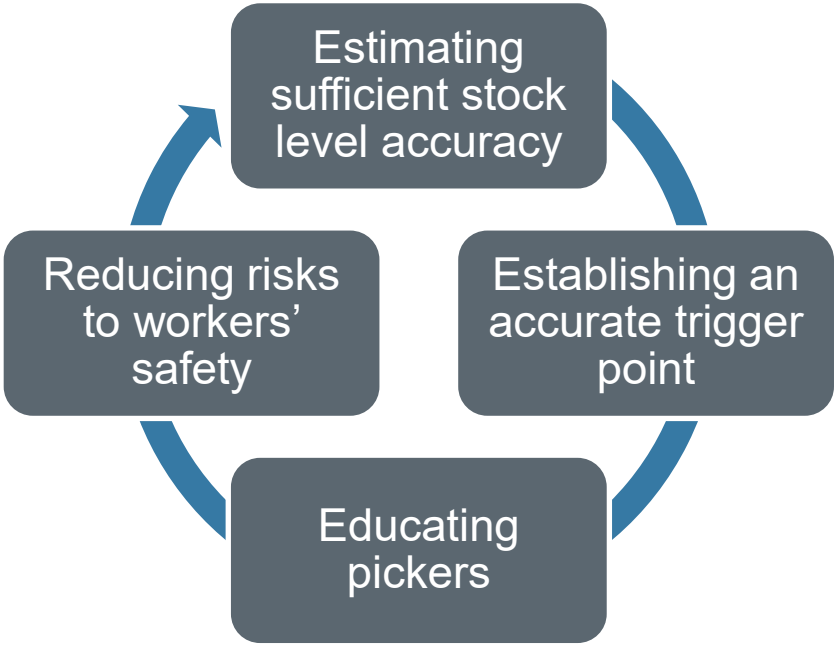
- Pre-receipt conditions
- Coordinating packing to the warehouse's needs
- Coordinating the means of delivery with the warehouse's abilities
- Ensuring that cases are palleted securely
- Labeling goods in an easy-to-read way
- Reviewing orders to catch errors

Storage Process

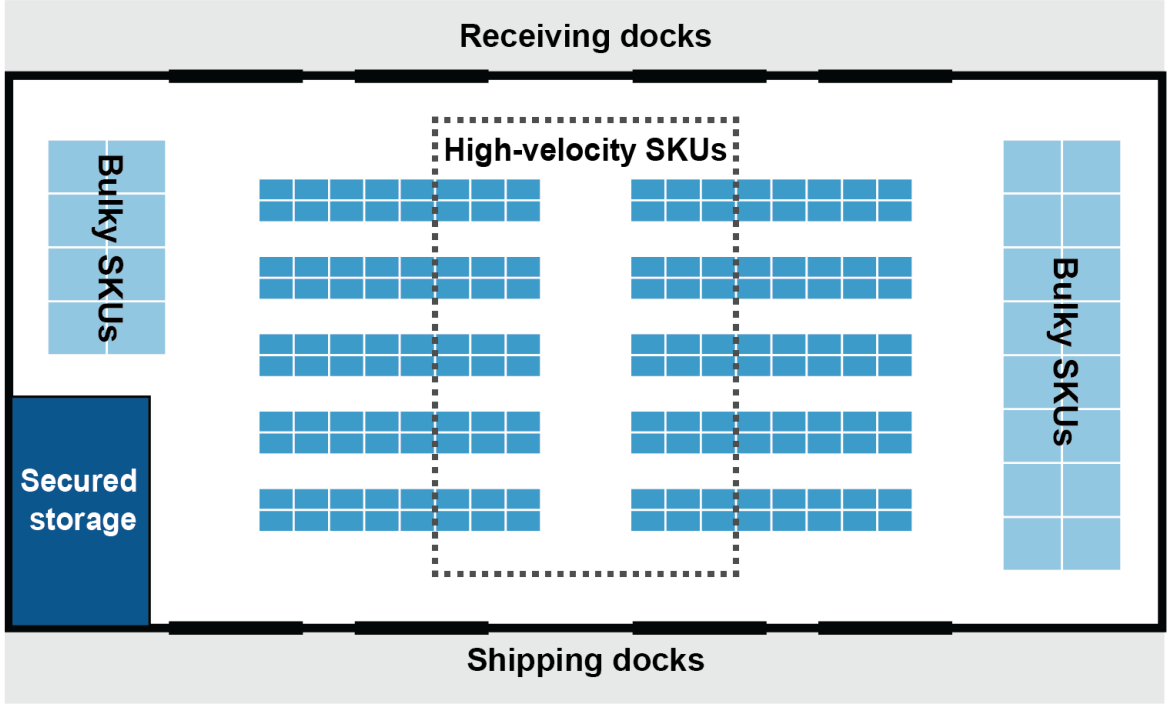


Replenishment and Other In-Storage Handling

- Replenish
  - On demand
  - Per a routine
  - Opportunistically
- Minimize other forms of in-storage handling



Factors Affecting Storage Performance



Warehouse's storage plan

- Product velocity
- Weight
- Special storage needs

Set Picking and Packing Strategy and Tactics

Warehouse Picking and Packing

System	Pick and Pack
▪ Part-to-picker – Carousels – AMRs ▪ Picker-to-part – Paper pick list – Pick by label, scanning, voice, vision, light – Automated	▪ Packing during picking – Eaches into pre-labeled carton – Labels to sealed cartons ▪ Fewer materials handling steps ▪ Less throughput

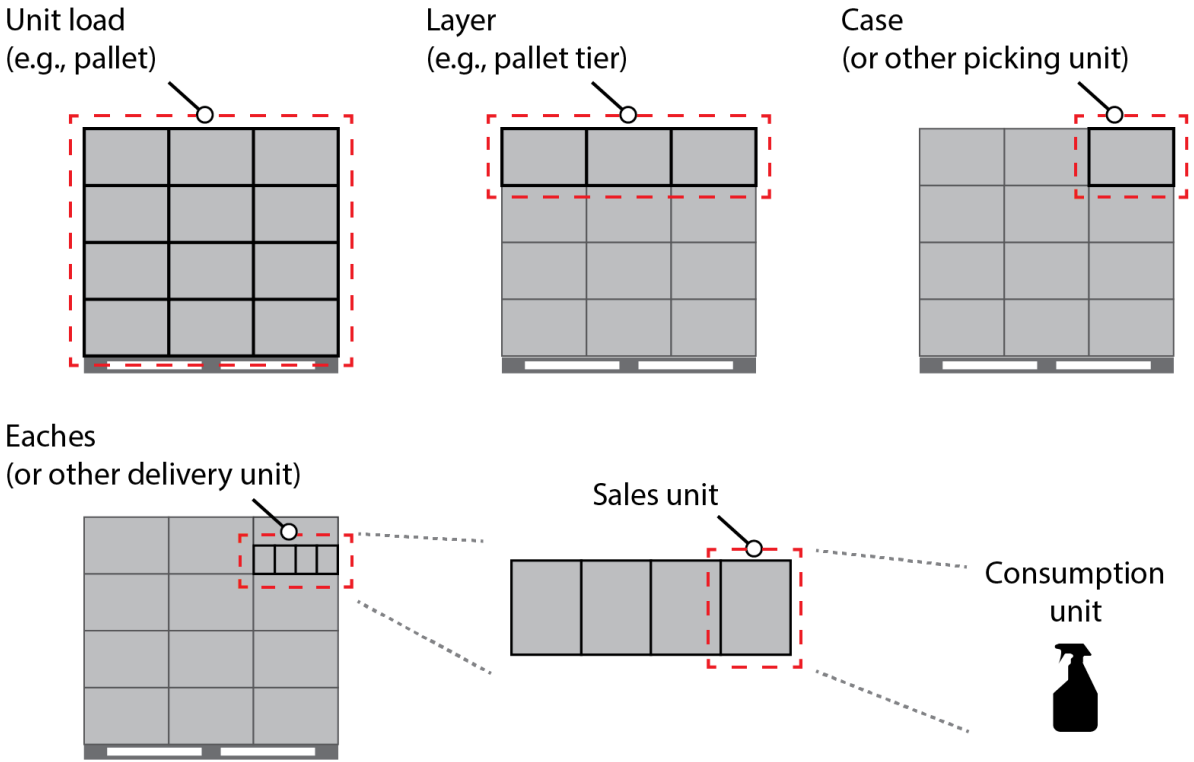
Set Picking and Packing Strategy and Tactics

Warehouse Picking and Packing

Value-Added Services at Warehouse	Level of Automation
▪ Postponement ▪ Fast processing ▪ Less cost	▪ By hand ▪ Automated equipment ▪ Both

Set Picking and Packing Strategy and Tactics

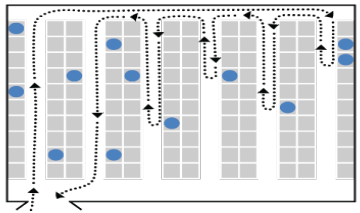
Order Increments



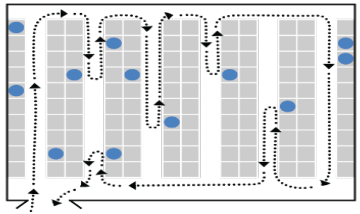
Set Picking and Packing Strategy and Tactics

Routing Strategy

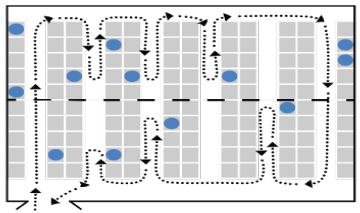
- Efficiency: Warehouse travel can be up to half of picking time
- Other variables
  - Congestion
  - Time
  - Capacity
  - Cost
  - Order sequence



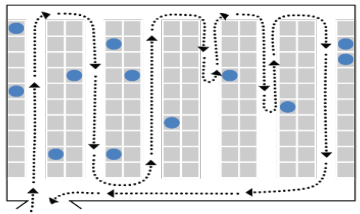
Optimal



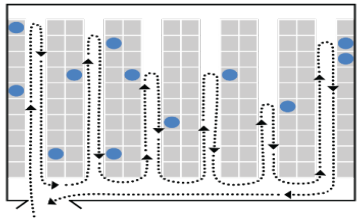
Largest gap



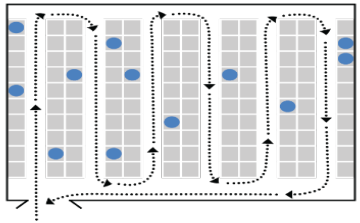
Midpoint



Combined



Return



S-shape

Set Picking and Packing Strategy and Tactics

Picking Structure

Discrete order picking

- Picked individually
- High level of customer service

Batch/Cluster picking

Batch

- Fills multiple orders at same time
- Sorting area

Cluster

- Pick lists not consolidated
- Sort on fly

Zone picking

- Storage area divided into zones
- Orders completed zone by zone

Wave picking

- Orders combined and released at specific times of day
- All zones picked simultaneously

Set Picking and Packing Strategy and Tactics

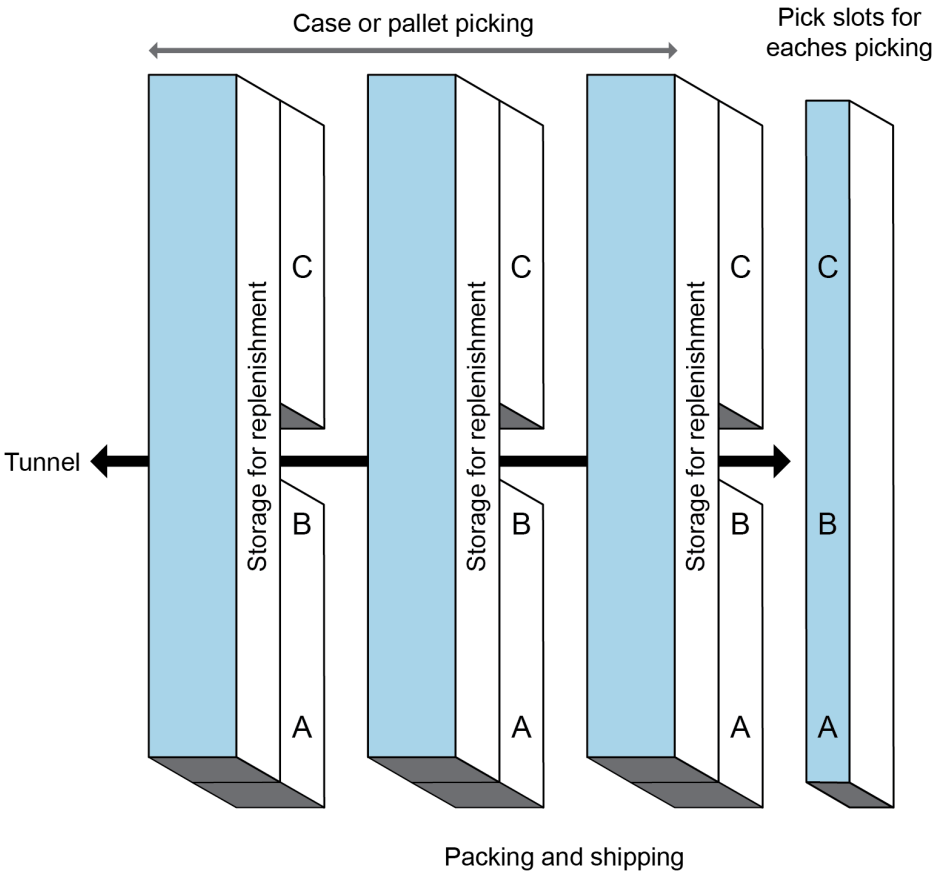
Factors Affecting Picking Productivity: Best Practices

- Use efficient picking routes.
- Clearly label SKUs.
- Light the picking area well.
- Clear clutter.
- Use technology to eliminate paperwork.
- Use automation and equipment.
- Verify order with check step.
- Maintain adequate inventory.
- Cross-train pickers.
- Analyze performance data.

Set Slotting Strategy

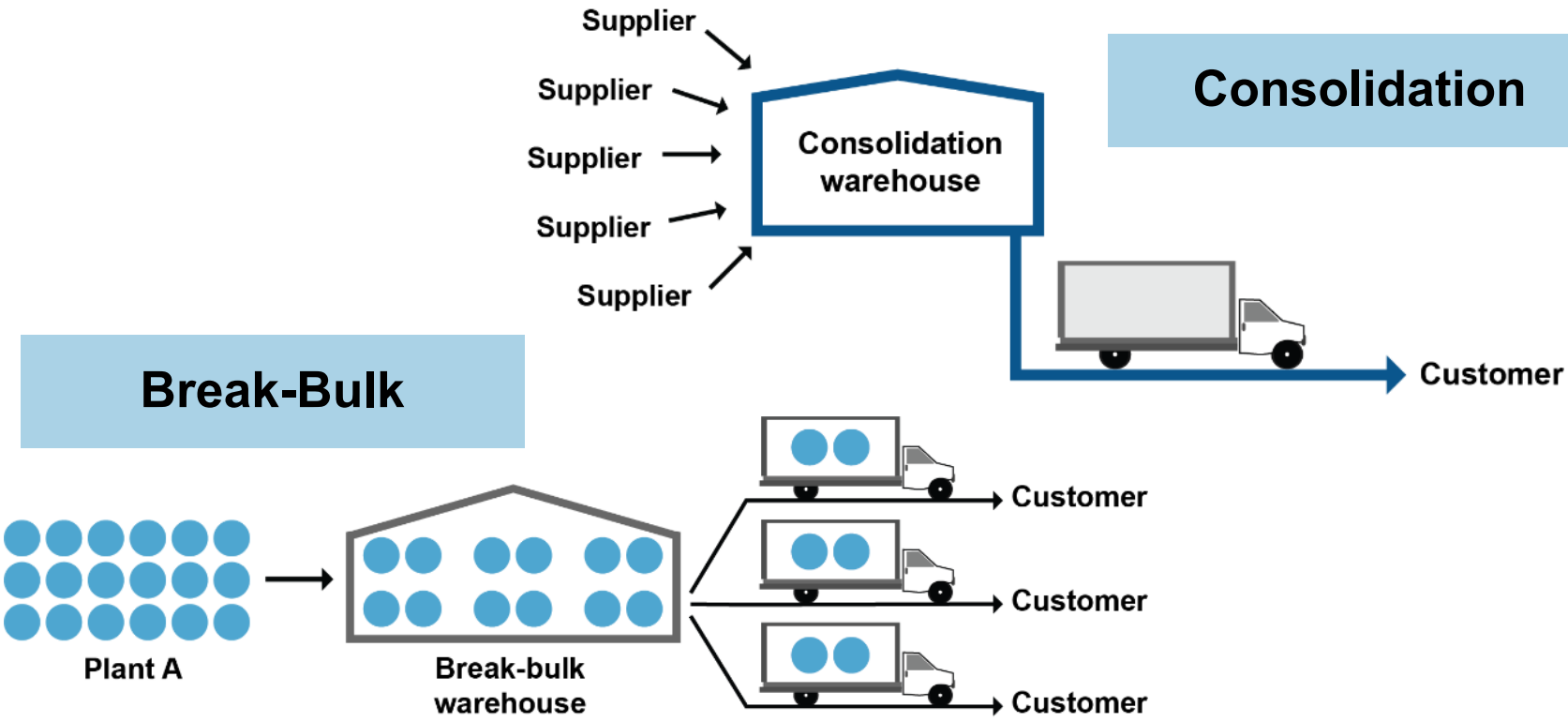
Slotting Factors

- Reslot seasonal
- By equipment type
- Cluster to support batch or cluster
- Temperature/secure
- Ordered together
- Customer group
- Loading schedule



Source: Inspired by Richards, *Warehouse Management.*

Consolidation, Break-Bulk



Sorting, Cross-Docking

Sorting

- "…physically separating a homogenous subgroup from a heterogeneous population of items." –*ASCM Supply Chain Dictionary*
- Separating, combining, verifying

Cross-Docking

- Bypass storage
- Receiving/inspection to staging area to dispatch

Packing and Unitizing

In a staging area, packaged loads may be unitized to form unit loads before shipping.

Packing occurs after goods are sorted to:

- Meet customer specifications.
- Avoid damage during shipping.
- Facilitate the most cost-efficient transportation.

Loading Crew Challenges

- Managing third-party shippers
- Coordinating traffic at loading bays
- Loading efficiently and safely
- Facilitating customer inspections
- Adhering to cargo stowage and securing good practices
- Completing all required documentation

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MODULE 4, SECTION C: EVALUATE WAREHOUSE FACILITY LAYOUT DECISIONS AND MANAGE PERFORMANCE

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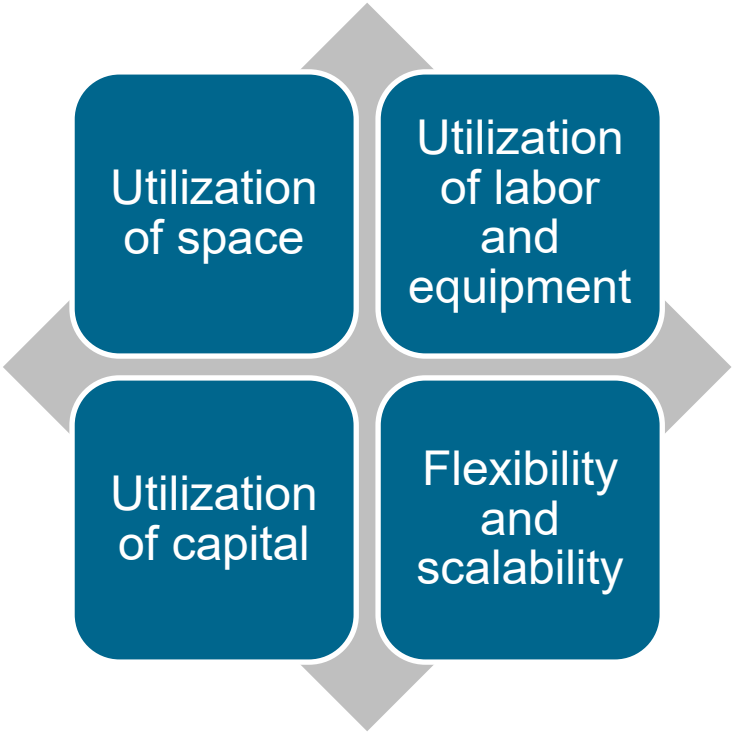
Warehouse Layout Design Principles

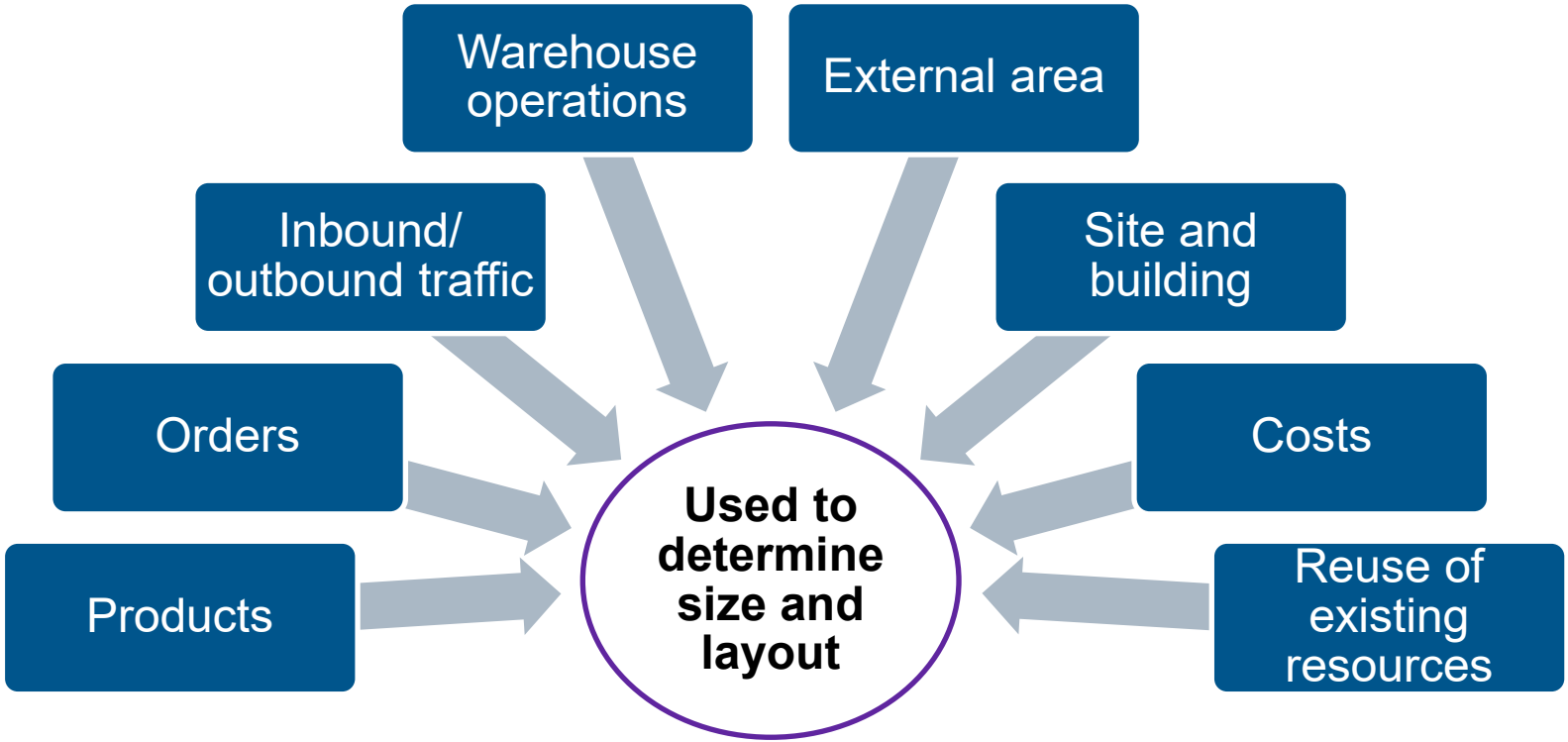


Warehouse Design Process

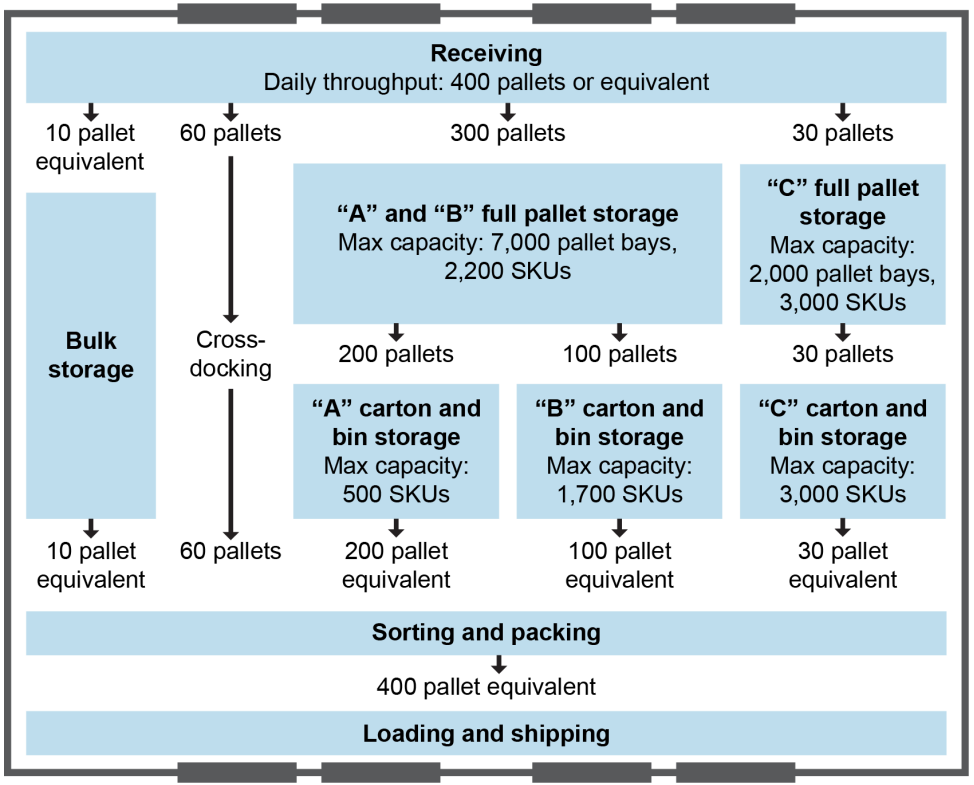
1.	Define business requirements and design constraints.
2.	Define and obtain data.
3.	Formulate planning base for defined throughput.
4.	Define and describe activity requirements.
5.	Select equipment.
6.	Create internal and external layouts.
7.	Define information system operation.
8.	Estimate capital and operating costs.
9.	Evaluate design against requirements and constraints.
10.	Finalize design.

Source: Adapted from Rushton et al., *The Handbook of Logistics and Distribution Management, fifth edition.*

Define and Obtain Data



Formulate Planning Base for Defined Throughput



Create Internal and External Layouts

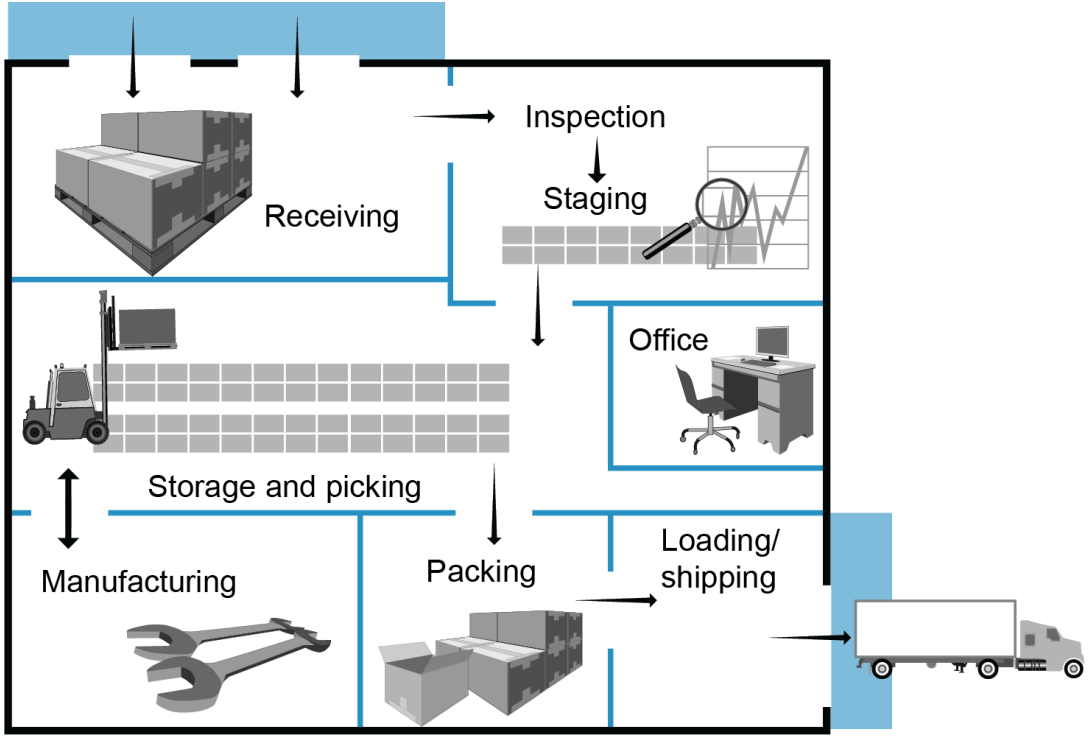
Internal layout needs	External layout needs	Environmental goals
▪ Dock heights ▪ Vertical clearance ▪ Distance between supports ▪ Floor unevenness tolerance ▪ Necessary services	▪ Yard ▪ Access roads ▪ Fencing ▪ Security ▪ Parking areas ▪ Vehicle maintenance ▪ Landscaping	▪ Insulation ▪ Infiltration ▪ Efficient – HVAC – Lights ▪ Automated controls ▪ LEED, BREEAM, etc.

Determine Facility Size

Warehouse Capacity and Design

Example: 400m x 90m = 36,000m^2

- **Deduct non-storage space:** 9,000m^2 leaving 27,000m^2
- **Add net vertical:** 27,000m^2 x 7.5m = 202,500m^3

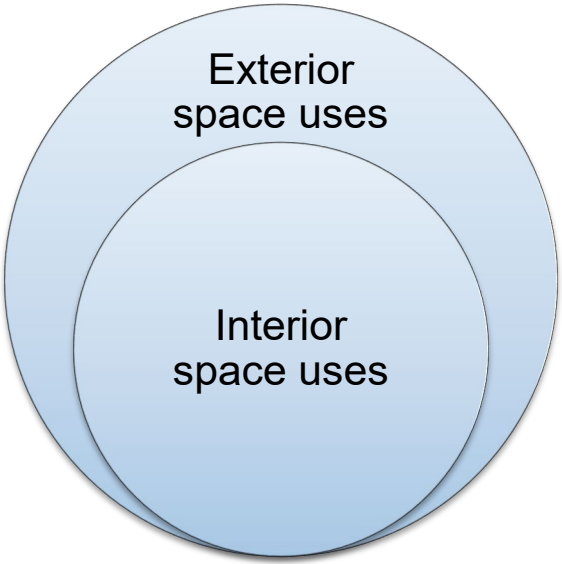


Source: David F. Ross, *Distribution Planning and Control—Managing in the Era of Supply Chain Management.* Used with permission.

Space Needs in Warehouses

Interior

- Picking/staging for both inbound and outbound
- Value-added
- Damaged goods storage
- Reverse logistics
- Employee areas and waiting area for drivers
- Equipment storage
- Utilities/infrastructure



Exterior

- Holding area
- Vehicle maneuvering
- Parking
- Storage
- Security fencing
- Outdoor recharging stations

Cube Utilization

"A measurement of the utilization of the total storage capacity of a vehicle storage bay, container, type of warehouse equipment, or entire warehouse. The intent is to minimize unused horizontal or vertical space." *(ASCM Supply Chain Dictionary)*

Improving cube utilization:

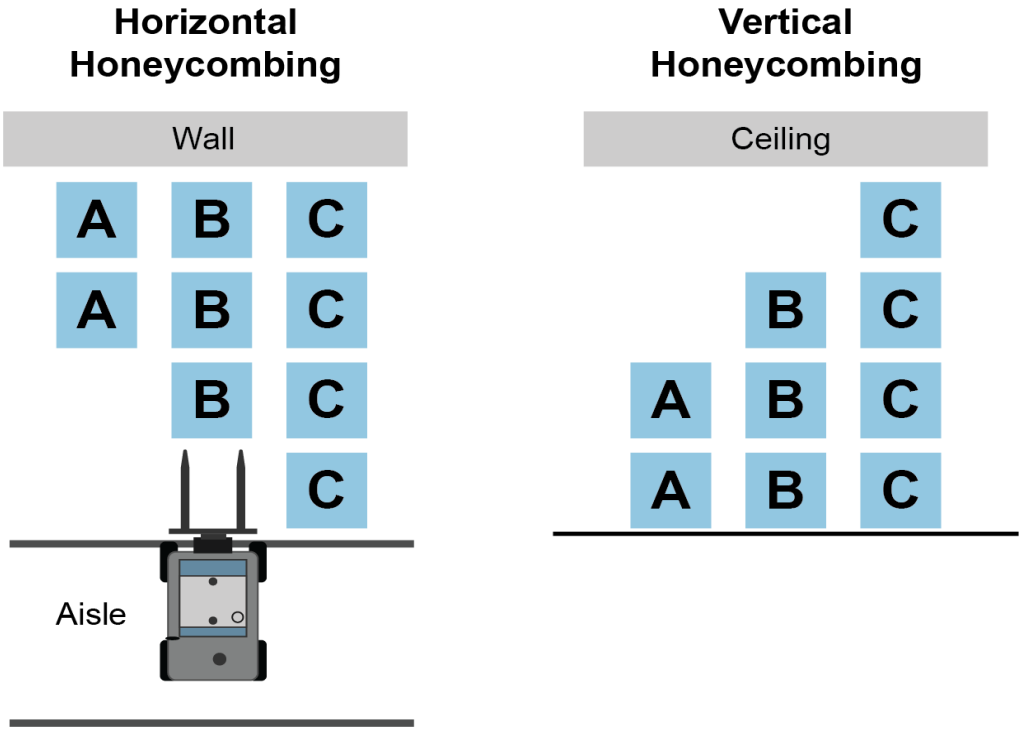
- Often requires different equipment (e.g., rack systems, forklift trucks)
- Finding additional unused space in existing structure (e.g., mezzanine)
- Standardizing packaging/pallet size

Calculating Storage Space

1. Define the number of pallets required to meet inventory needs.
2. Calculate the square and cubic meters needed to store product.
3. Add space for other storage tools.

Determine Facility Size

Honeycombing

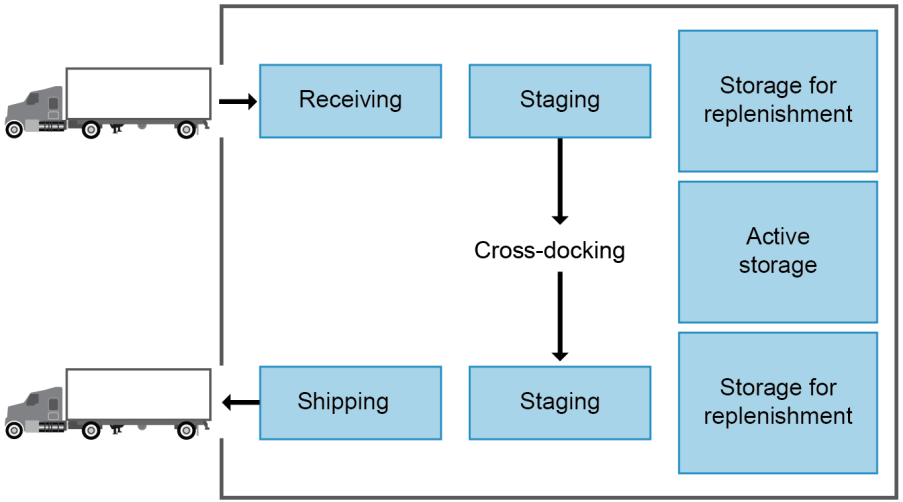


Source: David F. Ross, *Distribution Planning and Control—Managing in the Era of Supply Chain Management.* Used with permission.

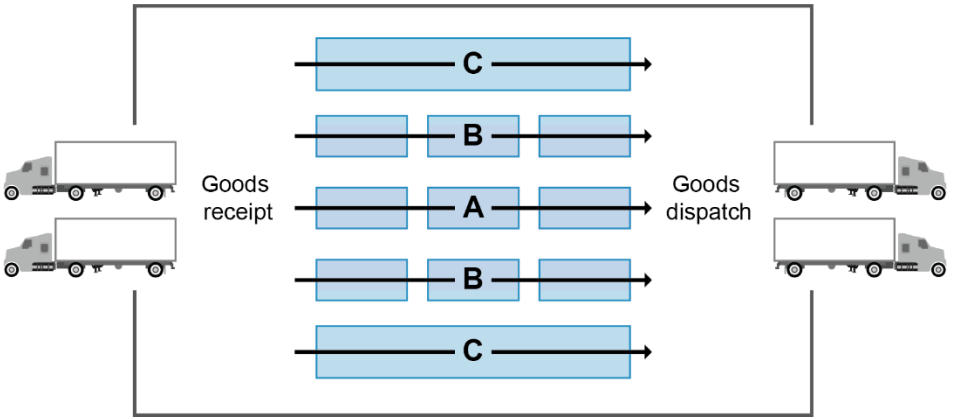
Evaluate Types of Layouts

Warehouse Layouts

U-flow



Through-flow

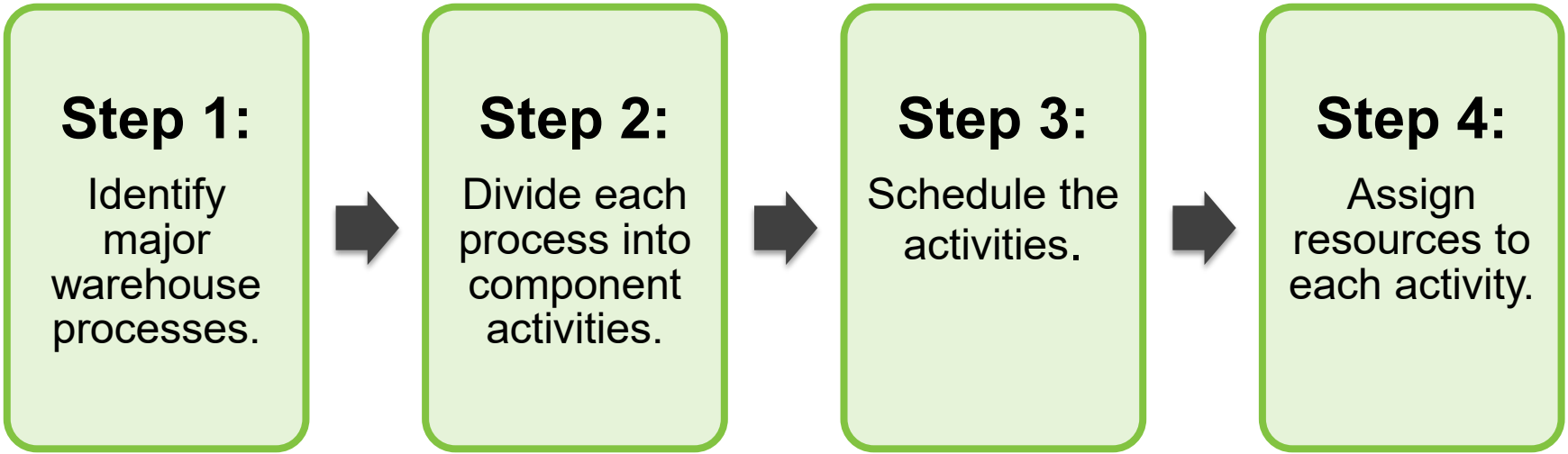


Finding Additional Warehouse Space

Use existing space better by:

- Consolidating stock.
- Moving from fixed location to random location.
- Changing storage medium or handling equipment.
- Reducing beam heights.
- Using variable height locations.
- Using temporary storage locations.

Resource Allocation: Modeling Resource Utilization



Developing Work Standards

- **Available Time** = Hours of Operation × Number of Workers or Equipment
- **Utilization Rate** $= \dfrac{\text{Hours Actually Worked}}{\text{Available Hours}}$
- **Efficiency Rate** $= \dfrac{\text{Actual Output}}{\text{Standard Output}}$
- **Rated Capacity** = Available Time × Utilization Rate × Efficiency Rate
- **Demonstrated Capacity** $= \dfrac{\text{Output for } n \text{ Periods}}{n}$

Examples of Waste in Warehouse

Equipment	♦ Driving an empty forklift
Time	♦ Time spent correcting errors in put-away or picking ♦ Delays caused by congestion in receiving and shipping areas
Motion	♦ Inefficient movements, such as staging before put-away ♦ Unnecessary steps (e.g., checking paperwork)
Space	♦ Too much inventory ♦ Inefficient use of storage space (poor use of vertical space, multiple half-empty pallets of the same SKU in different locations) ♦ Obsolete or out-of-date stock

Source: Adapted from Toby Gooley, “Lean Your Warehouse Workforce.”

WMS Features and Selection Factors

Features

- Manage orders and inventory
- Organize warehouse work
- Monitor and analyze performance
- Can manage multiple warehouses

Ability to interface or integrate with existing systems

Accessibility from internet

Modularization and scalability

Analysis and reporting capabilities

User-friendliness

Support of best warehouse practices

Support of specialized functionality

Other Warehouse System Types

Warehouse execution systems (WES)

- Organize, sequence, coordinate resources
  - Labor
  - Equipment
  - Work centers
- Support for voice data capture, pick-to-light, etc.
- Design warehouse layout

Warehouse control systems (WCS)

- Communicate directly with warehouse automated equipment
- Operate in real time
- Provide a single user interface
- Control systems in a single facility

Yard Management Systems

- Coordinate inbound and outbound shipments
- Account for equipment and goods in yard and warehouse
- Reduce delayed trailer return
- Manage “shunting” or “yard jockey” work

Warehouse Documentation

Inbound

- Material entry, quality
- Put-away/moves
- Lot control with pick list

Outbound

- Picklist, packing list, invoice
- Bill of lading origin
- Advance ship notice (ASN)

Building, facility, equipment

- Work records
- Safety training records, near miss
- Maintenance records

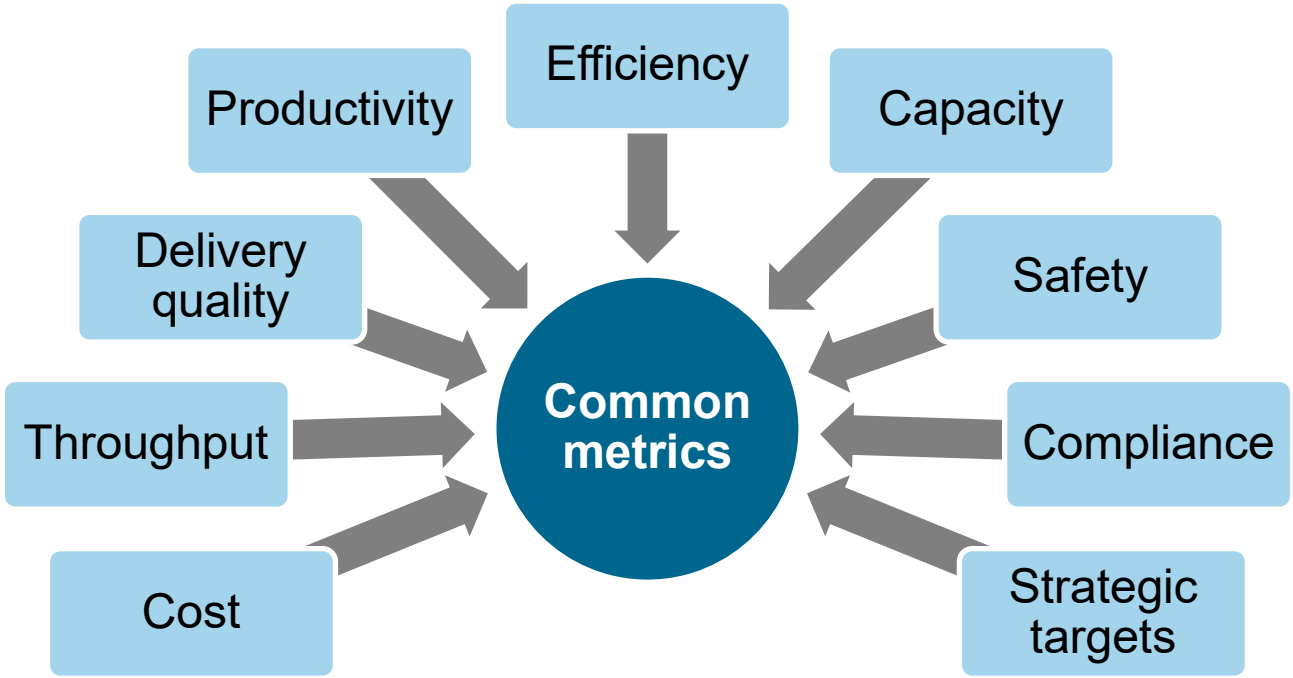
Product certification and traceability

- Temperature and humidity
- Organic, gluten free, halal
- Product origin lot

Implement Performance Management

Warehouse Metrics and Audits

- Criteria: how warehouse defines success
- Audits
  - SOPs
  - Observation and data analysis
  - Prepare staff



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CERTIFIED IN LOGISTICS,
TRANSPORTATION AND DISTRIBUTION

MODULE 4, SECTION D: INCORPORATE PACKAGING

APICS

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Packaging and Unitization

Packaging	• Materials surrounding item to protect from transport damage. • Packaging type influences risk.
Unitization	• How packaging makes unit loads impacts warehousing and transport efficiency/effectiveness. • Transport cost differs by packaging type
Unit loads	• Interface with customer's handling equipment (e.g., pallet type)?
Identifiers	• Labels, barcodes, tags to correctly, quickly identify item

Product State

Solids

- Bulk or packaged forms.
- Bulk includes materials too large for pallets and dense raw materials.

Liquids

- Differentiated by viscosity level.
- May be transported by pipeline or in units, such as barrels, drums, or tanks.

Gases

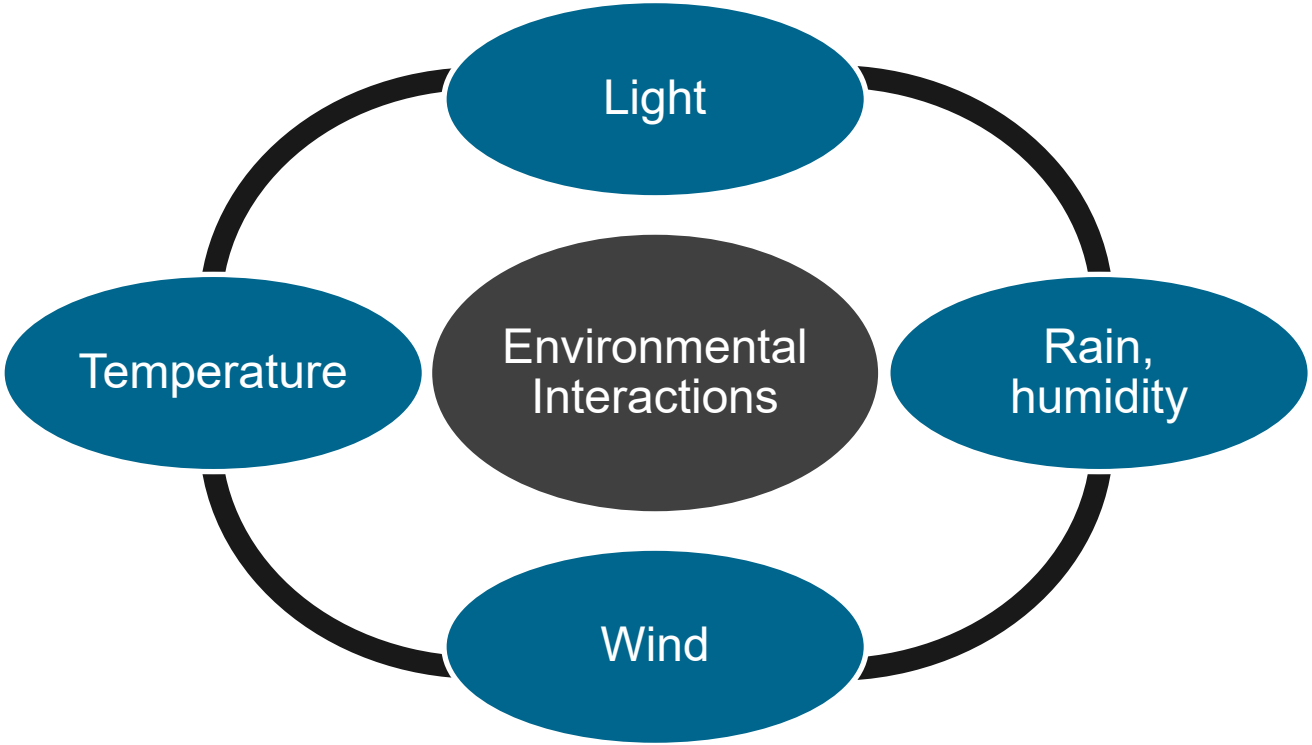
- Gases are compressible.
- Transported in bulk by pipeline or large pressurized tankers.

Density: Ratio of Mass to Volume

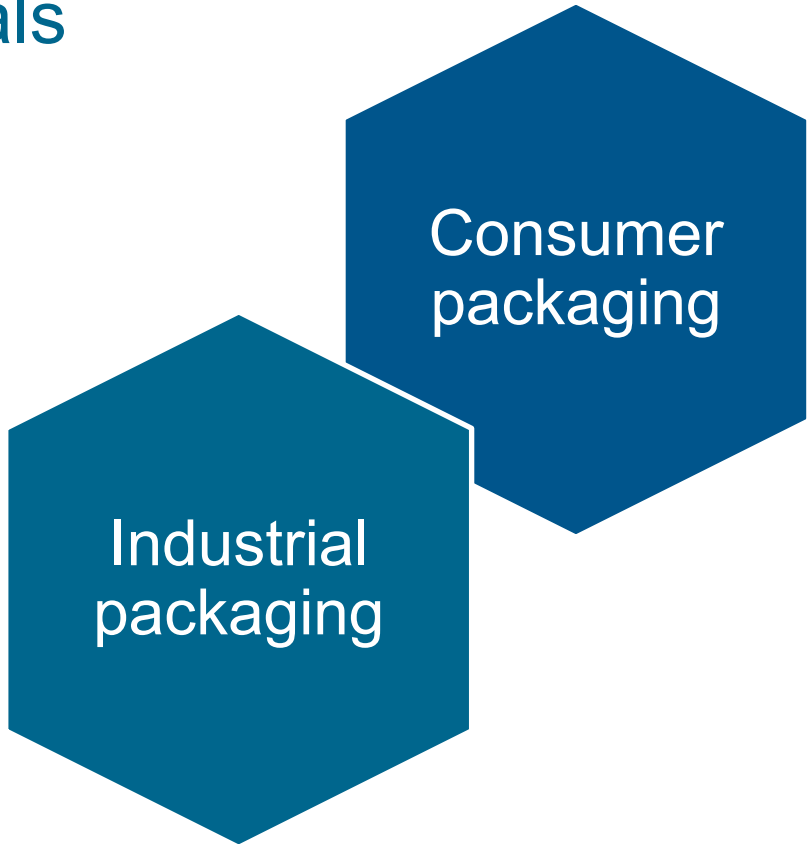
Highly dense products “weigh out” before they “cube out,” so a load reaches a vehicle’s weight limit before it fills the container.

- Iron ore (left image) will typically **weigh out** a river barge (highly dense).
- Coal (right image) will typically **cube out** a river barge (less dense).

Environmental Interactions



Packaging Goals



What consumers see in stores

Designed for transportation and logistics

Protecting Against Damage from Typical Causes

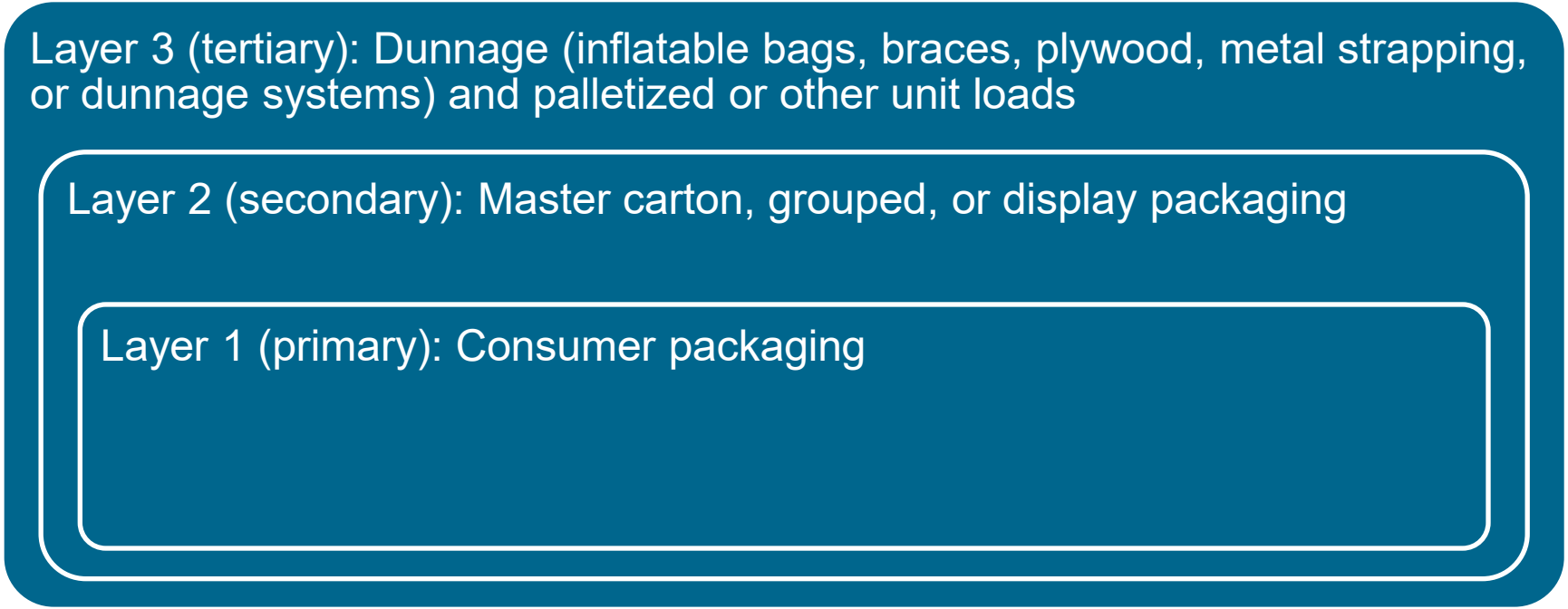
Impact and vibration

- This is provided by cushioning material, shrink wrap, etc.

Compression and puncture

- This is provided by a sturdy outside box or rigid container, protective corner additions to pallets, shrink wrap, etc.

Building-Blocks Concept



Sustainable Packaging

- Goal: minimize packaging volume/weight within reason
- Sustainable packaging may be a regulatory mandate
- Reusable packaging includes
  - Rigid containers
    - Stackable plastic bins, kegs, barrels, or metal containers
  - Reusable cushioning material
    - Inflatable dunnage bags
- Reusable packaging may require tracking or deposit system to ensure return.

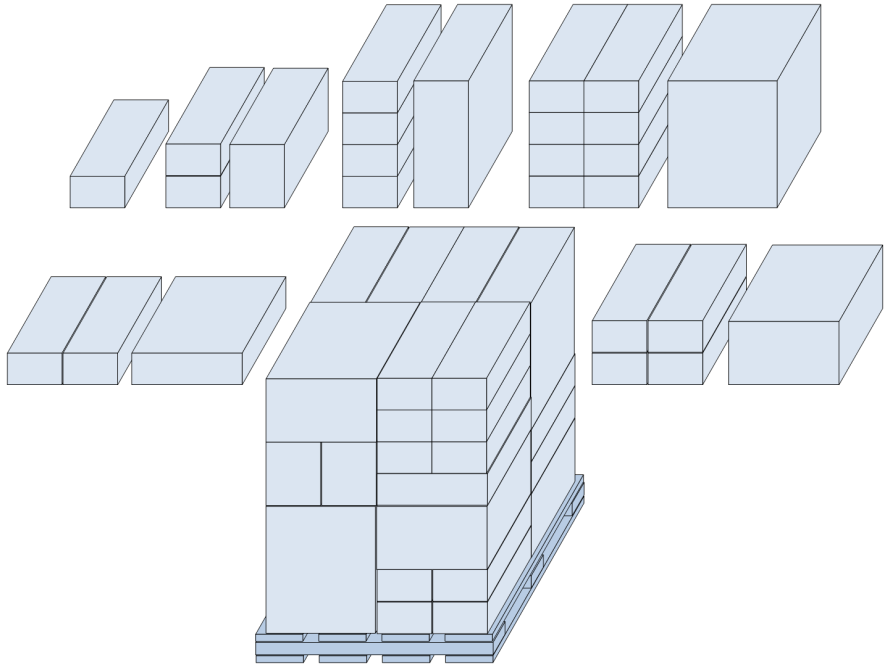
Unit Labeling

- Case, master carton
  - Identify SKU, production line, batch, lot
  - Marketing content or plain to deter pilferage
- National, regional, local requirements
- Dangerous goods (hazmat)
- Barcoding and RFID

Incorporate Unitization and Unit Loads

Unitization and Master Cartons

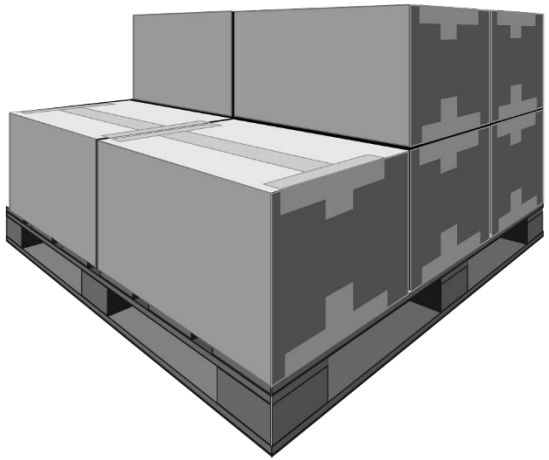
- Unitization: Consolidation for fewer handlings
- Carriers list tariffs based on type of packaging used
- Criteria for size of master carton:
  - Ease of handling
  - Economies of scale in transportation
  - Customer preference
  - Packaging efficiency
  - Sales velocity



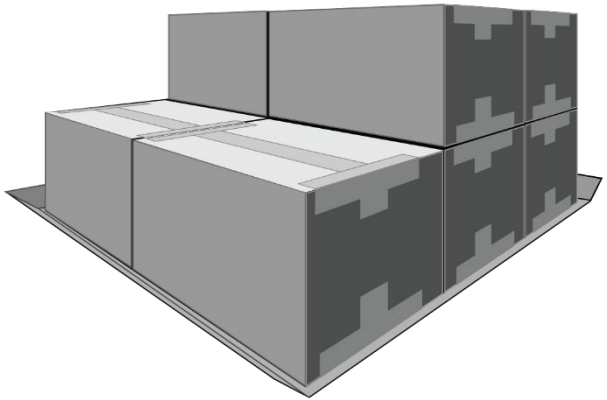
Incorporate Unitization and Unit Loads

Pallet Types

Wood pallet



Slip sheet pallet



Incorporate Unitization and Unit Loads

ISO Standard Pallet Sizes

W x L (mm)	W x L (inches)	# Pallets in 40' container	% Wasted Floor Space in Full 40'	Country
800 × 1,200	31.50 × 47.24	23-24	15.2%	ISO 1 (EUR 1)
1,000 × 1,200	39.37 × 47.24	20-21	6.7%	ISO 2 (EUR 2)
1,067 × 1,067	42.00 × 42.00	22-23	11.5%	Most countries
1,100 × 1,100	43.30 × 43.30	19-20	14.0%	Asia
1,165 × 1,165	45.87 × 45.87	20-21	8.1%	Australia
1,219 × 1,016	48.00 × 40.00	20-21	3.7%	North America

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MODULE 4, SECTION E: INCORPORATE MATERIALS HANDLING AND WAREHOUSE AUTOMATION

APICS

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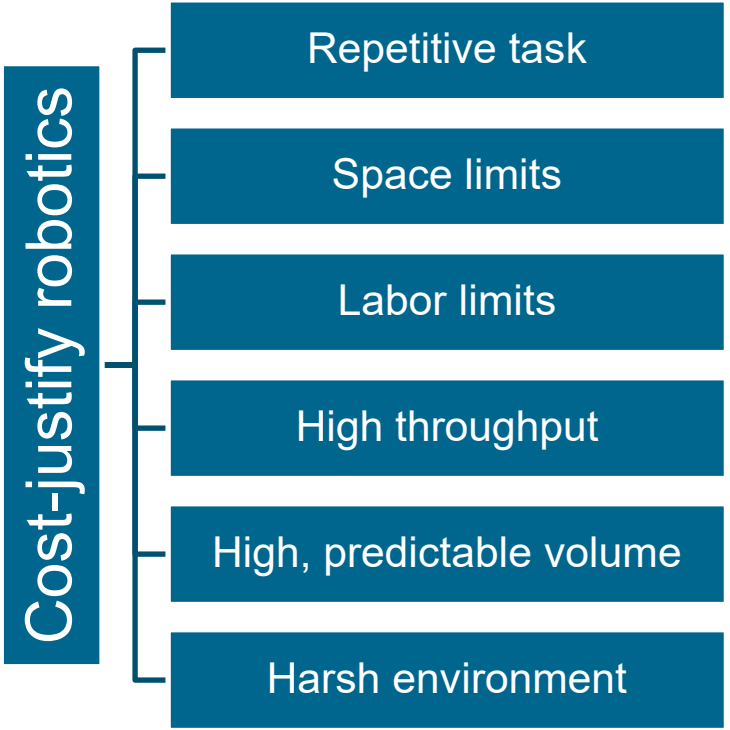
Materials-Handling Principles

1.	Plan for materials handling through well-thought-out processes and procedures.
2.	Standardize equipment and procedures.
3.	Work smarter. Eliminate unnecessary work.
4.	Design processes to be ergonomic.
5.	Consolidate smaller unit loads into larger units.
6.	Maximize the use of space.
7.	Apply systems thinking to the materials-handling process.
8.	Use automation when possible.
9.	Minimize short- and long-term environmental impacts.
10.	Evaluate equipment and systems purchases.

Source: Adapted from “The Ten Principles of Material Handling,” Material Handling Institute, www.mhia.org.

Types of Materials Handling Systems

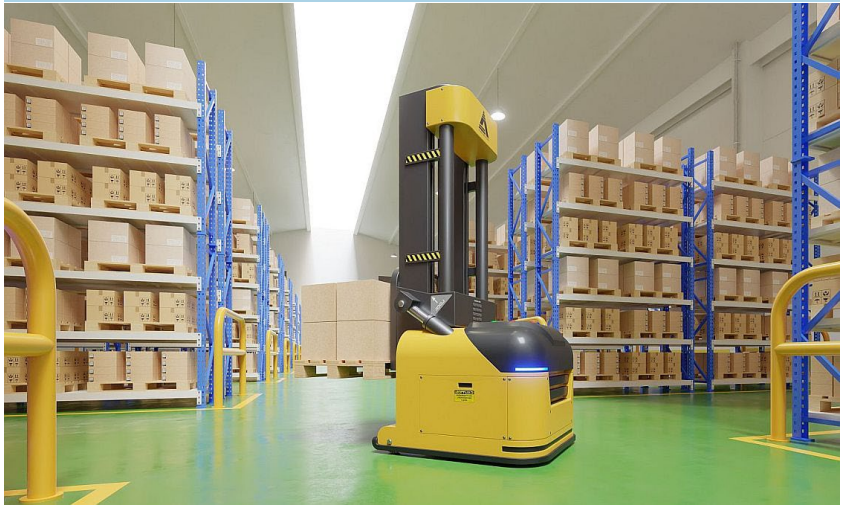
- Manual and mechanized
- Automated/robotic
  - Industrial robots
  - AGVS
  - AMRs
  - UAVs and UVs
- Sortation systems



Automated/Robotic Systems

Industrial Robot: Layer picker

Driverless Forklift Autonomous Mobile Robot (AMR)



Source: Bastian Solutions, LLC, www.bastiansolutions.com/solutions/technology/industrial-robotics/industrial-robotic-solutions/robotic-palletizing/robotic-mixed-load-palletizer. www.ek-automation.com (AGV). Both images used with permission.

Automated/Robotic Systems

Automated guided vehicle (AGV)

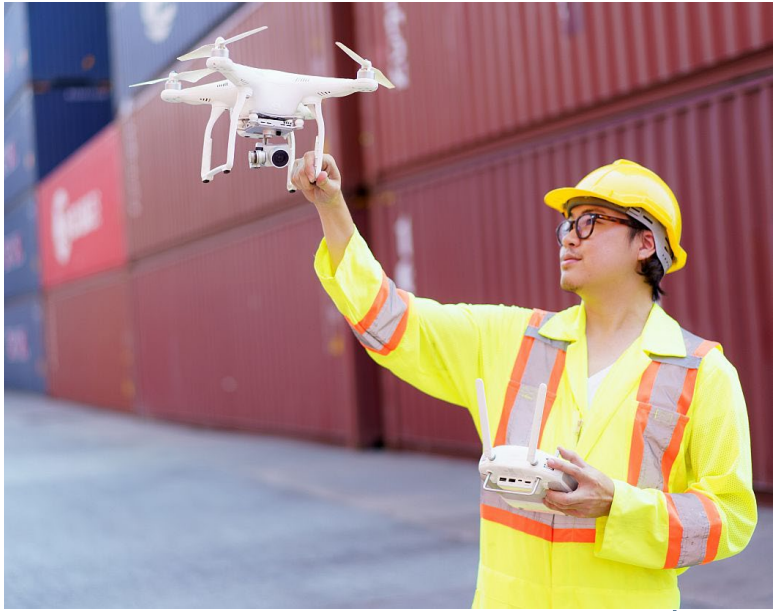
Source: www.ek-automation.com (AGV). Used with permission.

UAV for Port Container Moves

Automated/Robotic Systems

UAV for Package Delivery

UV or Drone

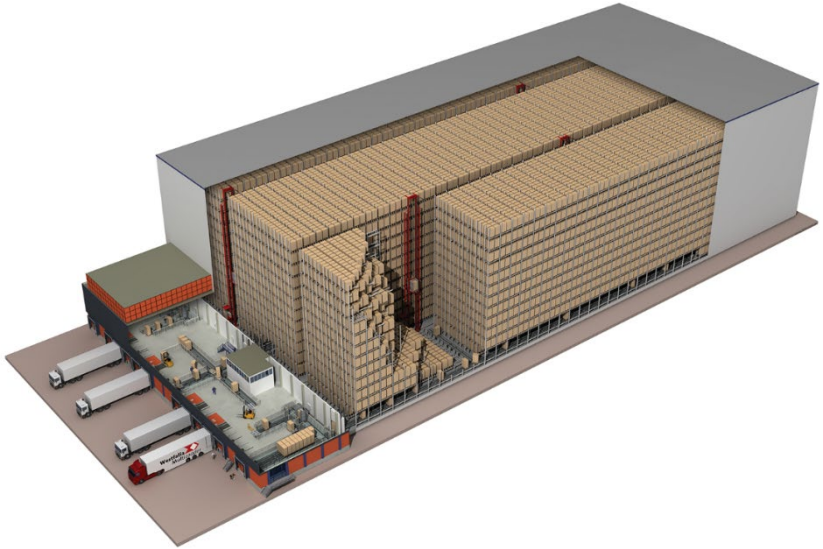


Fully Automated Systems

Benefits

- Reduce labor costs
- Improve space utilization
- Enable denser storage
- Provide consistent and high throughput
- Improve accuracy, control, and visibility
- Ensure FEFO or other rules followed
- 24/7

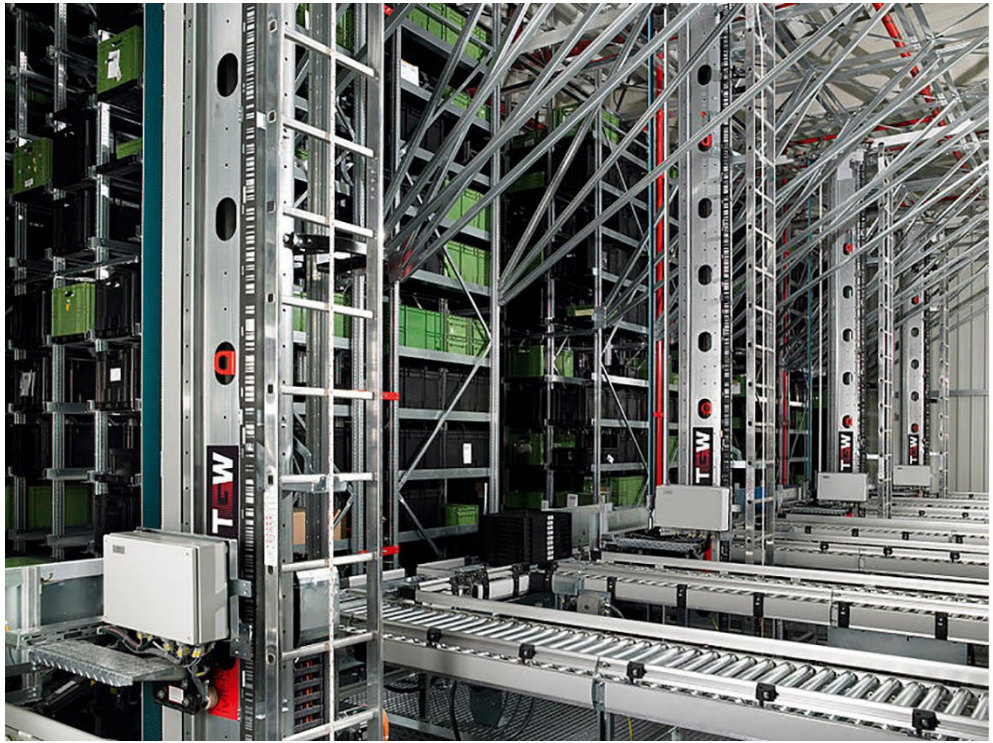
Automated Storage and Retrieval System (AS/RS)

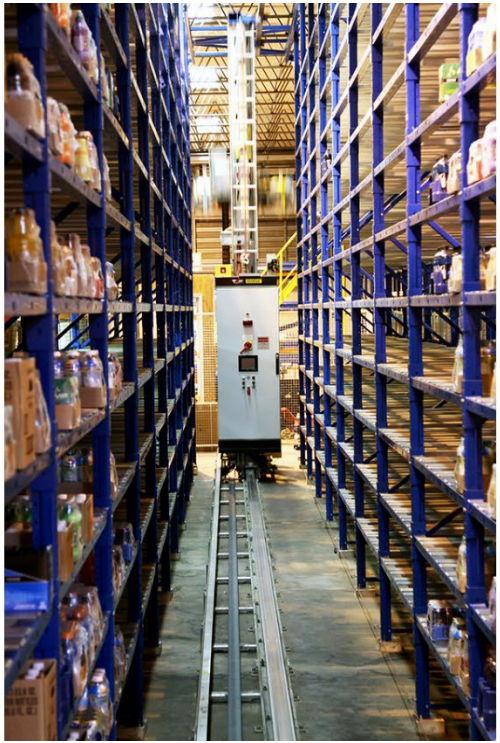


Source: Westfalia Technologies, Inc., www.WestfaliaUSA.com. Used with permission.

Automated Sortation/Retrieval Systems (AS/RS)

- Unit load systems
- Miniload systems (shown)





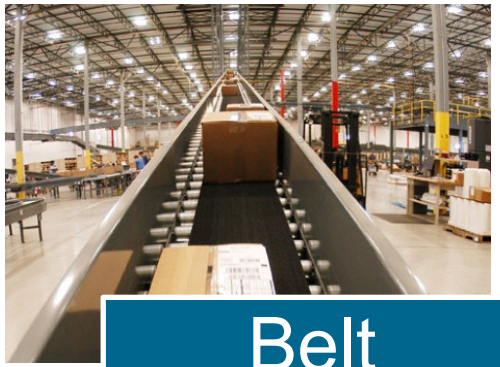
Sortation Systems

- Sorting
  - Manual
    - Put-to-light
  - Mechanized
  - Automated/ robotic
- Automatic identification
- Warehouse execution system

Sortation Systems: Conveyor Types

Roller

Bulk



Belt

Source: Intelligrated (roller), Omni Metalcraft (bulk), Intelligrated (belt). All images used with permission.

Picking Communication Systems

Pick-to-light system

Visual picking system

Sources: Bastian Solutions, LLC, www.bastiansolutions.com/solutions/technology/supply-chain-software/picking-technology/pick-to-light (pick-to-light). Deutsche Post DHL Group (visual picking system). Both images used with permission.

Picker-to-Part and Part-to-Picker Systems

Picker-to-part systems

Part-to-picker systems: Carousel

Part-to-picker: AMR for shelf-modules-to-picker

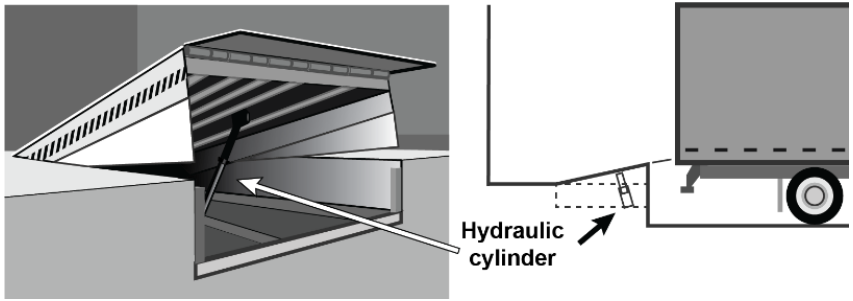
Sources: Bastian Solutions, LLC, www.bastiansolutions.com/solutions/technology/supply-chain-software/picking-technology/pick-to-light (pick-to-light system), Intelligrated (picker-to-goods), Kardex Remstar (goods-to-picker). Both used with permission.

Use Dock and Internal Transportation Equipment

Use Handling Systems

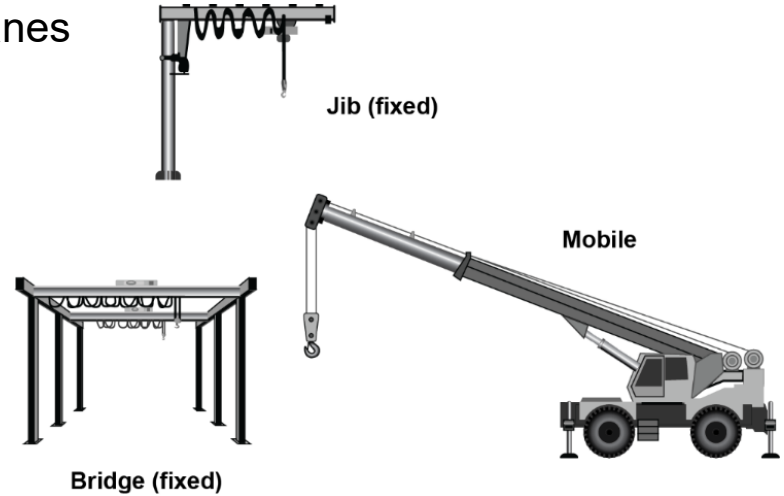
Dock equipment

- Dock levelers
- Door systems
- Wheel guides
- Bumpers
- Lighting
- Safety equipment



Product-handling equipment

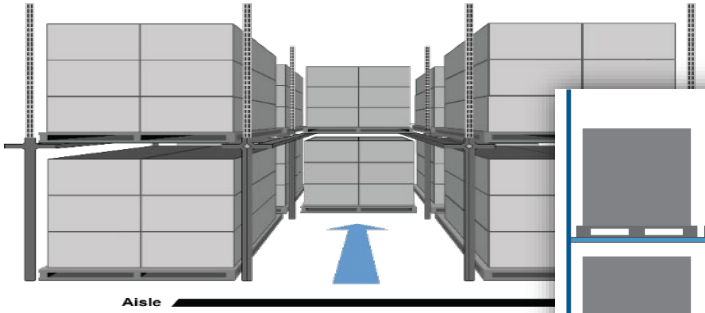
- Boom conveyors
- Forklifts
- Pallet trucks
- Cranes

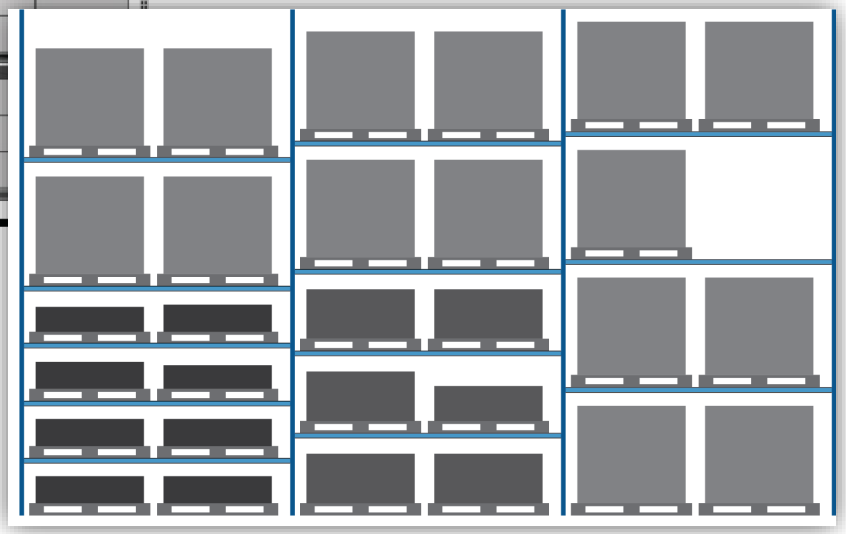


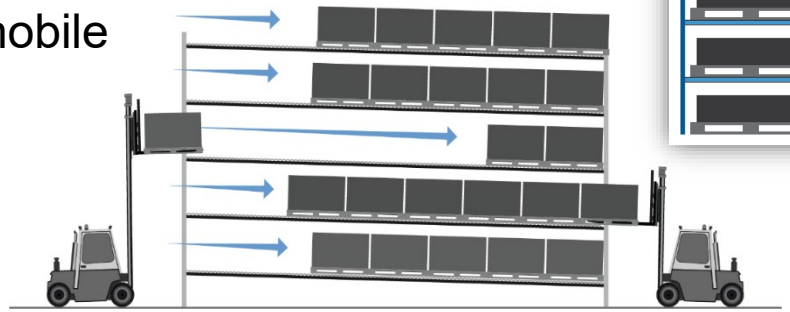
Use Storage Systems

Palleted Storage

- Block stacking
- Drive-in/drive-through racks
- Flow racks
- Adjustable pallet racks (APR)
- Powered mobile racks

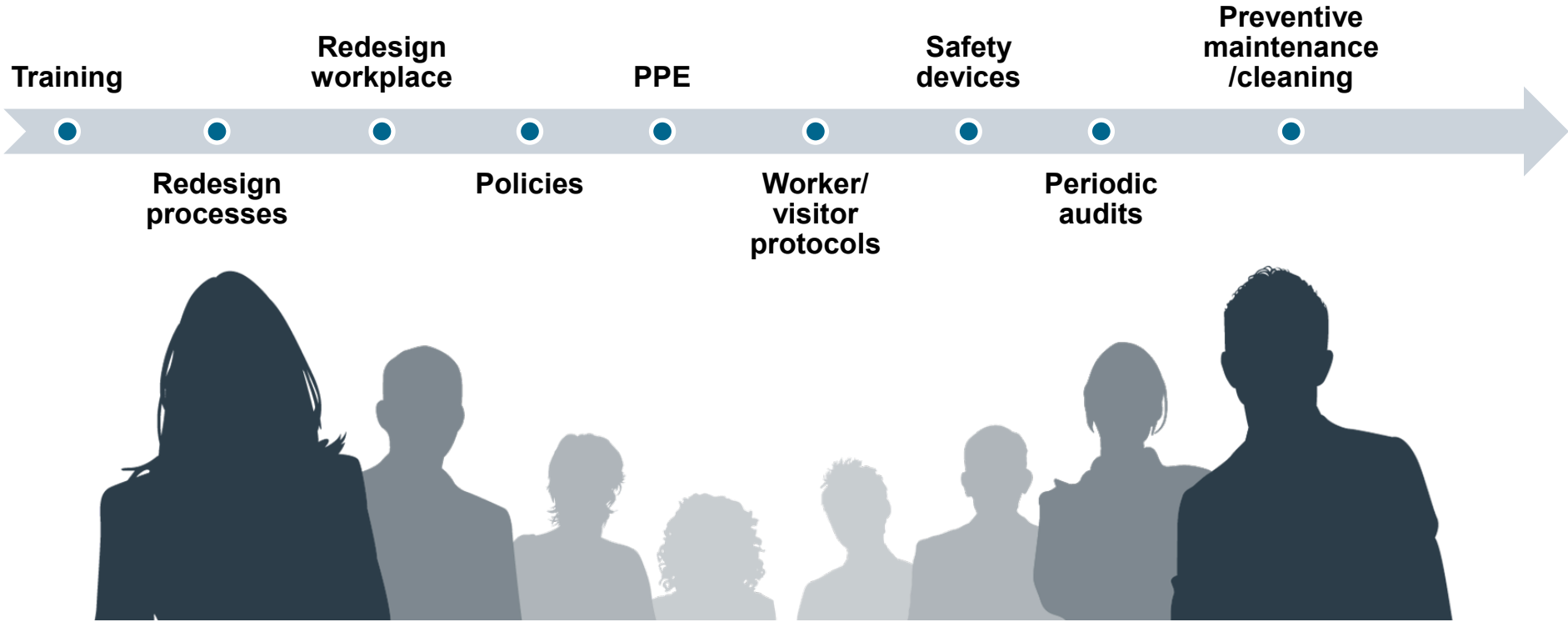






Consider Health, Safety, and Security

Warehouse Health and Safety Measures



Securing Warehouse Assets and Contents

Warehouse Loss Forms

- Damage and destruction of the facility/contents
- Gradual degradation of inventory shelf life
- Cyber theft and hacking
- Vandalism and theft by outsiders and insiders

CTPAT (U.S. Customs)

Security plan focus areas:

- Physical security
- Standard operating procedures
- Personnel
- Access controls
- Information technology
- Customer evaluation