

Warehousing, why?

- ✓ Market trend for many products is: **buying small lots of them in a quick way**
- ✓ But what about if your production factory is based in Europe and you want to serve America, China and New Zealand? And your overseas customers just need a small lot of products...
- ✓ In this case you need to **decentralise** your internal warehouses or even your factory

SCM and the need of Warehousing

Across the supply chain, the distribution of products, from raw materials, semi-finished products to finished products, uses **warehouses**

Truthfully, we will study that according to lean manufacturing theory every time we create a warehouse or inventory we create a so-called **waste**

However, it is physically impossible to transport, move and transform a product directly from raw materials to the customer without holding it at a specific place

Warehousing and Lean Manufacturing

- ✓ Warehousing is considered by Lean a big waste of money
- ✓ Lean basically tries to synchronise (JIT) the customer's demand and supply chain in the best way
- ✓ The shorter the supply chain lead time the less inventories and warehouse management we need



Warehousing, why?

- ✓ Even Toyota, the car manufacturer which invented the Toyota Production System and JIT principles, has got 8 manufacturing plants, 11 vehicle logistics centres and 14 part logistics centres across Europe
- ✓ Warehouses and inventories are a big waste, but if you want to **maintain a good and quick service to customers** you are supposed to deal with warehousing





What is **warehousing**?

- ✓ Part of a company logistical system that stores products at and between the point of origin and the point of consumption
- ✓ Warehousing is the integration of processes and activities involving **storage of goods on a large-scale in a methodical manner** and making them available conveniently when needed
- ✓ Warehousing implies **holding, preserving and controlling goods** from the time of their purchase or production until their actual use, sale or distribution
- ✓ **Warehousing (or Warehouse Management) can be seen as a relevant process (or function) of logistics, SCM and of course operations**

Warehousing

Why warehousing?

- ✓ Seasonal production
- ✓ Seasonal demand
- ✓ Mass production (Large-scale production)
- ✓ Quick supply
- ✓ Continuous processing system
- ✓ Price speculation



Warehousing

✓ Seasonal production

Some commodities such as agricultural products or some particular natural rubbers can be bought only in particular seasons; however their consumption or use takes place throughout the year

Therefore, there is a need for storing these commodities in advance when bought



Thailand – February, April

Italy – Warehouse Italy – Production over the year

Warehousing

✓ Seasonal demand

Certain products are usually demanded seasonally; for instance woolen garments in winters or motorbikes during spring and summer. The production of these goods takes place over the year to meet the seasonal demand. The demand peaks in that period , therefore there is a need to store these products in a warehouse to make them available at the right time



Warehousing

✓ **Mass production (Large-scale production)**

Although we will study that Mass production was invented by Ford we will see that in the US and in Europe has died out. However, in some particular markets it is alive and kicking. Manufacturers of standardised consumer goods such as smartphone accessories, cheap toys, etc. are used to producing products in huge quantities to get the benefits of large-scale production

The finished products, which are produced on a large scale, have to be stored in warehouses and big containers waiting for shipping (usually by container ships from the Far East to Europe)



Warehousing

✓ Quick supply

Some cheap industrial products such as tools, devices systems, personal protective equipment, etc. can also be bought in a unplanned way when they are needed.

If you are working on a building site and you need a hammer you would not wait for shipping from the Chinese factory !! You just go to the closest hardware store !! This implies several warehouses in between China and the hardware store



Warehousing

✓ Continuous processing system

Some particular industries manufacture chemicals using a continuous processing system which works 24 hours per day, 365 days per year. This particular kind of plant usually stops only for big failures or scheduled maintenance. Because the plant continuously produces, if the demand decreases they have to store the product



Warehousing

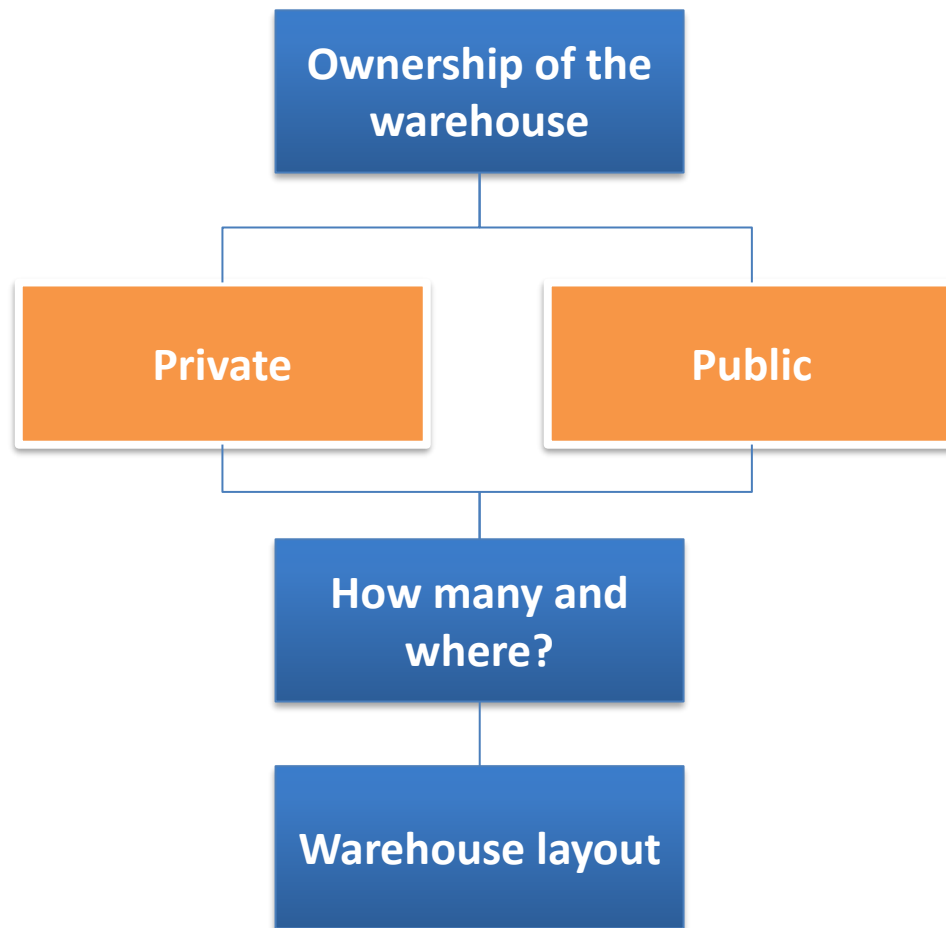
✓ **Price speculation**

Even if it is not properly related to Operations Management, some companies buy and store commodities such as steel, copper and other raw materials just as an investment.

In order to raise the price of the products, big players sometimes keep a high quantity of goods or commodities in the warehouse. According to the basic law of supply and demand, the scarcity of product may increase in price in the market and the other way around



The selection of warehouses in SCM policies



Ownership of the warehouse

- ✓ **Private Warehouses** - Warehouses directly owned and managed by the manufacturer or trader
- ✓ In the private warehouse usually companies store exclusively their own stock of products
- ✓ Private warehouses can be located either by the companies (e.g. factory warehouse) or decentralised (e.g. distribution centres, etc)
- ✓ The design and the facilities provided therein are according to the nature of products to be stored.

Ownership of the warehouse

- ✓ **Public Warehouses** - Warehouses run to store goods of many companies
- ✓ Anyone can store his goods in these warehouses on payment of rent
- ✓ These warehouses are already designed and built

Ownership of the warehouse

✓ Rationale for Public Warehousing:

- Limited capital investment
- Flexibility in your decisions

✓ Rationale for Private Warehousing:

- Better control of products and logistics activities
- High flexibility in volume

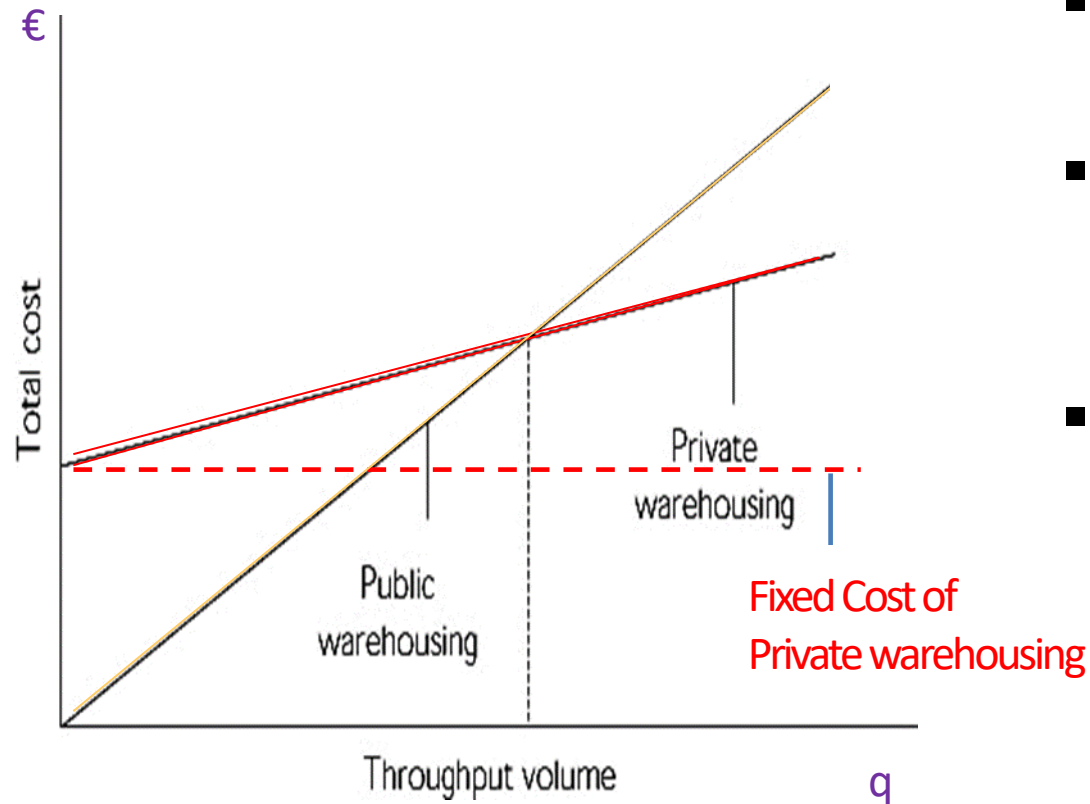


Product characteristics affecting warehouse decision

Characteristic	Private warehouse	Public warehouse
Throughput value	High	Low
Customers' demand	Stable	Fluctuating
Physical control	High	Low
Security control	High	Low
Customer service required	High	Low



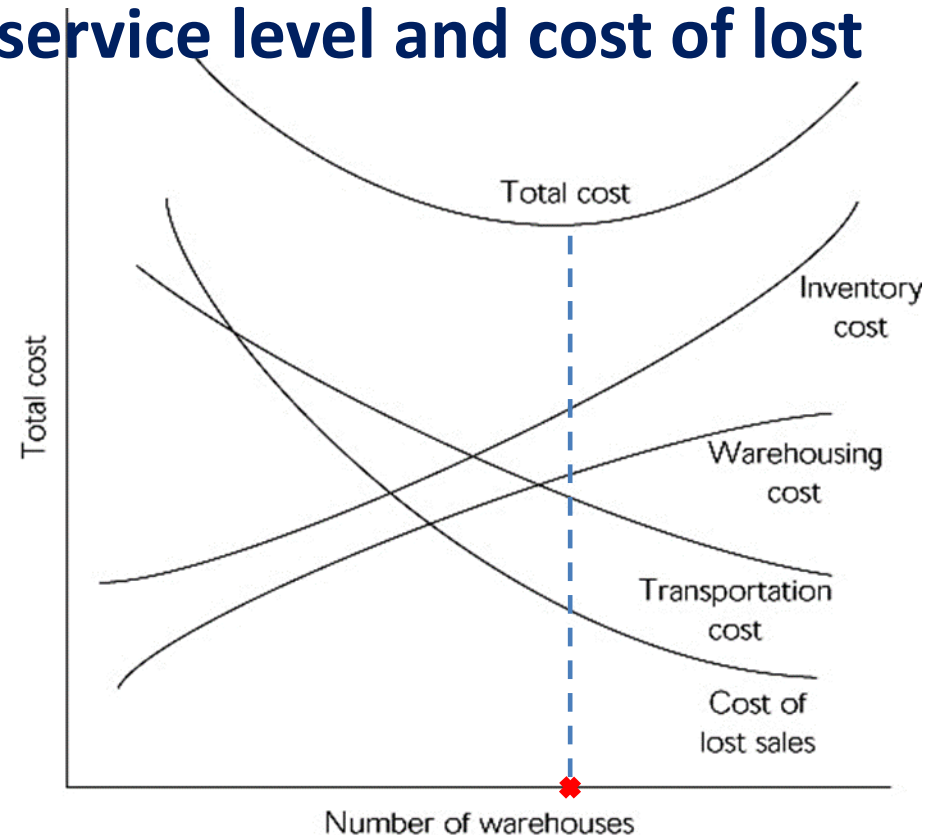
Costs affecting warehouse decision



- Public warehousing costs are usually variable
- Private warehousing costs have a higher fixed cost component
- In order to cover fixed cost of private warehousing we need high and constant volume

How many warehouses?

- ✓ It is not that simple to decide how many warehouses we have to use in our supply chain
- ✓ It depends on many costs such as inventory, transportation, customer service level and cost of lost sales, etc.



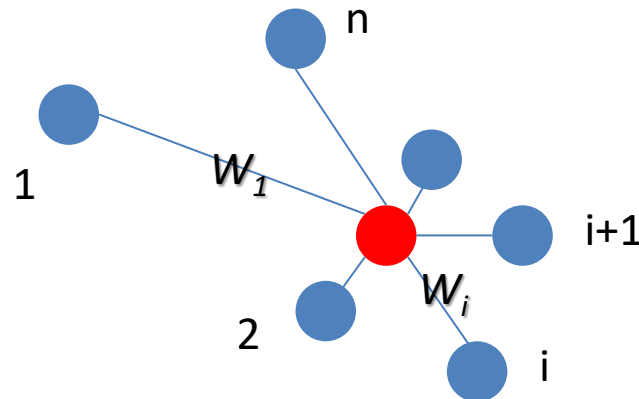
Strategic issues related to warehouse decentralisation

When we want to open a new decentralised warehouse we have to take into account also these strategic issues:

- ✓ Cost of distribution from the factory to the market(s)
- ✓ Easy transport in the form of rail, link roads and road vehicles
- ✓ Competitors have warehouses in the same area
- ✓ Labour costs in the area
- ✓ Industrial relations climate and labour productivity
- ✓ Individual company requirements and constraints
- ✓ Import duty and taxes
- ✓ Potential for later expansion
- ✓ Cost of land for the warehouse and other costs
- ✓ Possibility of change in the use of the facility at a later date

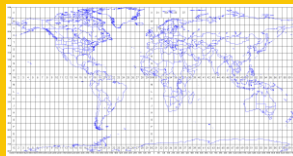
Where to build a new warehouse – the Centre of gravity

- ✓ When cost of distribution and transport are prevalent, we can use the **centre of gravity methodology** for identifying the location of our warehouse
- ✓ The methodology minimises transportation cost between a centre of gravity (example a distribution centre) and some points of destination which have to be served (example wholesalers or retailers) by the centre



Where to build a new warehouse – the Centre of gravity

- ✓ Place locations to be served on a map with grid coordinates



- ✓ Grid has arbitrary origin and scale
- ✓ Maintains relative distances
- ✓ Calculate X and Y coordinates for the centre of gravity using the formulas:

$$C_x = \frac{\sum_i d_{ix} \cdot W_i}{\sum_i W_i}$$

$$C_y = \frac{\sum_i d_{iy} \cdot W_i}{\sum_i W_i}$$

Where to build a new warehouse – the Centre of gravity

- ✓ C_x and C_y are the coordinates of the centre of gravity
- ✓ d_{ix} is the x coordinate of location i
- ✓ d_{iy} is the y coordinate of location i
- ✓ W_i is the weight given to the distance to or from location i (e.g. volume of goods moved to or from location i, transport cost to or from location i, etc.)

$$C_x = \frac{\sum_i d_{ix} \cdot W_i}{\sum_i W_i}$$

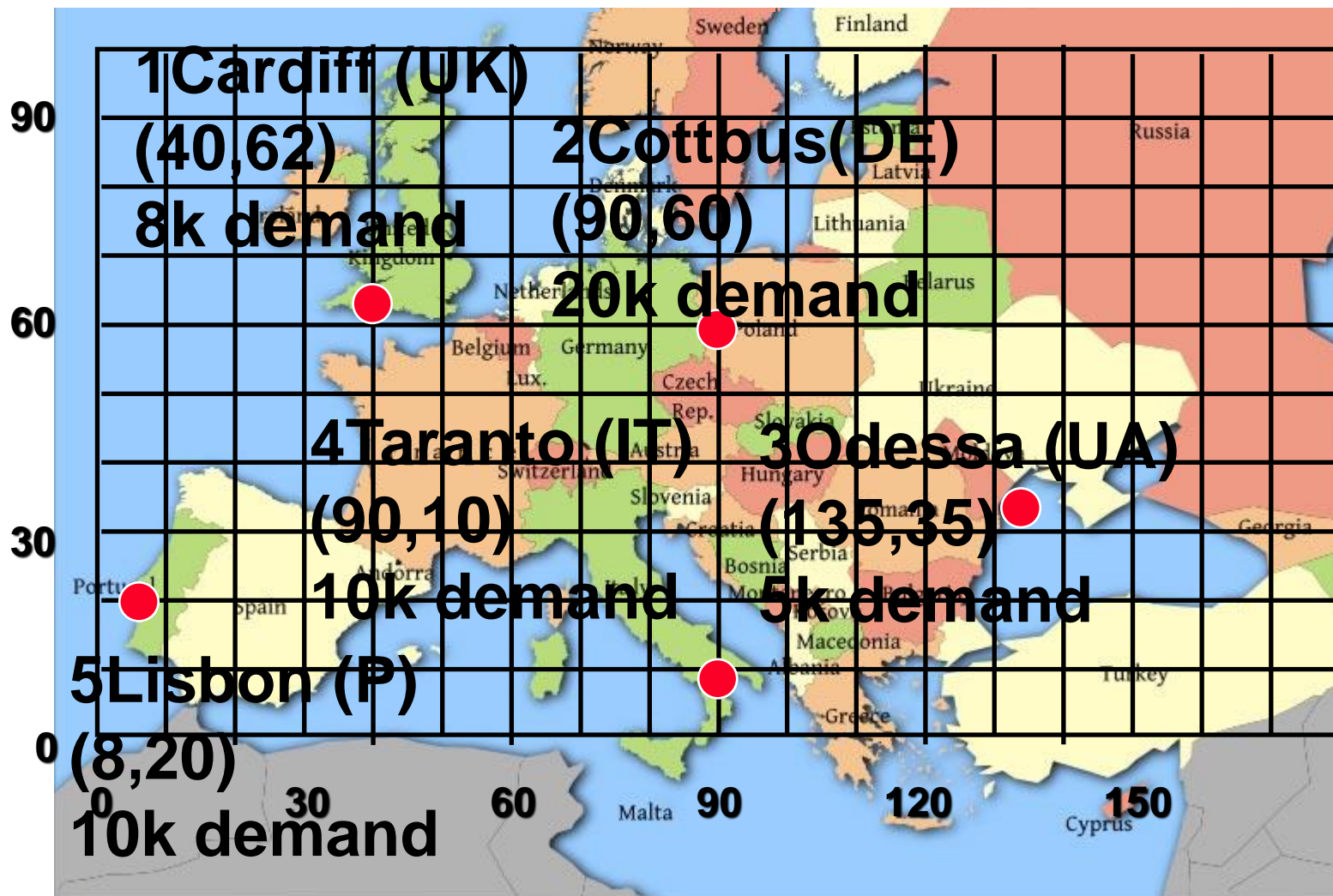
$$C_y = \frac{\sum_i d_{iy} \cdot W_i}{\sum_i W_i}$$

Centre of gravity – Case study

ACME would like to distribute its new glue to 5 dealers around Europe in order to better service all the European countries. Indeed, ACME is an American manufacturer and every time they have to ship some products to Europe it takes 20 days. Besides the vessel just accepts containers, while the European customers usually buy small quantities of mixed products. This is the reason why they have decided to use a distribution centre and 5 dealers. The European dealers are located in Cardiff (8,000 Kg/year), Cottbus (20,000 Kg/year), Odessa (5,000 Kg/year), Taranto (10,000 Kg/year) and Lisbon (10,000 Kg/year). ACME wants to evaluate where to build the distribution centre

Solution:

1. Place existing locations on a European coordinate grid
2. Grid has arbitrary origin and scale
3. It is fundamental to maintain relative distances among the 5 dealers
4. Find X & Y coordinates for each location
5. In this case the shipped Kg/year represents the Weight (W)



Centre of gravity – Solution

i	d_{ix}	d_{iy}	W_i
1	40	62	8K
2	90	60	20K
3	135	35	5K
4	90	10	10K
5	8	20	10K

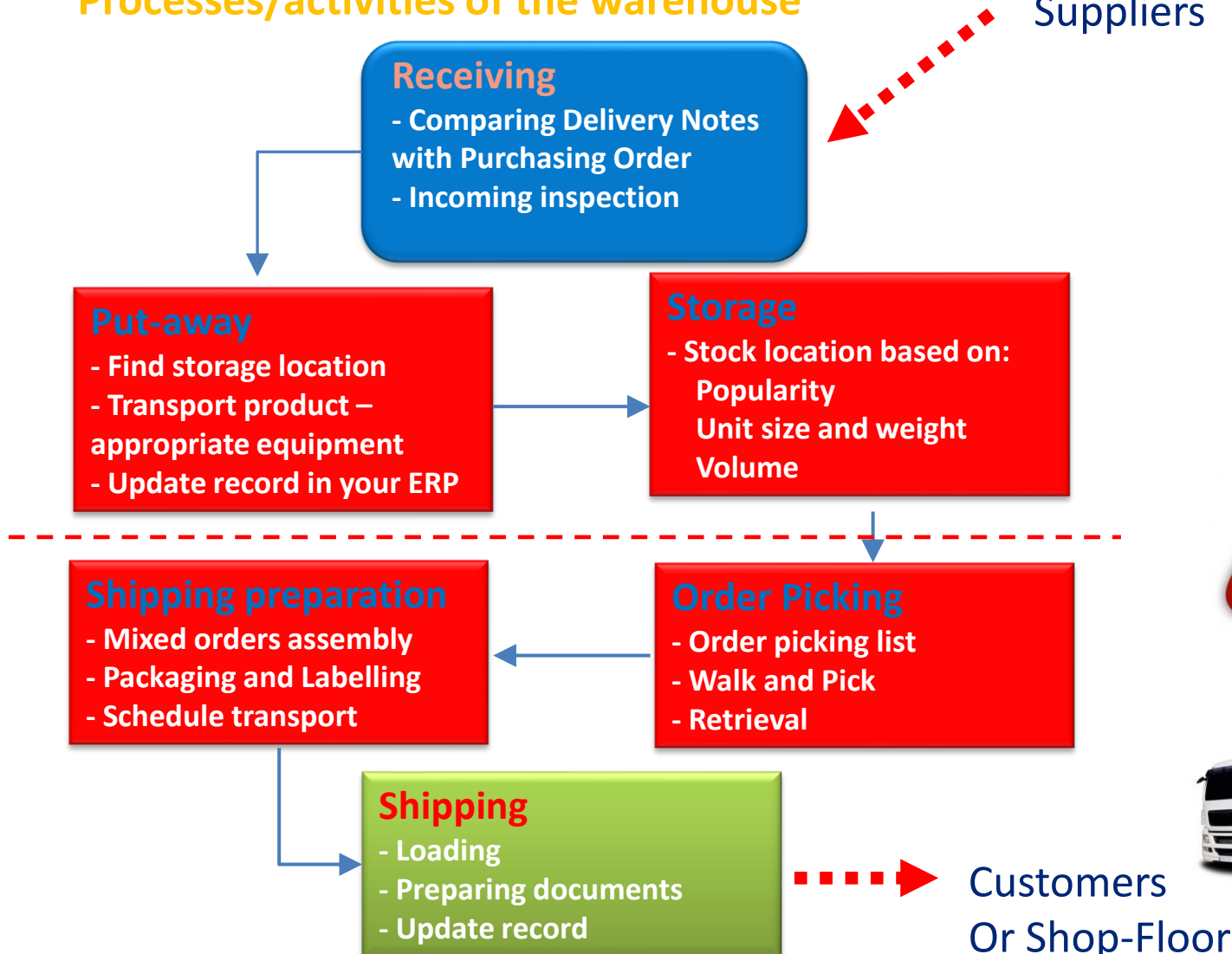
$$C_x = \frac{(40)(8) + (90)(20) + (135)(5) + (90)(10) + (8)(10)}{8+20+5+10+10} \approx 71$$

$$C_y = \frac{(62)(8) + (60)(20) + (35)(5) + (10)(10) + (20)(10)}{8+20+5+10+10} \approx 41$$

(71;41) It seems we had better build our centre of gravity nearby Switzerland and Austrian border

What happens within a warehouse?

Processes/activities of the warehouse



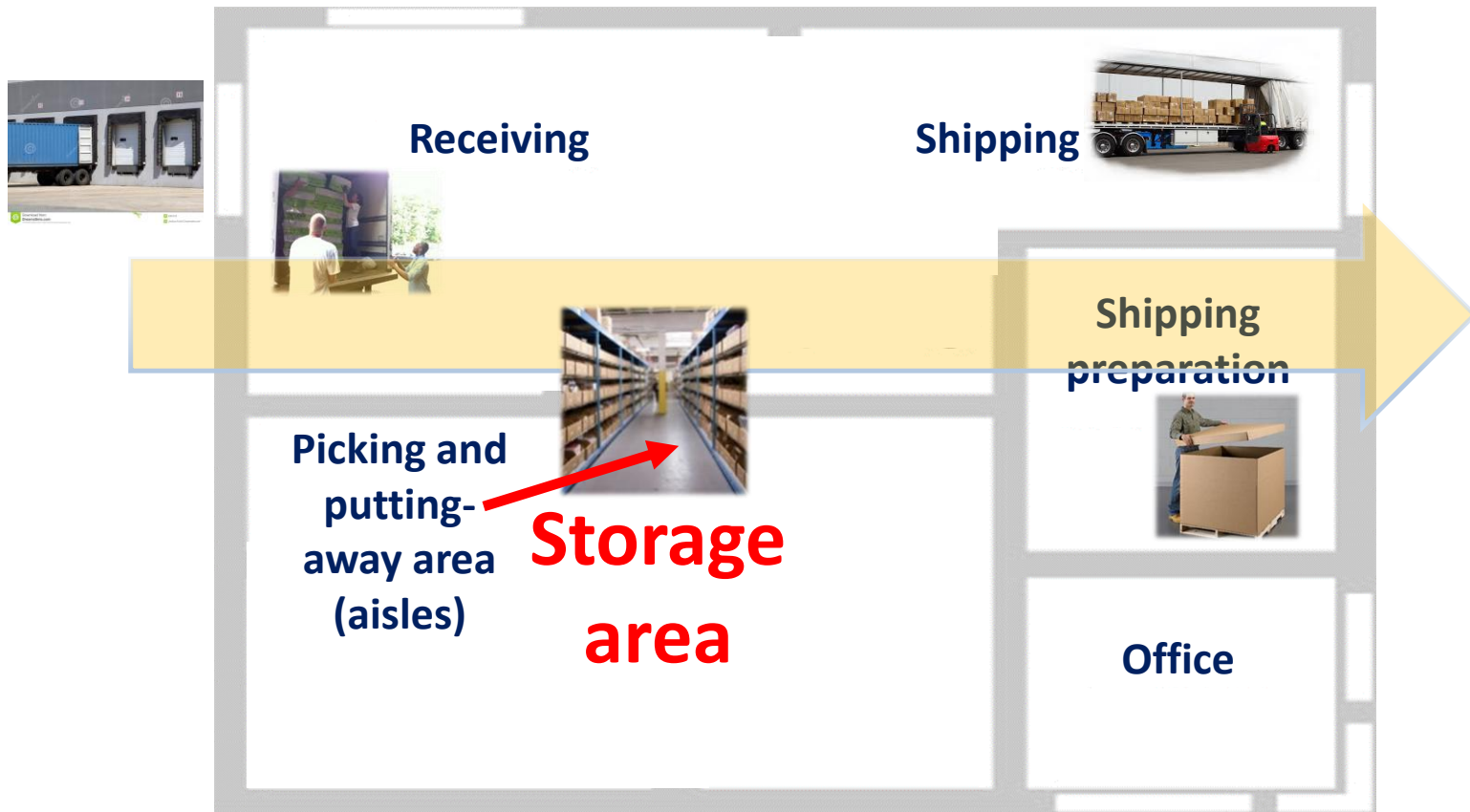
Warehouse layout and its design

When we design the warehouse layout we have to take into account room for:

- ✓ truckload and unload activities
- ✓ order-picking and putting-away activities (aisles)
- ✓ **storage area or space (simply referred sometimes as warehouse)**
- ✓ shipping preparation
- ✓ offices and miscellaneous spaces



Example of warehouse layout



Warehouse layout and its design

According to Lean – Toyota Production System theory you have to avoid wastes such as transportations and people's motions. At the same time you have to take care of safety. Therefore the best warehouse layout:

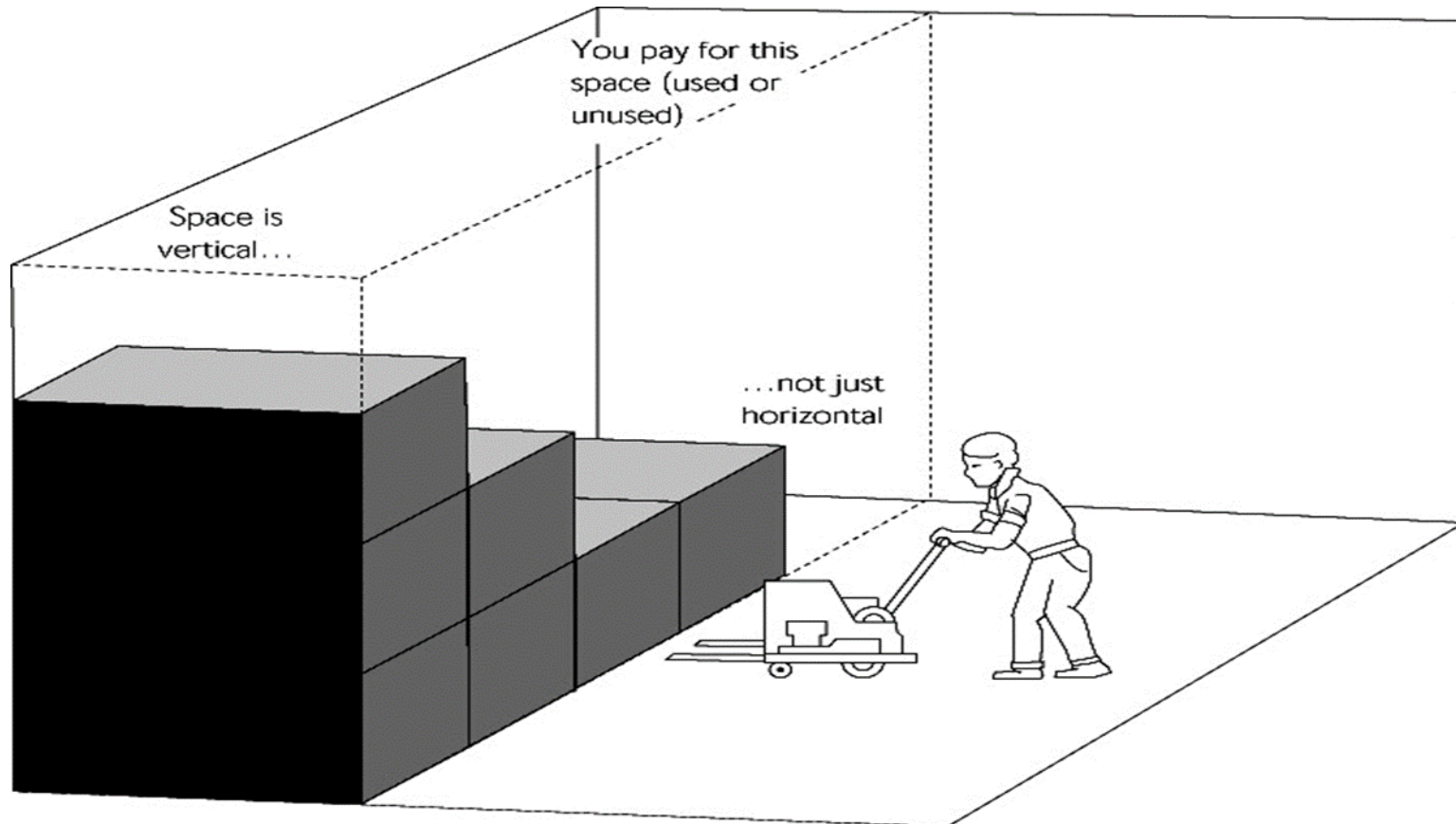
- ✓ has to be with just a ground floor
- ✓ products are transported from receiving to shipping in a straight line
- ✓ use the more appropriate material-handling equipment
- ✓ use an effective and efficient storage system
- ✓ minimise aisles space preferring straight lines (avoid twisted and bent ways)
- ✓ accurately separate material-handling equipment traffic from workers pathway



- ✓ **use maximum height of the warehouse**



Using full building height



Material handling and Storage Systems for warehousing

Material handling is a transportation of items that takes place within the confines of a specific building such as a warehouse, an industrial plant, a wholesaler or a transportation company (e.g. ports and airports)

A **Storage System** allows materials to be stored over the course of time in a specific storage area made up of **storage bins or locations**

Stock or stored materials can be:

- ✓ raw materials
- ✓ semi-finished supplied parts
- ✓ Work-In-Process (WIP)
- ✓ maintenance spare parts and tooling
- ✓ scrap and rework (non conformance products)
- ✓ office supplies
- ✓ Etc.



Each of these items is typically stored under different conditions and controls



Storage Systems, basics

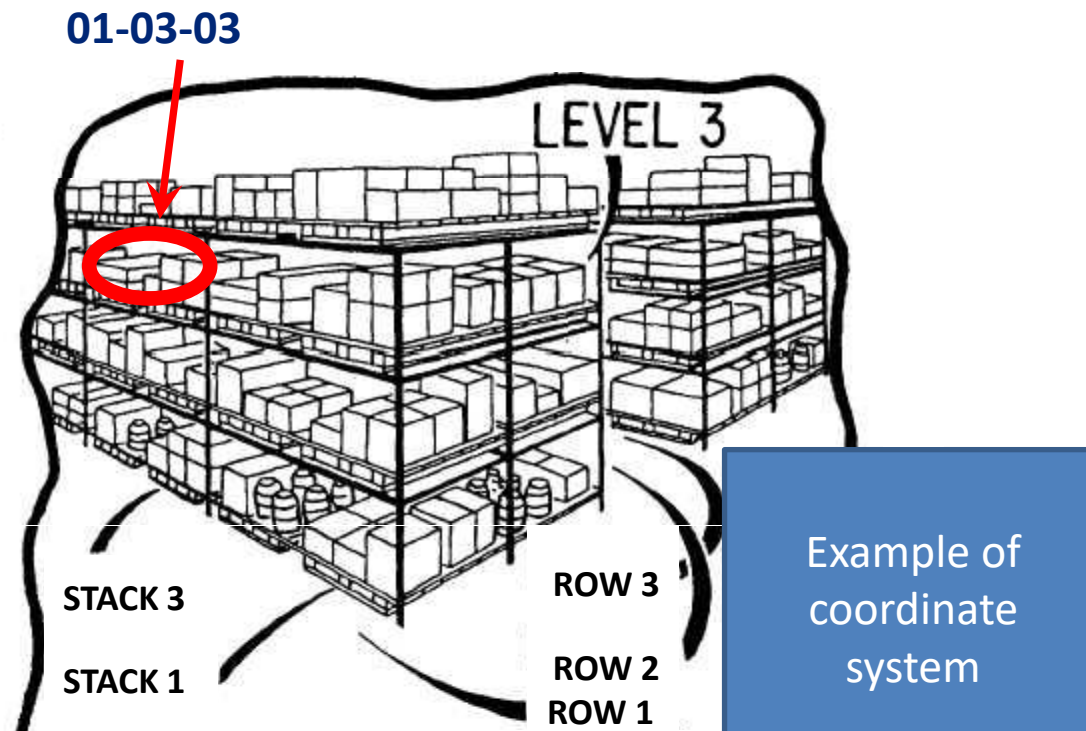
- ✓ A **Storage area** is made up of several **storage spaces** or slots or locations
- ✓ **Storage spaces** are usually named as **Storage Bins** (IT term)
- ✓ The storage bin is the smallest available **unit of space** which you assign to a storage space or location
- ✓ A **Stock-Keeping Unit (SKU)** refers to a **specific item** stored in a specific location (single or with others) within a bin or space. It is intended as the most disaggregated level when dealing with inventory. In retail a SKU is associated with any purchasable item in a store or catalogue

Material handling and Storage Systems, basics



- ✓ Depending on your business, within a storage bin you can have a single SKU (e.g. retail) or a **pallet** made up of several SKUs or a box. SKUs usually have got an assigned code number (e.g. bar code).
- ✓ From an IT and data management point of view, the storage bin describes the position in the storage area where items are or can be stored
- ✓ The address of a storage bin is usually derived from a **coordinate system**; a storage bin is often referred to as a **coordinate**





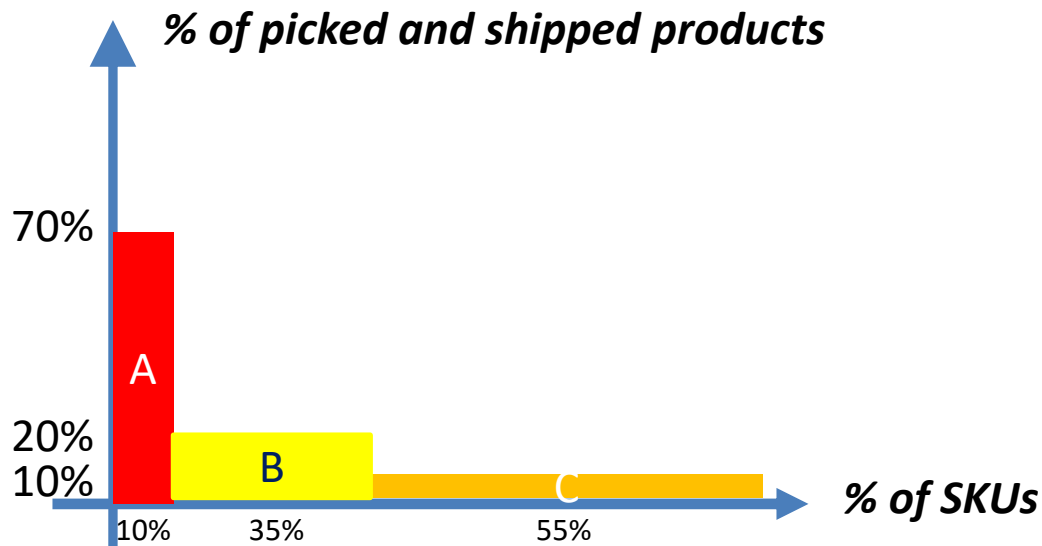
Typical coordinates are: **row, stack and level**. 01-03-03 for example refers to a storage bin in row 1, stack 3, and level 3 or simply **aisle and location** (**two-dimensional coordinates**)

Material handling within the warehouse, basics



The majority of material handling activities are linked to the picking and putting-away areas. Using **ABC - Pareto analysis** we can classify items by **popularity** or **moving frequency** or **turnover**

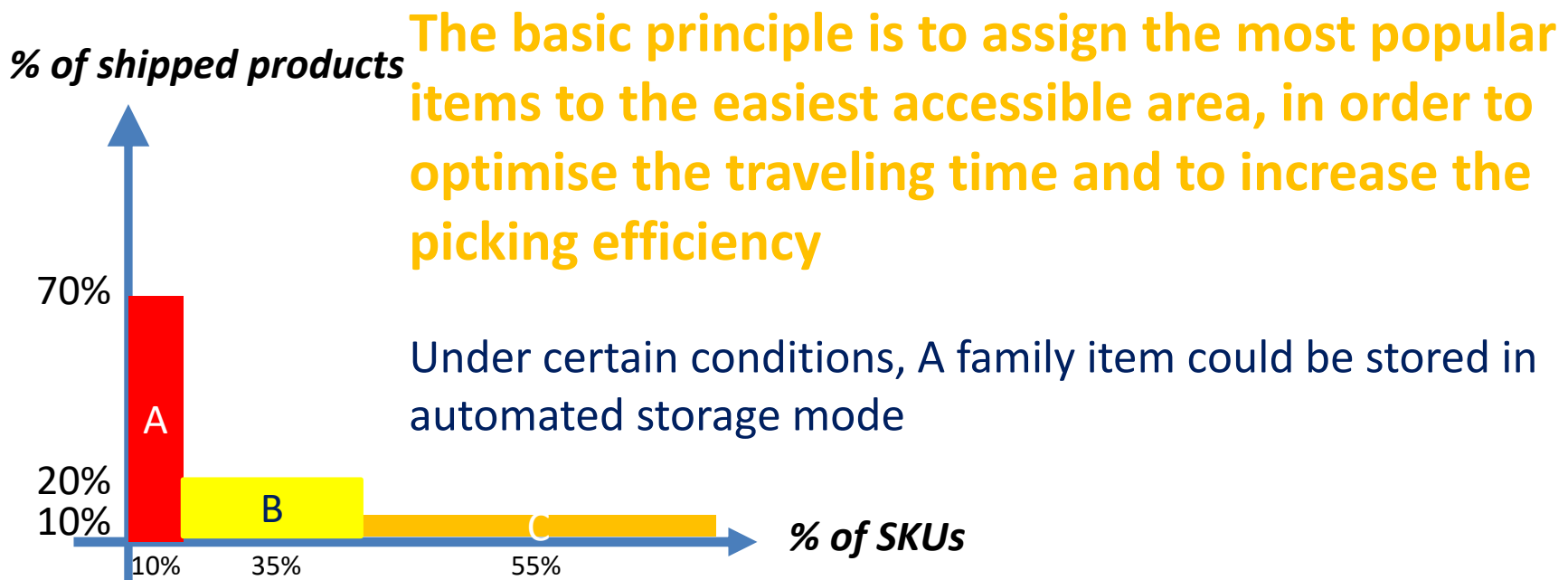
Popularity is measured by number of **SKUs (Stock-Keeping Units)** or items picked in a certain period (one year, one month, one day) and shipped or moved





Material handling within the warehouse

In this example, the popularity distribution shows that 10 percent of items (family A) represents 70 percent of the picking activity (**fast-moving**), the 35 percent of items (family B) represents 20 percent of the picking activity and the 55 percent represents just 10 percent of the picked products (**slow-moving**)





Material handling within the warehouse

Slow or Fast-moving product is a matter of **INVENTORY TURNOVER**. We will discuss this indicator in the next module

Storage within the warehouse



We can organise and group storage bins or locations depending on criteria such as:

- ✓ Type of product or family
- ✓ Moving frequency
- ✓ Item weight
- ✓ Item height
- ✓ Etc.



Material handling and Storage Systems, basics



- ✓ **Packaging Management System** is a managerial and technical combination of many operations activities in order to achieve goals such as:
 - Quality and preservation of the product
 - Marketing
 - Cost reduction during transportation, material handling and storage activities
 - Safety and Environmental compliance
 - Etc.
- ✓ Packaging is classified as:
 - **Primary Packaging**, packaging that surrounds a product when sold to a final consumer. Primary packaging is in direct contact with the product which adds complexity in terms of image, quality and safety requirements
 - **Secondary or grouped packaging** is that which is used to put together a number of primary items or SKUs for ease of handling and storing. Typically this packaging can be cardboard boxes or plastic bins, or shrink-wrapped plastic packs
 - **Tertiary or transport packaging** is that which is used to facilitate transport, handling and storage of a number of secondary packs in order to prevent damage and ease activities. Typically this packaging can be **pallets** bound by plastic or metal straps with stretch-wrap plastic film or shrink-wrapped plastic hoods or **big bags** (for chemical and food industry)

Material handling and Storage Systems, basics



Primary secondary and tertiary packaging are typically used all together when we want to reach the final consumer giving him/her a final product



For typical industrial or trading scopes (e.g. raw materials and semi finished products) often we can use secondary and tertiary packaging or just tertiary packaging

Material handling and Storage Systems, Industrial Packaging



Plastic or metal bins



Standard metallic bins



Big bags



Big bag + pallet



Cardboard box + pallet



Plastic or metal box pallet

Pallet collar



Plastic pallet



Standard pallet
Euro 1200x800



Carton pallet



Pallet strapping



Material handling and Storage Systems



Storage systems can be classified into:

- ✓ **Manual or conventional** storage systems



- ✓ **Automated Storage and Retrieval (AS/RS) Systems**

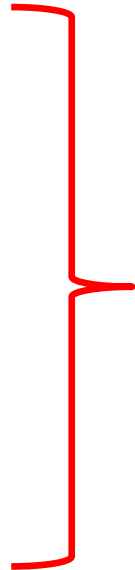




Conventional Storage Systems

The most important Conventional Storage systems for industrial and trading operations:

- ✓ Bulk Stacking
- ✓ Bulk Rack
- ✓ Drive-Through
- ✓ Drive-In
- ✓ Flow-Through
- ✓ Push-Back
- ✓ Cantilever



Bulk Stacking Storage System

Pros

- ✓ The **cheapest and simplest** way of storing pallets. No investment in racks and shelves
- ✓ Good for multiple pallets of **like product**.
- ✓ Good for **shipping lines of fast-moving products** going towards a single destination (e.g. train, vessel, lorry)

Cons

- ✓ Fork-lift could directly damage items. Stacked Pallets could collapse
- ✓ Maximum storage height of 2 or 3 pallets. Low use of warehouse volume (not optimised for space), **low/very low storage density**
- ✓ Not recommended for single/small case picking



Pallets are stacked
directly on the ground

Bulk Rack Storage System

It can be considered as an evolution of the Bulk system. We have to build a rack systems using shelves and we can stack SKUs in specific storage locations. So we can create a real three dimensions warehouse (coordinate: row, stack and level, or aisle and location)

Pros

- ✓ Very flexible. Different kinds of SKUs
- ✓ Good for multiple stacked pallets with more levels
- ✓ Allows to easily reach every bin (especially with just two rows or two stacks)



Cons

- ✓ Low medium storage density (usually it takes two aisles each one or two rows)
- ✓ Maximum storage height of 4 - 6 levels (it depends on the weight). Medium use of warehouse volume

Storage density can be increased using a **mobile rack system** ([watch it on youtube](#))

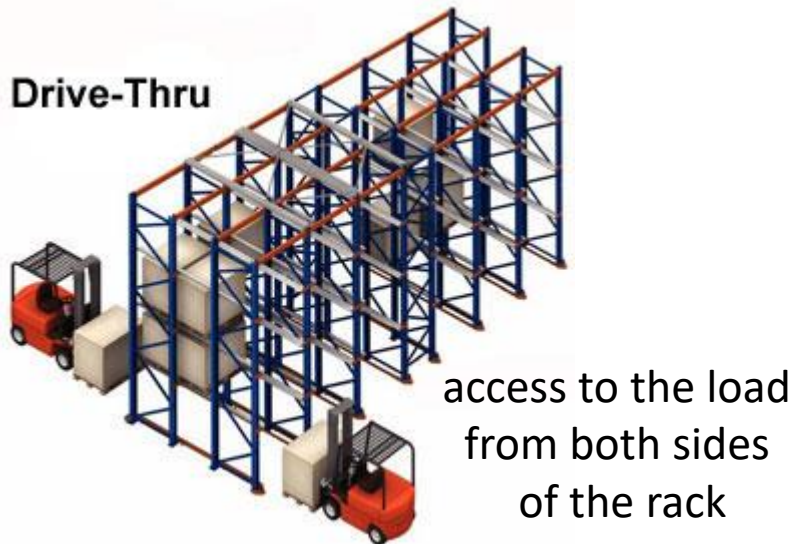
Drive-Through Storage System

Pros

- ✓ Cost-effective solution ideal for **homogeneous products** with **medium-high levels of turnover**
- ✓ Allows to place pallets on rails, providing **medium-high density storage**
- ✓ Drive-Thru allows **FIFO (First-In-First-Out)** management

Cons

- ✓ Fork-lift could damage items and racks



Drive-In Storage System (watch it [on youtube](#))

Pros

- ✓ Cost-effective solution ideal for **homogeneous products** with **low levels of turnover**, often combined with bulk lines for shipping
- ✓ Provides **the highest use of available space** in terms of both area and height

Cons

- ✓ Drive-In allows only **LIFO (Last-In-First-Out)** management (not recommended for products which are time or date sensitive)
- ✓ Typical for alike products
- ✓ Real chance of damaging racks and items



only one
access aisle

rini@univr.it



Flow-Through Storage System ([Watch it on youtube](#))

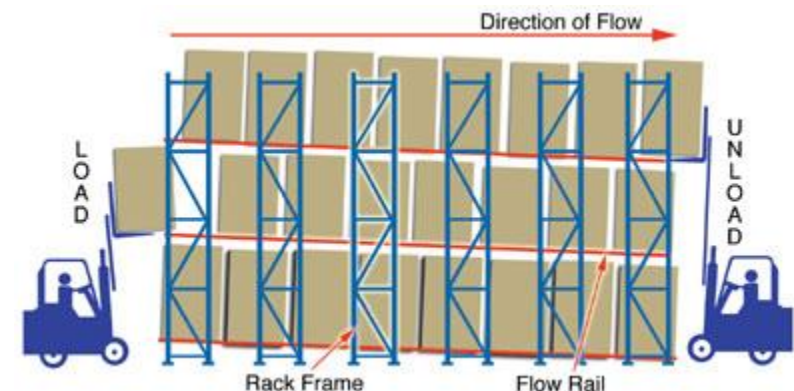
Similar to the Drive-Through rack, but Flow-Through **uses skate wheels and natural gravity**. Items are loaded in one end and gently slide down to the other end to be unloaded

Pros

- ✓ **The best for FIFO management**
- ✓ Very efficient for traffic and movement management. Pallets are loaded from a **replenishment aisle** and picked from an **order-picking aisle**. This defines traffic patterns and separates also workers from lift trucks

Cons

- ✓ More expensive than the Drive systems (it needs also maintenance)
- ✓ Needs good quality pallets (otherwise they can get stuck in the system)
- ✓ Capacity is lost due to the slope of the rack



Push-Back Storage System ([watch it on youtube](#))

This system loads pallets in sequence onto wheeled carts or carriages. Pallets are pushed back along in sequence. As a new pallet is loaded, the previous pallets are 'pushed back', hence the name. Once you remove the front pallet, the pallets behind it will slide forward

Pros

- ✓ Time-efficient system
- ✓ It reduces aisles need and room (medium - high density storage)
- ✓ Can be used by a variety of lift trucks

Cons

- ✓ A little more expensive than the Drive systems (it needs also maintenance)
- ✓ Push-back allows only LIFO (Last-In-First-Out) management





Conventional Storage System characteristics

	Storage density	Putting-away/picking speed	Manag.	Overall Cost
Bulk Stacking	Very low	Medium	All kinds	Very cheap
Bulk Rack	Low-Medium	Medium-High	All kinds	Cheap
Drive Through	Medium	Medium	FIFO	Medium
Drive In	High	Low	LIFO	Medium
Flow Through	Medium	Medium-High	FIFO	Expensive
Push back	Medium-High	Medium-High	LIFO	Expensive

Cantilever rack is similar to typical front loading shelf when you are within a supermarket or better in a hardware store. It separates small loads or loose items such as sheets, bar stocks, pipes or long flexible materials of any kind

Pros

- ✓ Time-efficient system
- ✓ 'Visual' system
- ✓ Cost effective system for small loads of different SKUs

Cons

- ✓ Not for products over pallets or in boxes
- ✓ Not for high quantities of items
- ✓ Provides medium-low density storage



INDUSTRY 4.0 AND SMART PICKING / KITTING:

Different ways of picking, from traditional scanners to Augmented Reality (AR)



Traditional with scanner



Pick-To-Voice

PICKING LIST

		Product	Price	Qty	
		Simple Product 19	€8.50	1	<input type="checkbox"/>
		Simple Product 50	€8.50	5	<input type="checkbox"/>
		Simple Product 20	€8.50	3	<input type="checkbox"/>
		Simple Product 51	€8.50	1	<input type="checkbox"/>
		Simple Product 21	€8.50	1	<input type="checkbox"/>
		Simple Product 52	€8.50	1	<input type="checkbox"/>



Pick-To-Light



Augmented Reality



<https://www.youtube.com/watch?v=5E6qambiCo0>

INDUSTRY 4.0 AND SMART PICKING / KITTING:

Different ways of picking, from traditional scanners to **Augmented Reality (AR)**

Pick-To-Voice	Pick-To-Light	AR
Operators have always their hands free. They give a vocal confirmation	Operators have to use their hands for confirmations	Operators have always their hands free. They give a vocal confirmation and/or they can use the equipment
Headset and wi-fi	You have to modify shelves with led and displays	Wearable smart glasses and wi-fi
Operators can quickly move anywhere in the warehouse	Only one operator at a time in the area	Operators can quickly move anywhere in the warehouse
Not suitable for noisy environment – Psychologically annoying	Not the fastest. Better for ‘sequencing’ in the same aisle (e.g. kitting) rather than picking around	Psychologically annoying

Automated Storage and Retrieval System (AS/RS)



- ✓ AS/RS is a storage system used in manufacturing plants, distribution centres and warehouses in general. It is not necessarily large; it can be 'simply' a order-picking machine operating in a small storage structure like a laboratory or a pharmacy
- ✓ AS/RS consists of **automatic and computerised machines** that move up and down, left and right, one or multiple parallel storage aisles, storing and retrieving items
- ✓ AS/RS needs **a relevant up-front investment** and ongoing costs for maintenance and updating of various subsystems
- ✓ We have to be very careful when we come to AS/RS investments, especially in manufacturing environment. Payback could be a long and difficult journey....
([Watch it on youtube](#))



When AS/RS implementation can be considered

- ✓ The number of SKUs is very popular and not large and weighty
- ✓ Very strict item tracking is necessary (e.g. drugs, medical devices, etc.)
- ✓ Critical inventory level
- ✓ Need for high storage density (aisles are very narrow and you use an automatic mini-load system)
- ✓ No limit on building height
- ✓ high labour cost using a conventional system
- ✓ Storage conditions are dangerous for health and safety (e.g. cold storage environment, refrigerating rooms)
- ✓ Joint storage of parts and tools
- ✓ Need for fast and accurate kits of different items
- ✓ Technical skills are available

Material handling equipment for warehousing

There are many different kinds of handling equipment, we will see just the most used ones within typical manufacturing warehouses

- ✓ Counterbalance Forklift Trucks (diesel or gas engine)
- ✓ Counterbalance Forklift Trucks (electric engine)
- ✓ Reach Trucks
- ✓ Hand Pallet Trucks

Material handling equipment for warehousing

Counterbalance Forklift Trucks (diesel or gas engine)

- ✓ Typical for **external use**
- ✓ Used for lifting **heavier loads** (including shipping containers)
- ✓ They need more maintenance than electric ones



Material handling equipment for warehousing

Counterbalance Forklift Trucks (electric engine)

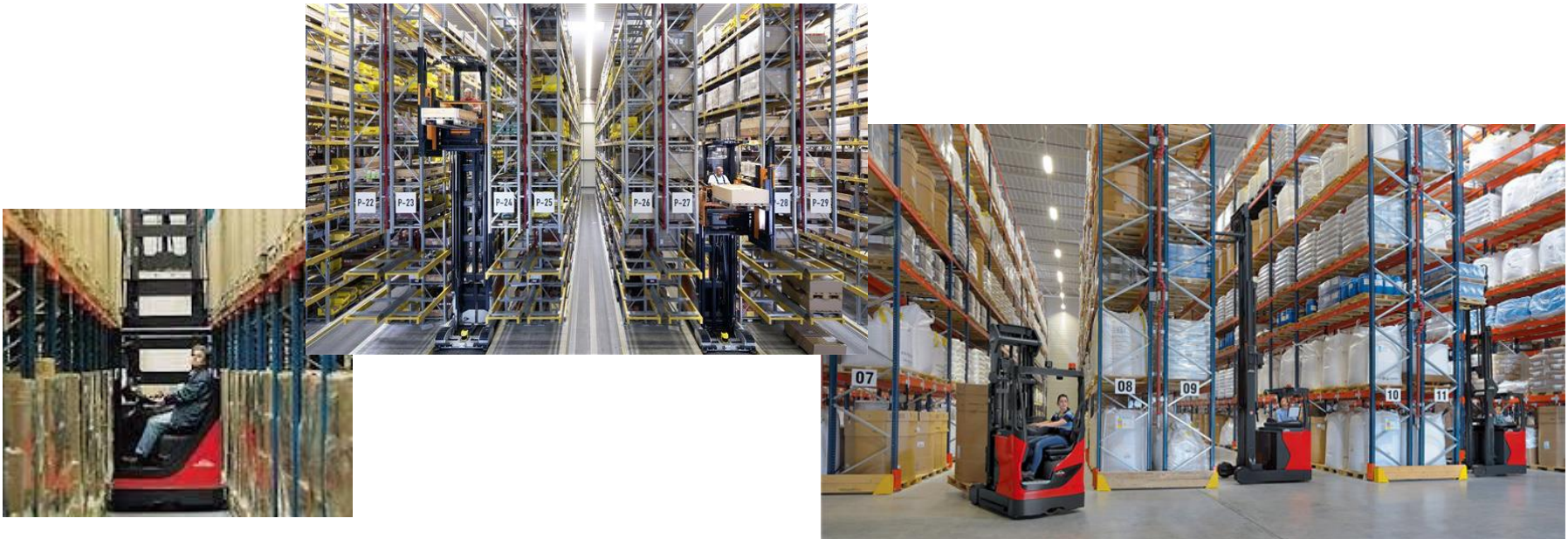
- ✓ The most used ones for many handling activities, very flexible
- ✓ Good lifting capacity (up to 3000-3500 kg)
- ✓ Clean, silent, compact
- ✓ Electricity costs less than diesel and gas
- ✓ Unavailable for use while the battery is being recharged
- ✓ Needs a good floor surface to work



Material handling equipment for warehousing

Reach Trucks (electric engine)

- ✓ Designed predominantly for internal storage activities
- ✓ Good lifting capacity (1200-3000 kg)
- ✓ Excellent maneuverability and high lift height (up to 15 meters)
- ✓ **Narrow Aisle Truck** version with wire or rail guidance



Material handling equipment for warehousing

Hand Pallet Trucks

- ✓ Designed predominantly for horizontal activities (transport, order picking, loading/unloading)
- ✓ Medium lifting capacity (750-2500 kg)
- ✓ Ease of use (No qualification)
- ✓ Very low maintenance



Warehouse, Material Handling – Some KPIs

- ✓ Putaway cycle time
- ✓ Picking cycle time
- ✓ Inventory storage per square (or cubic) meter (storage density)
- ✓ Average days-on-hand
- ✓ Percentage of compliant picked lines
- ✓ Percentage of compliant shipments
- ✓ Time from picked order to shipping
- ✓ Overall vehicle travel distance or time
- ✓ Number of loads completed over a period of time by all of the material handling vehicles
- ✓ Volume received per man-hour
- ✓ Accurate receipts
- ✓ Labour hours consumed per order
- ✓ Overall percentage of loaded vehicle time
- ✓ Etc.