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CBHE ERASMUS+ 2018: Crisis and Risk Engineering for Transport Services

# Contemporary issues in global warehousing

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# Agenda



1. Trends and challenges in warehousing in 2022
2. Frames of modern warehousing technology
3. Information systems in warehousing and WAP
4. Teaching warehousing in WUT

# 1. Trends and challenges in warehousing in 2022

# CRENG objectives vs warehousing?



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Warehouses **buffer, consolidate, deconsolidate, transform** and **direct** material flows

Logistics services costs can be 8 % of sales, where about:

- 3,3 % - transportation costs
- **4,5 % - warehousing and inventory carrying**

Warehousing costs range from 10 % to 50 % of total logistics costs:

- **more than 54 % is labour cost and 27 % is transportation equipment.**
- less than 13,7 % of total cost results from inventory keeping and storage.
- Global warehousing market reached a value of \$ 451,9 Billion in 2021 (anticipated to reach \$ 605,6 Billion by 2027) (*IMARC Group*)

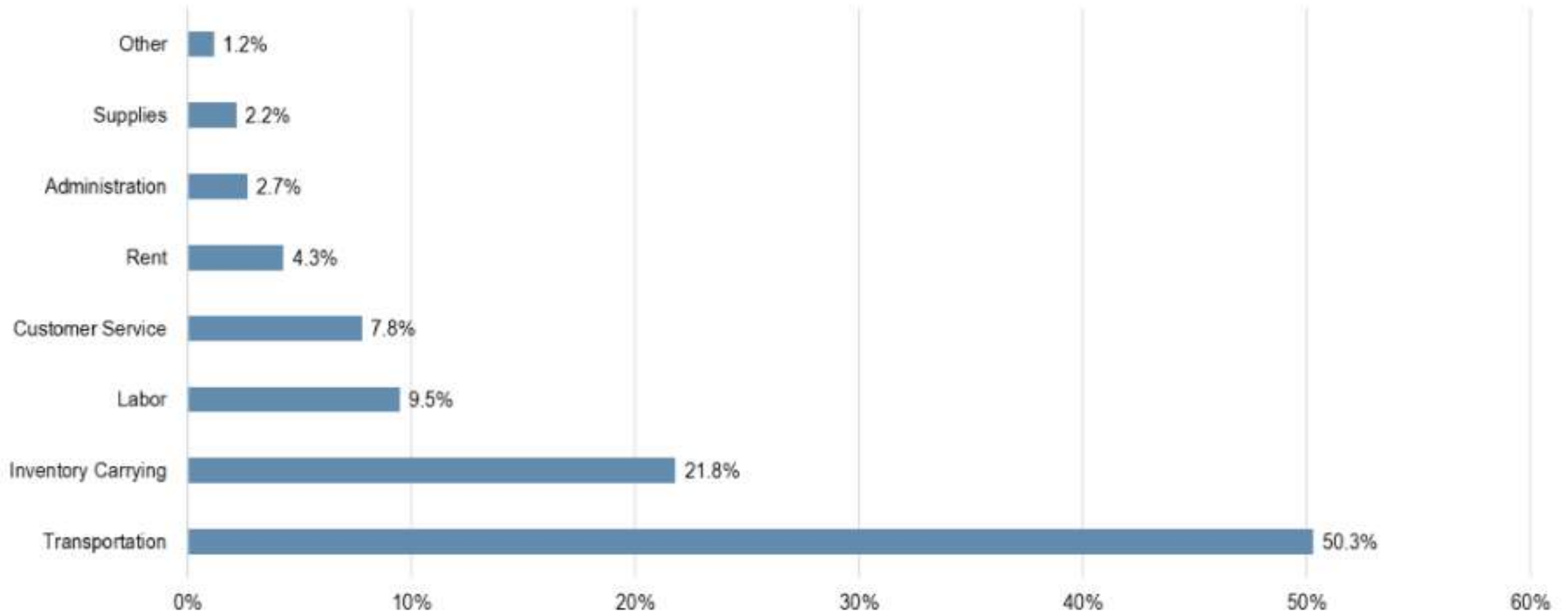
## **C**risis and **R**isks **E**ngineering **for Transport Services**

- Ensure **sustainability** of UA, AZ, TM transport systems and integration with **global transportation network**
- Create environment for **education** of skilled specialists in CRENG

# Warehousing in logistics costs



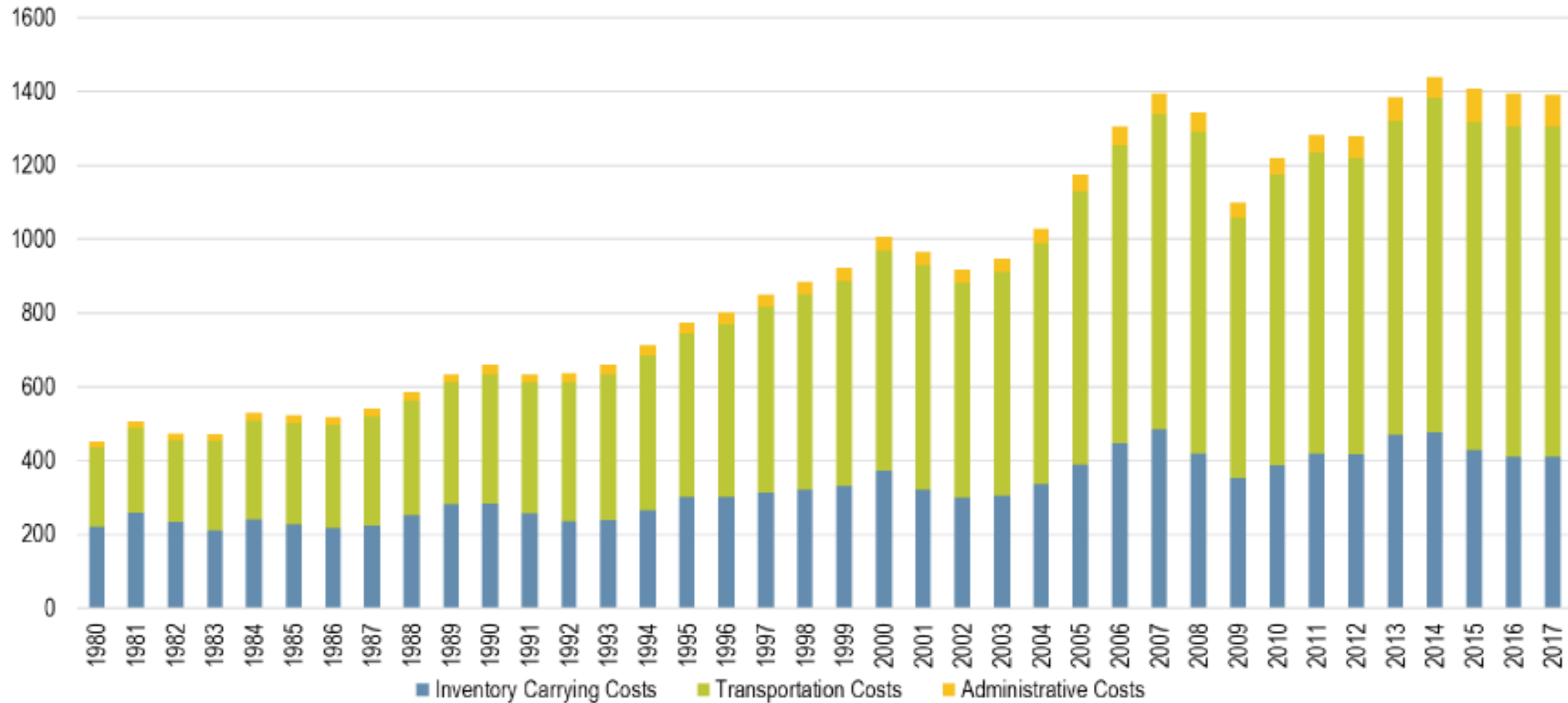
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# Warehousing in logistics costs



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Logistics Costs, United States, 1980-2017 Note: In billions of USD. Source: Council of Supply Chain Management Professionals, State of Logistics Report, (after 2012). Logistics Management & Distribution Report (before 2012).

# What drives the warehouses?



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## Client

### Needs

- Instant service
- Extended configuration of product and service
- Full information support to client
- Convenience of the transaction process
- After-sales support
- Pre-sale programs
- Information about the product and service in public space
- Reliability, availability on a global scale

### Conditions

- Global acting
- New crises and risks
- Unforeseen events
- Information transformation
- Sustainable development
- Emerging technologies

McKinsey: customers, especially the so-called Millennials are willing to pay 30% more for same day delivery and even more for guaranteed delivery

# The logistics (warehousing) challenges in 2022



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Disturbed balance between supply and demand

Production delays

Shortage of critical raw materials and logistics services

Broken supply chains and broken contracts

Semiconductors - "crude oil of the 21st century"



**Pandemic**  
=  
**a new scale of challenges**

Assessment and modernization of supply chains

Inventory rationalization

Increased investment in digital technologies

Diversification of partners in supply chains

Development of e-commerce and last-mile processes

**The demand for logistics space**





# The logistics (warehousing) challenges in 2022



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Lack of specialists (drivers)

Carbon footprint and water footprint

Warfare

Breaks (bottlenecks) in supply chains

Pandemic recurrences (e.g. in southern China)

Weather phenomena: hurricanes

Changes in law and tax systems

Environmental regulations, international policy

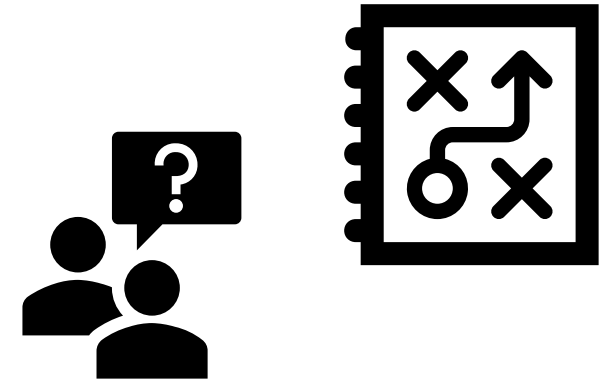
Financial crises

Migration

Economic conflict (China vs USA)

Technological changes

Remote communication



By 2030, the growth of e-commerce will lead to a more than 30% increase in supply-related CO<sub>2</sub> emissions.

Retail supply chains produce around 50% of the industrial CO<sub>2</sub>

# Trends in warehousing 2022



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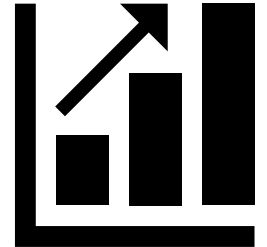
Local and international e-commerce, q-commerce?  
Local orientation of supply chains, nearshoring  
Expansion of last-mile solutions  
Supply crowdsourcing  
Omnichannel  
Returns, circular supply chain  
City logistics and micro-fulfilment centres  
Rising demand for outsourcing warehouse services  
Increasing popularity of refrigerated warehousing  
E-commerce portals

The main goal of the warehousing sector in the near future is to increase the resilience of supply chains to unexpected events, improve their agility, efficiency, and transparency.

All in light of the information transformation assumptions, i.e., Logistics 4.0 and everything it entails.

> 50% of the data held by companies is 'dark data'.

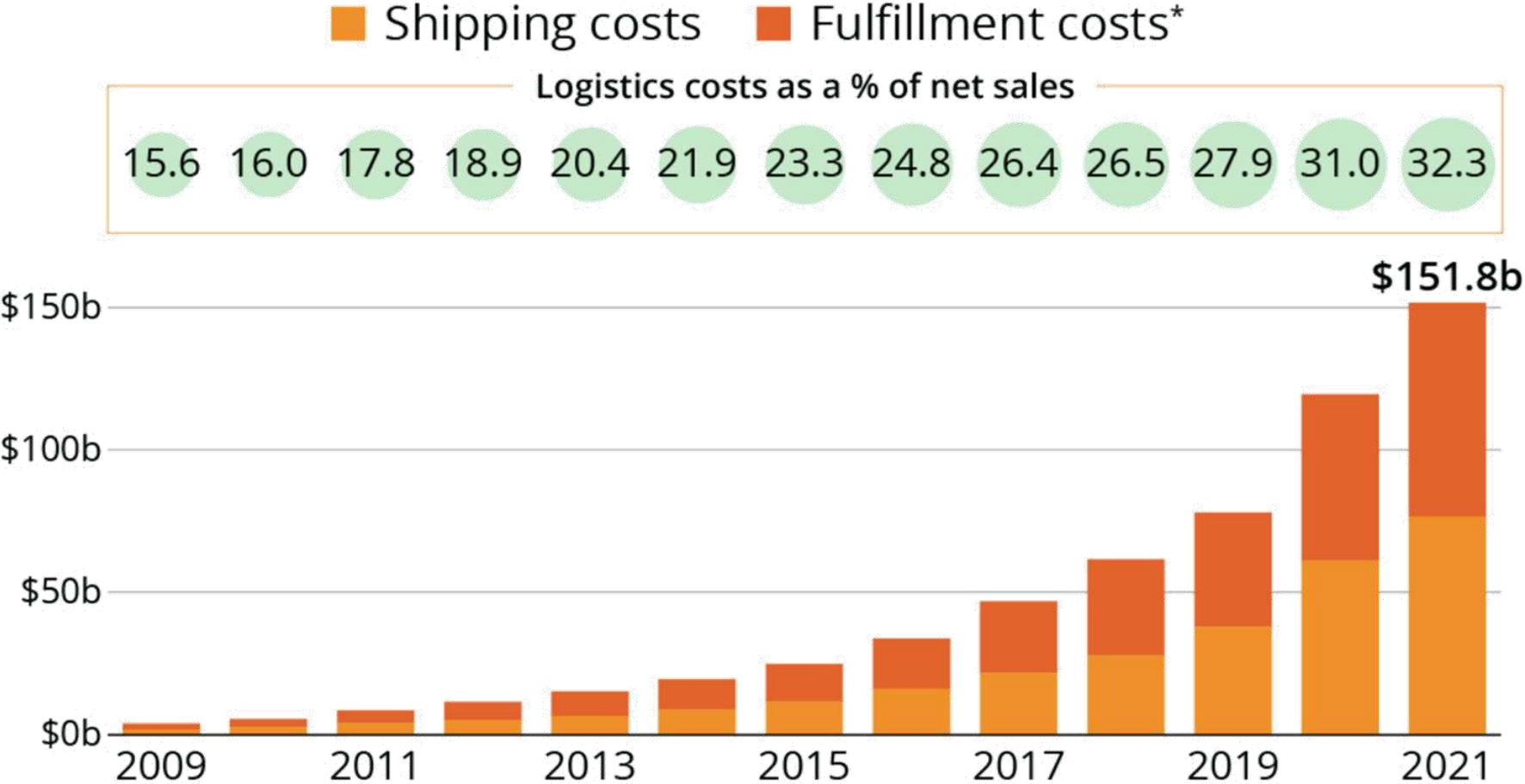
Gartner believes that 80% of B2B sales will be digital by 2025.



# Trends in warehousing 2022



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\* costs incurred in operating and staffing fulfillment centers, customer service centers and physical stores as well as payment processing costs

Source: Amazon

# Trends in warehousing 2022



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Big-data

Machine learning and artificial intelligence

Real-time data gathering and increased  
interconnectivity

Warehouse mobility solutions (smartphones) and  
people-technology connection

Internet of things, blockchain, and digital twin

Cloud-based systems, SaaS

Supply Chain Visibility, E2E

Sustainable development: reduction of carbon  
and water footprint (**green warehousing**)

Intelligent means of transport, autonomy, electric  
vehicles

Automation and robotization

Forbes: More than 90% of logistics executives  
consider supply chain visibility as a key to  
success

Gartner predicts that by 2024 50% of bodies will  
implement solutions using artificial intelligence

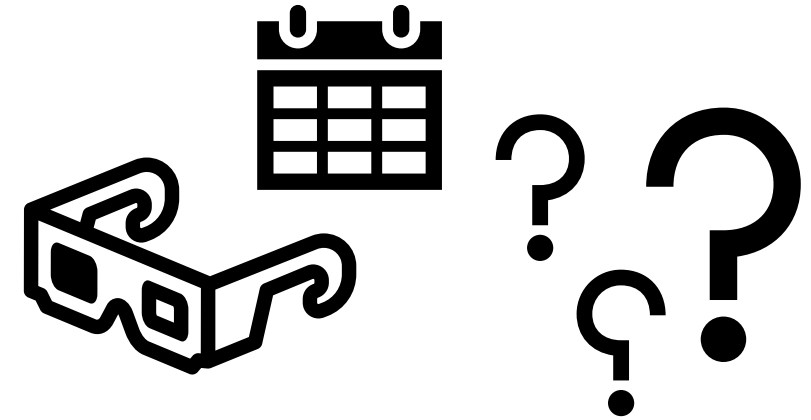
McKinsey Global Institute: The transportation  
and warehouse industry has the third largest  
automation potential of all sectors.

Markets & Markets Research: Blockchain market  
will grow from \$ 4.9 billion in 2021 to \$ 67.4  
billion by 2026.

# Next 20 years? 50 years?



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Pre-emptive logistics

Effective use of artificial intelligence

Blurring of decision centers at the machine level

Common 3D printing

Full autonomy

End of combustion engines

New energy sources?

Quantum computer?

Human-computer interface?



<https://trojwymiarowo.pl>

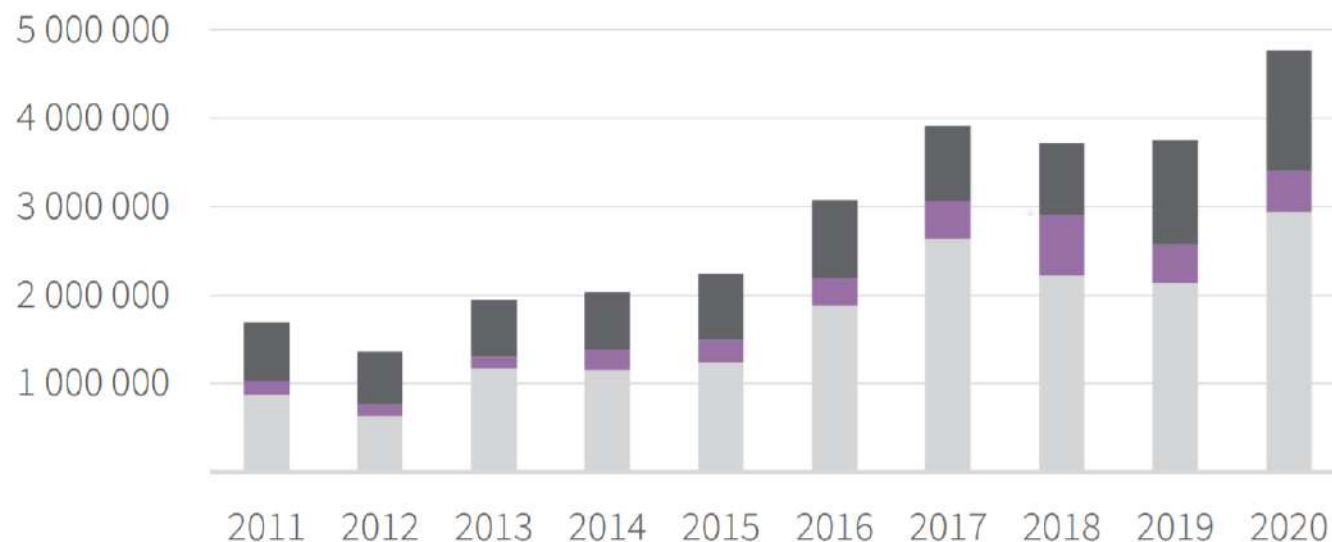
# Warehousing market on the example of Poland (H1 2021)



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## Gross demand (m<sup>2</sup>)

■ New contracts   ■ Expansions   ■ Renegotiations



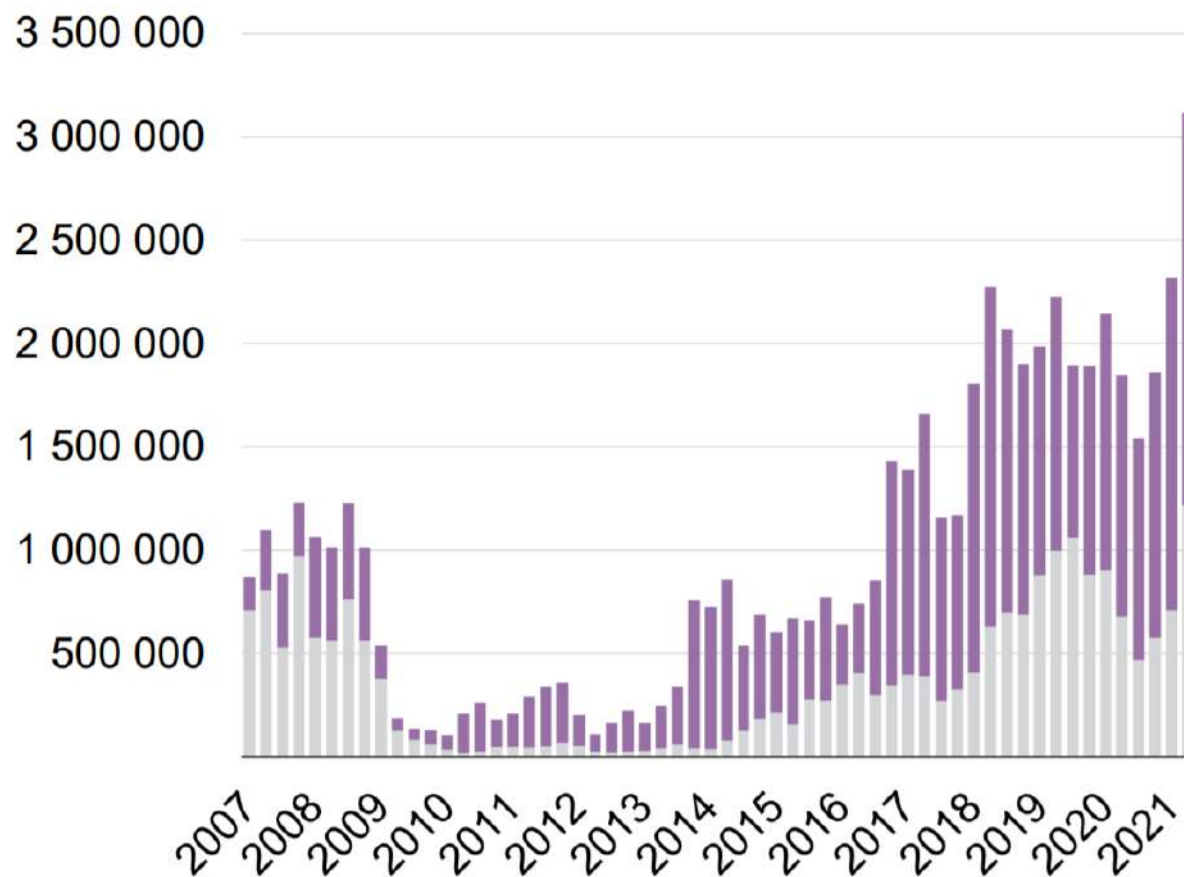
Source: JLL, magazyny.pl, IV kw. 2020 r.

# Warehousing market on the example of Poland (H1 2021)



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## Warehouse space under construction (m<sup>2</sup>)



- Signed contracts
- Speculative



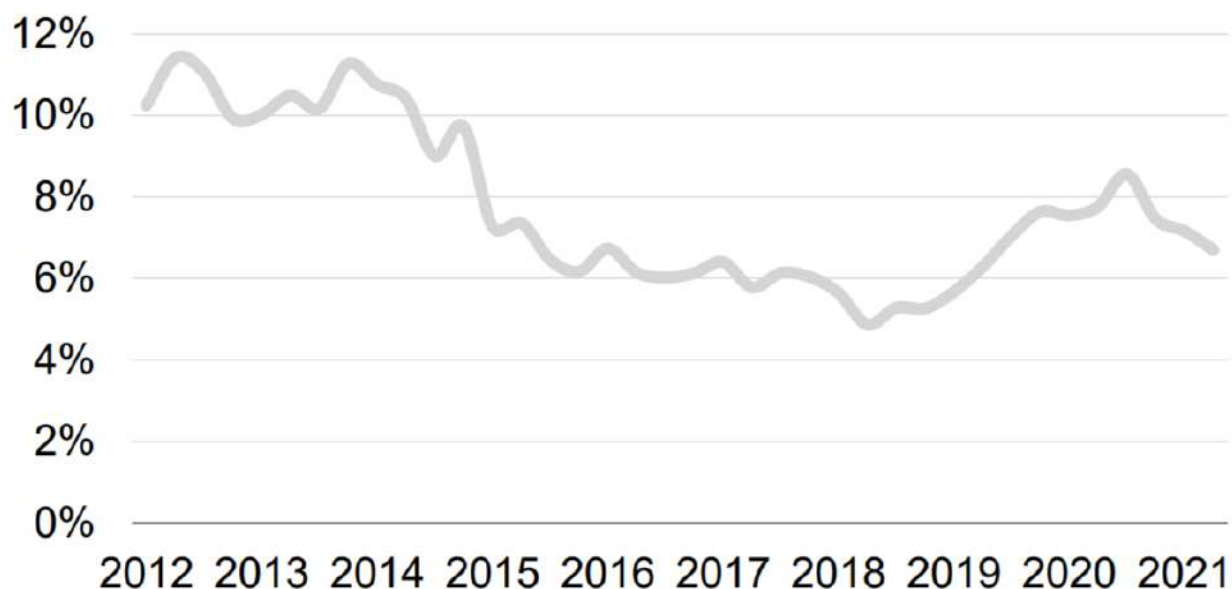
Source: JLL, magazyny.pl, IV kw. 2020 r.

# Warehousing market on the example of Poland (H1 2021)

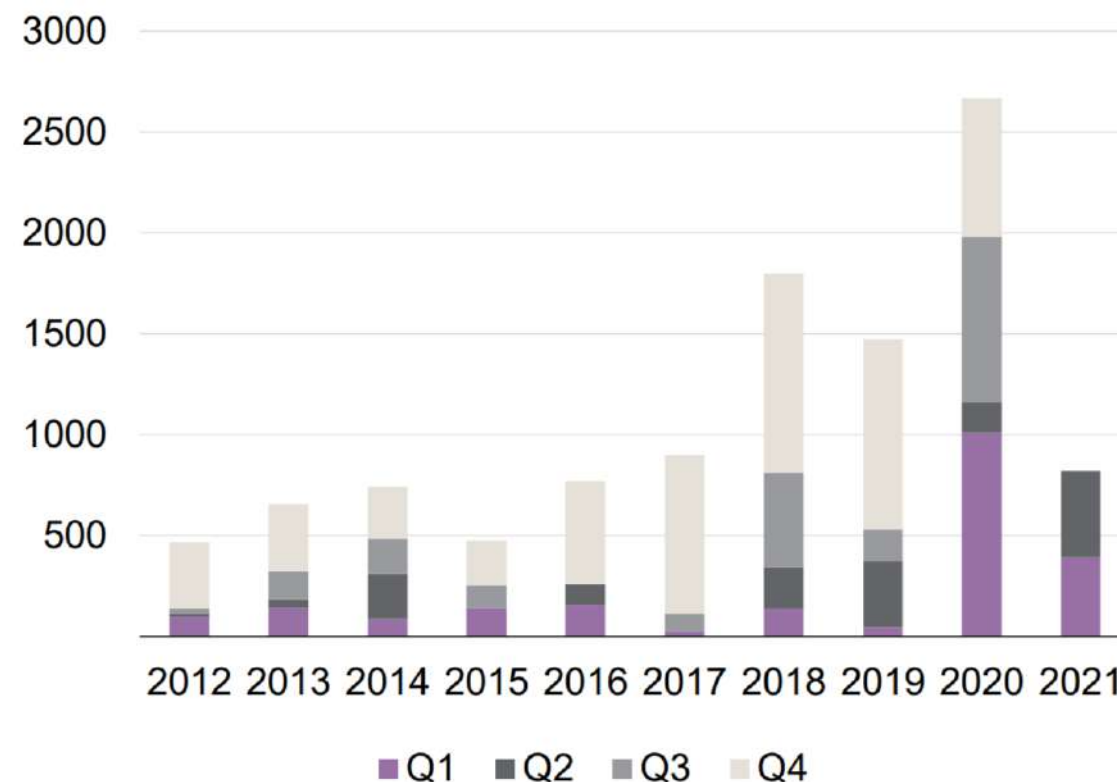


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## Vacancy rate (%)



## Investment value (millions of Euro)



Source: JLL, magazyny.pl, IV kw. 2020 r.



## 2. Frames of modern warehousing technology

## Warehouse as an element of supply chain

- **Warehouse** – commercial building for storage of goods. Node in the logistics network.
- **Warehousing** – **set of activities** (operations) performed on materials and information by people, equipment, and means of transportation **within warehouse area** starting from unloading, through receiving, storage, order-picking, retrieval and loading of means of transport. Various technologies can realize warehousing.

Warehousing can be considered in two aspects:

- **Buffering; *for material flow control*** (emphasis put on **internal transport** technology, **organization**, material and information flow, distribution, moving, *touching*)
- **Storing; **making reserves**** (emphasis placed on product determination, conservation, packing, product density, security, marking, labeling and space consumption)

What distinguishes a warehouse system from a transport system?

- **Designing, not planning** in warehousing
- Very **short** duration of operations in warehouse vs. **long** duration in external transport systems
- Many repetitions of the same operation within disposed time in warehousing
- Empty runs are about 50% of operations in warehouse

# Types of warehouses



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Warehouses can be categorized **by type**, which is preliminary determined by their **place in logistics network**:

- ❑ **Industrial warehouses**; raw materials, package materials, semi-finished products, finished goods. *Securing production continuity.*
- ❑ **Distributional warehouses**; commercial goods, trade-goods. *Securing consumption continuity and service of returns.*
- ❑ **Reserve-warehouses**; cumulating and storing materials for a long time, i.e. military warehouses, *Securing strategic reserves.*

# Types of warehouses



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## Functions and location in supply chain

<b>Levels of distribution system</b>	<ul style="list-style-type: none"><li>– Retail sale reserves</li><li>– Local distributor</li><li>– Regional distributor</li><li>– National (global) distributor</li><li>– Industrial warehouse (producer)</li></ul>
<b>Material flow volumes</b>	<ul style="list-style-type: none"><li>– Warehouse handling very low volumes (locally negligible)</li><li>– Warehouse handling medium volumes (locally important)</li><li>– Warehouse handling high volumes (regionally important)</li><li>– Warehouse handling very high volumes (significant on the national scale, or for particular business)</li></ul>
<b>Production processing level</b>	<ul style="list-style-type: none"><li>– Landfills in raw (natural) resources origin places</li><li>– Landfills and storage in natural resources processors</li><li>– Warehouses of simple parts and low-processed goods</li><li>– Warehouses of components and medium-processed goods</li><li>– Warehouses of high-processed goods, typically finished goods</li><li>– Recycling dumps and scrapyards</li></ul>
<b>Supply chain element</b>	<ul style="list-style-type: none"><li>– Production supply centers (branch)</li><li>– Industry warehouse of raw materials and package materials</li><li>– Industry warehouse of production in progress</li><li>– Industry warehouse of finished goods</li><li>– Distribution centers (branch)</li><li>– Retail sale reserves</li></ul>

<b>Rotation (inventory turnover)</b>	<ul style="list-style-type: none"><li>– Reserve warehouses (strategic reserves)</li><li>– Slow rotating warehouses</li><li>– Medium rotating warehouses</li><li>– Fast rotating warehouses</li><li>– Cross-docking</li></ul>
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<b>Type of business (production/ services)</b>	<ul style="list-style-type: none"><li>– Fast Moving Consumer Goods (HACAP)</li><li>– Household chemicals</li><li>– Industrial chemistry</li><li>– Automotive</li><li>– White goods and home appliances</li><li>– Pharmaceuticals</li><li>– Electronic and computer equipment</li><li>– Textiles and clothing</li><li>– Frozen food</li><li>– Hazardous materials</li><li>– Paper products and industry</li><li>– Other</li></ul>
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<b>Material flow transformation level</b>	<ul style="list-style-type: none"><li>– Shopping centers</li><li>– Logistics centers, logistics parks</li><li>– Cargo consolidation facilities</li><li>– Retail distribution centers</li><li>– Service parts distribution centers</li><li>– Catalog fulfillment/e-commerce centers</li><li>– 3PL warehouses</li><li>– Sorting terminals and cross-docking</li></ul>
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# Types of warehouses



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## Technical parameters and technologies

<b>Package form</b>	<ul style="list-style-type: none"><li>– Pieces</li><li>– Boxes-pieces</li><li>– Pallets-boxes-pieces</li><li>– Pallets-boxes</li><li>– Pallets</li><li>– Containers-pallets</li><li>– Containers</li><li>– Long and non-normative materials</li><li>– Loose and lump</li><li>– Liquids</li><li>– Gaseous</li></ul>
<b>Functional arrangement</b>	<ul style="list-style-type: none"><li>– Sack-type</li><li>– Flow-through-type</li><li>– Angled</li><li>– One-level</li><li>– Multilevel</li><li>– Mixed</li></ul>
<b>Storage conditions</b>	<ul style="list-style-type: none"><li>– Open landfills</li><li>– Roofed landfills</li><li>– Covered warehouses for materials not requiring special conditions</li><li>– Warehouses for hazardous materials, ADR</li><li>– Warehouses providing special sanitation, pollution and cleanliness conditions</li><li>– Heated / airconditioned warehouses</li><li>– Cooled warehouses and cold store</li></ul>

<b>Type of building</b>	<ul style="list-style-type: none"><li>– Open - storage yards</li><li>– Semi-open - shelters</li><li>– Cellars and bunkers</li><li>– Tanks for liquids, gases and powdery materials</li><li>– Silos</li><li>– Industrial steel buildings</li><li>– Industrial concrete buildings</li><li>– Warehouse buildings based on the construction of racking system</li></ul>
<b>Warehouse building height</b>	<ul style="list-style-type: none"><li>– Storage yard</li><li>– Ground-floor buildings</li><li>– Low buildings (up to 4.8m)</li><li>– High-bay warehouses (up to 12 m)</li><li>– High-rack warehouses (up to 36 m)</li><li>– Pallet silos</li></ul>
<b>Material flow control</b>	<ul style="list-style-type: none"><li>– Manual</li><li>– Automatic receiving and shipment registration</li><li>– Automatic receiving and shipment registration with directioning material flows from/to warehouse locations (Warehouse Management System)</li><li>– WMS + ERP</li></ul>
<b>Mechanization and automation level</b>	<ul style="list-style-type: none"><li>– Non-mechanized</li><li>– Partially mechanized</li><li>– Mechanized</li><li>– Partially automated</li><li>– Automatic</li></ul>

# Types of warehouses



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## Technical parameters and technologies

<b>Number of floors</b>	<ul style="list-style-type: none"><li>– One-storey buildings on the entire surface</li><li>– One-storey buildings within the storage space and a multi-storey within the office and social space</li><li>– Multi-storey buildings</li></ul>
<b>Warehouse class</b>	<ul style="list-style-type: none"><li>– Class A+</li><li>– Class A</li><li>– Class B+</li><li>– Class B</li><li>– Class C</li><li>– Class D</li></ul>
<b>Warehouse floor</b>	<ul style="list-style-type: none"><li>– Permissible pressure min. 5t/m<sup>2</sup></li><li>– Permissible pressure lower than 5t/m<sup>2</sup></li><li>– Specialized industry floors (expansion, strength, abrasion resistance, resistance to chemical agents)</li></ul>

# Types of warehouses



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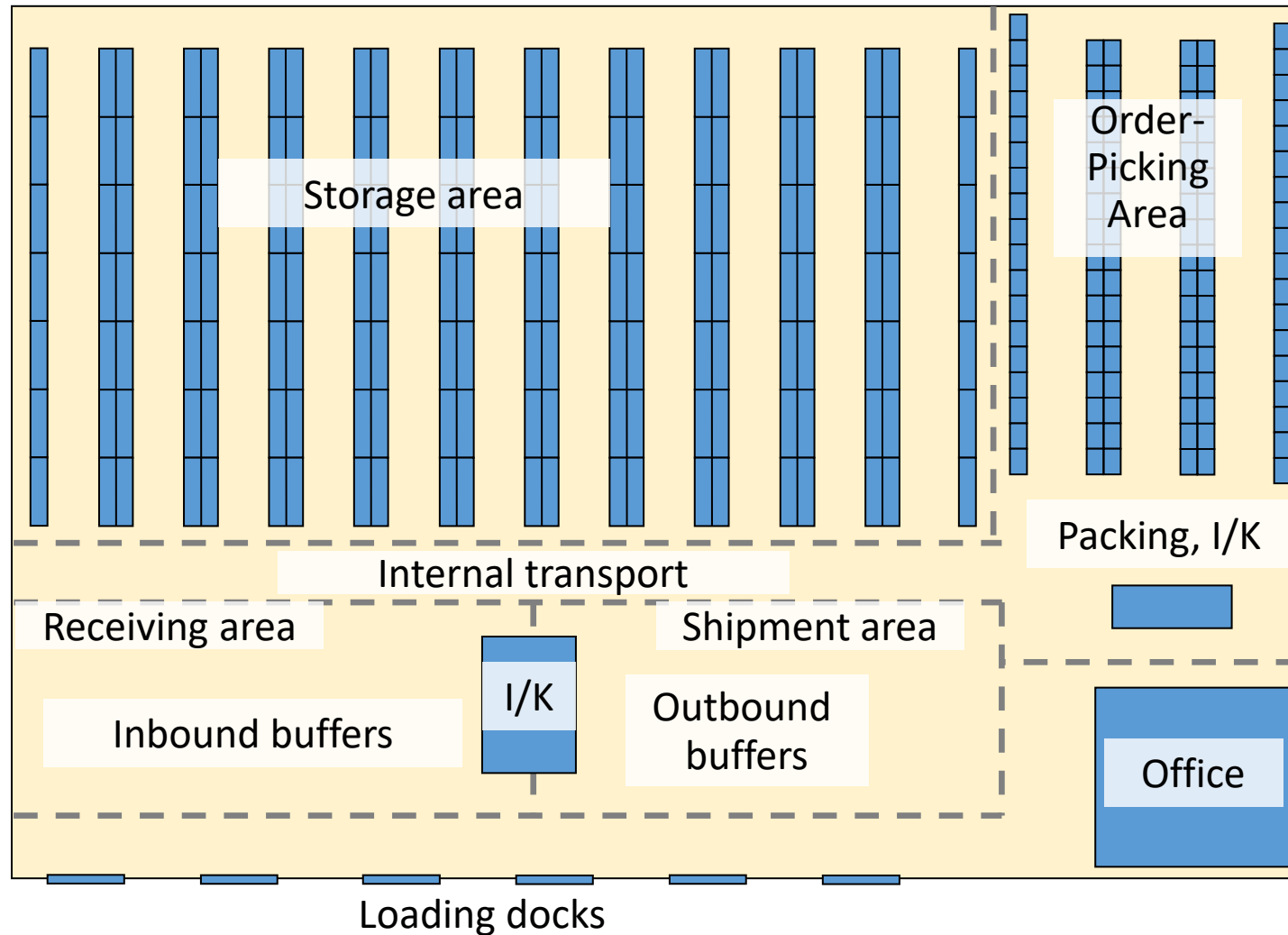
Class	Key features
<a href="#">A+ class warehouse</a>	Anti-dust floor with a <b>load capacity of 5 t/m<sup>2</sup></b> , at a height of 1,20 m above the ground; <b>Ceiling height - 13 m</b> ; adjustable temperature regime; fire alarm and automatic fire extinguishing system; ventilation; fiber optic cabling; alarm and video surveillance system; autonomous electrical substation; automatic <b>industrial gates (min. 1 per 500m<sup>2</sup>)</b> ; parking for employees and trucks; place for maneuvering trucks; offices and other additional rooms; optical fibers; <b>location near central highways; railway line.</b>
<a href="#">A class warehouse</a>	Anti-dust floor with a <b>load capacity of 5 t/m<sup>2</sup></b> , at a height of 1,20 m above the ground; <b>Ceiling height - 10 m</b> ; adjustable temperature regime; fire alarm and automatic fire extinguishing system; ventilation; fiber optic cabling; alarm and video surveillance system; autonomous electrical substation; automatic <b>industrial gates (min. 1 per 700m<sup>2</sup>)</b> ; parking for employees and trucks; place for maneuvering trucks; offices and other additional rooms; optical fibers; <b>location near central highways.</b>
<a href="#">B+ class warehouse</a>	Anti-dust floor with a <b>load capacity of 5 t/m<sup>2</sup></b> , at a height of 1,20 m above the ground; <b>Ceiling height - 8 m</b> ; adjustable temperature regime; fire alarm and automatic fire extinguishing system; ventilation; fiber optic cabling; alarm and video surveillance system; autonomous electrical substation; automatic <b>industrial gates (min. 1 per 1000m<sup>2</sup>)</b> ; parking for employees and trucks; place for maneuvering trucks; offices and other additional rooms; optical fibers; <b>location near central highways.</b>
<a href="#">B class warehouse</a>	<b>Asphalt or concrete floor without anti-dust coating</b> ; heating system; <b>ceiling height from 6 m</b> ; fire alarm and extinguishing system; place for maneuvering trucks; alarm system and video surveillance system; ventilation; offices.
<a href="#">C class warehouse</a>	<b>Asphalt or concrete floor without anti-dust coating</b> ; heating system; <b>ceiling height from 4 m</b> ; fire alarm and extinguishing system; truck maneuvering areas; ventilation.
<a href="#">D class warehouse</a>	No requirements for such facility, except that it should not be in a poor, unsuitable for use technical condition.,



# Functional areas in warehouse



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## Other:

Receiving

Sorting and consolidation

Value Adding Services

Production

Processing

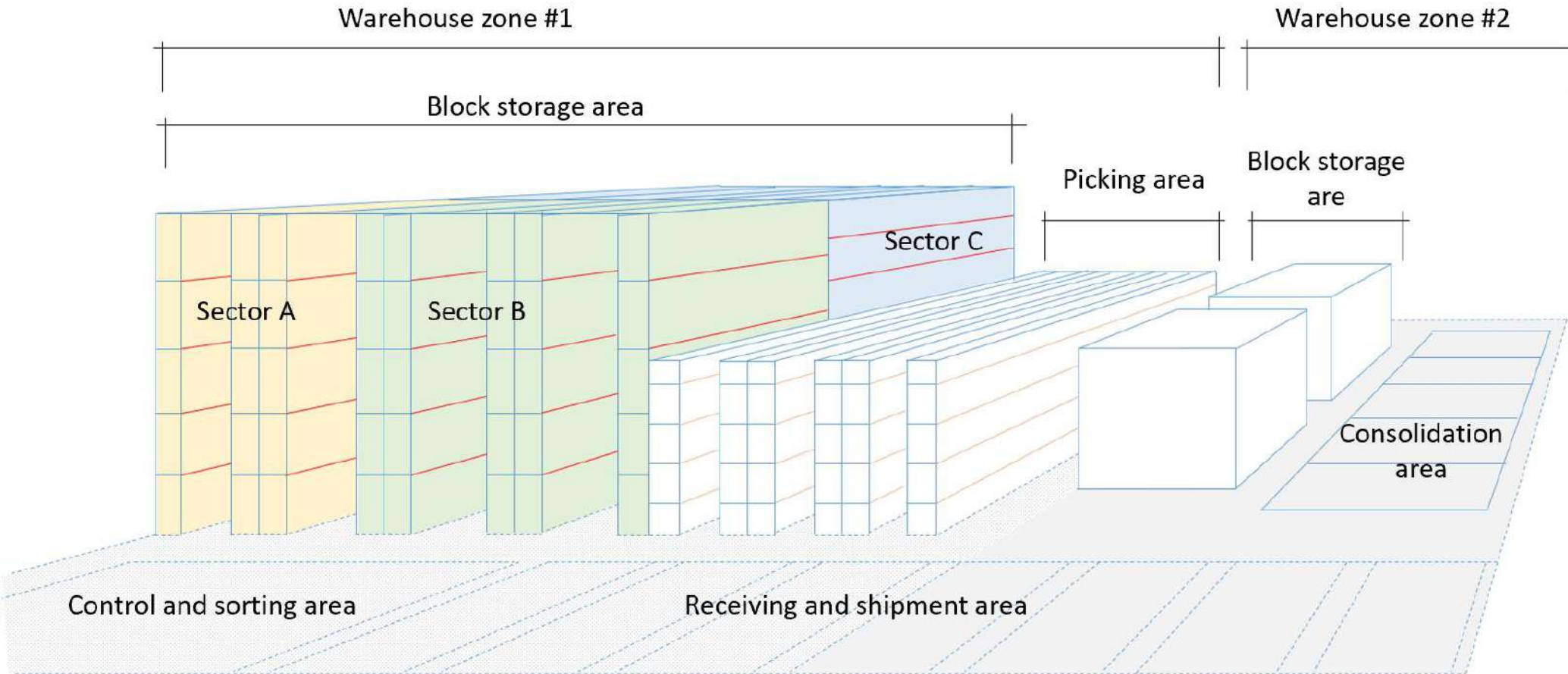
Additional and technical

Parking lots and yards

Social

...

# Functional areas in warehouse



- Warehouse
- Zone
- Area
- Sector
- Rack
- Cell
- **Location**

# Functional areas in warehouse

PW



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# Functional areas in warehouse

PW



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# Functional areas in warehouse

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# Functional areas in warehouse

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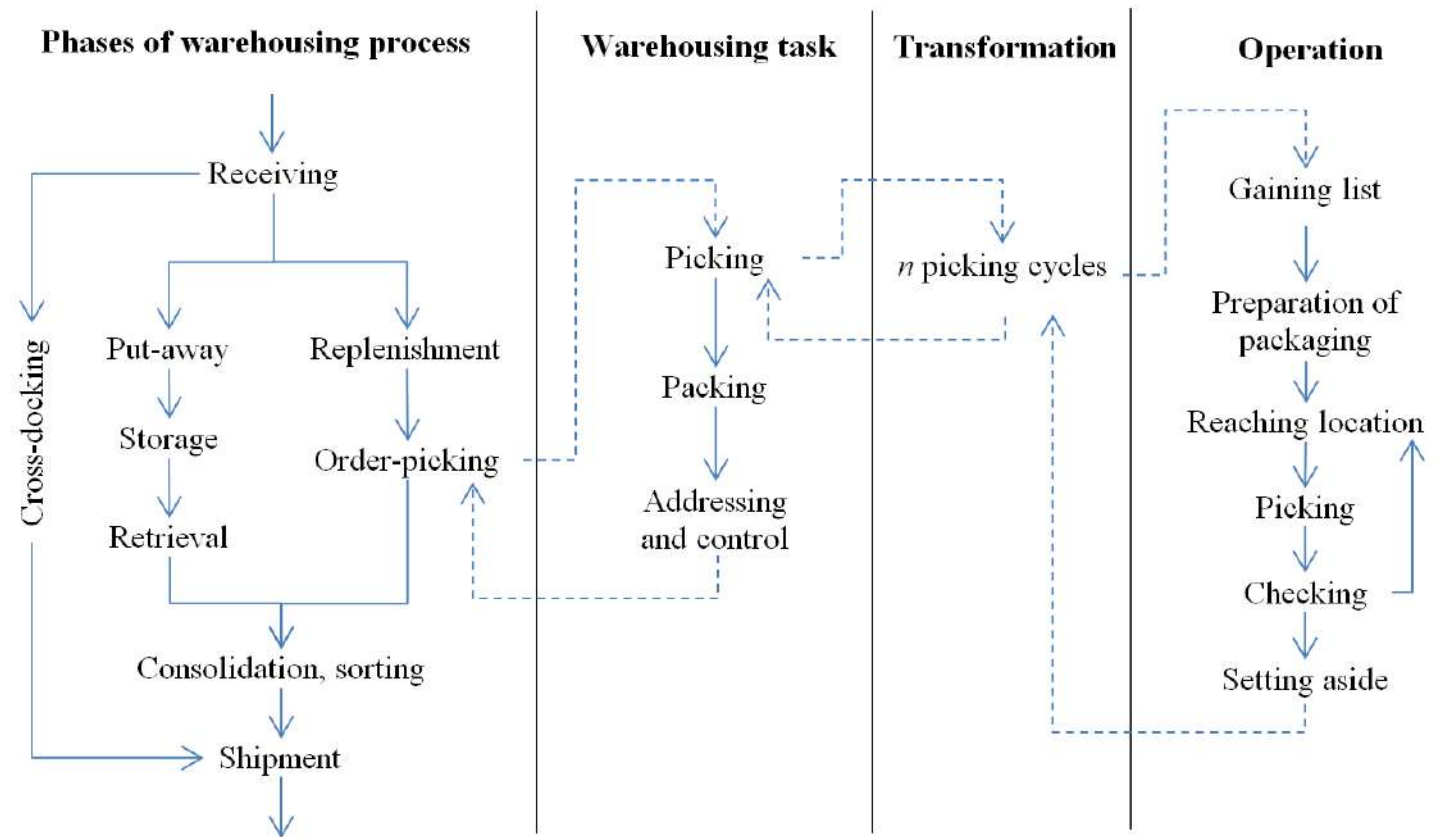


# Warehousing process – components



## Elements of warehousing processes:

- ❑ **Entering warehouse;** unloading, buffering
- ❑ **Receiving;** control, identification, addressing, labeling, forming warehouse units, buffering, quality control
- ❑ **Put-away;** selecting warehouse location, moving material, confirming location availability, storing,
- ❑ **Retrieval;** moving material,
- ❑ **Replenishment;** moving material and unpacking, disposing material to locations
- ❑ **Order-picking;** picking client's order, forming new loading units,
- ❑ **Packing and consolidation;**
- ❑ **Shipping;** sorting, identification, control, labeling, addressing, composing transport units, loading...
- ❑ **Value-adding operations;**
- ❑ ...



# Warehouse equipment classification



- Handling units
- Transporting devices and material handling systems (MHS)
- Robotized and specialized systems
- Storage systems
- Information processing systems
- Automatic Identification and Data Collection devices and systems (AIDC)
- Space partitioning
- Auxiliary equipment
- Special (dedicated) systems



## □ Type of handling unit

- Stackable (block storage),
- Non-stackable (block storage in racks),
- For pallets
- For pallets – cases
- For pallets – cases – pieces
- For cases – pieces

## □ Inventory selectiveness

- Selective storage (clear access to all units)
- Non-selective storage (limited access to stored units)

## □ Inventory assignment

- Block storage,
- Line storage,
- High storage
- High storage warehouse (silo)
- Cross-docking

## □ Handling equipment

## □ Typical storage policies

- Block storage
- Block storage in racking,
- Line storage handled by reaching forklift truck,
- Line storage in racking:
  - ✓ handled by reaching forklift truck,
  - ✓ handled by reaching forklift truck with bilateral of side forks and low/medium reaching pallet cranes
  - ✓ handled by high reaching pallet cranes
- Handling policies:
  - ✓ FIFO – First-in-First-out
  - ✓ LIFO – Last-in-First-out
- Material flow policies:
  - ✓ FIFO – First-in-First-out
  - ✓ LIFO – Last-in-First-out
  - ✓ FEFO – First-expired-First-out
  - ✓ HIFO – Highest-in-First-out
  - ✓ LOFO – Lowest-in-First-out



Block storage in racks



Block storage




Block storage in racks



Block storage in racks



Line storage in racks

 HYPERACK  
YOUR STORAGE PARTNER



Line storage in racks

# Picking policies and technologies



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## ❑ Order picking techniques

- Man-to-material
- Material-to-man
- Manual
- Automatic (robotized)

## ❑ Picking policies

- Simple picking (article based)
- Simple picking (order based)
- Pallet picking
- Batch picking
- Multi-order picking
- Zone picking
- Wave picking

## ❑ Picking areas

- Separated picking area
- Picking in storage area (all)
- Picking in storage area (floor level)
- Combined systems
- Work-stations

## ❑ Picking height

- Point pick (stationary)
- Single-dimensional picking (across conveyor)
- Two-dimensional picking
- Three-dimensional picking

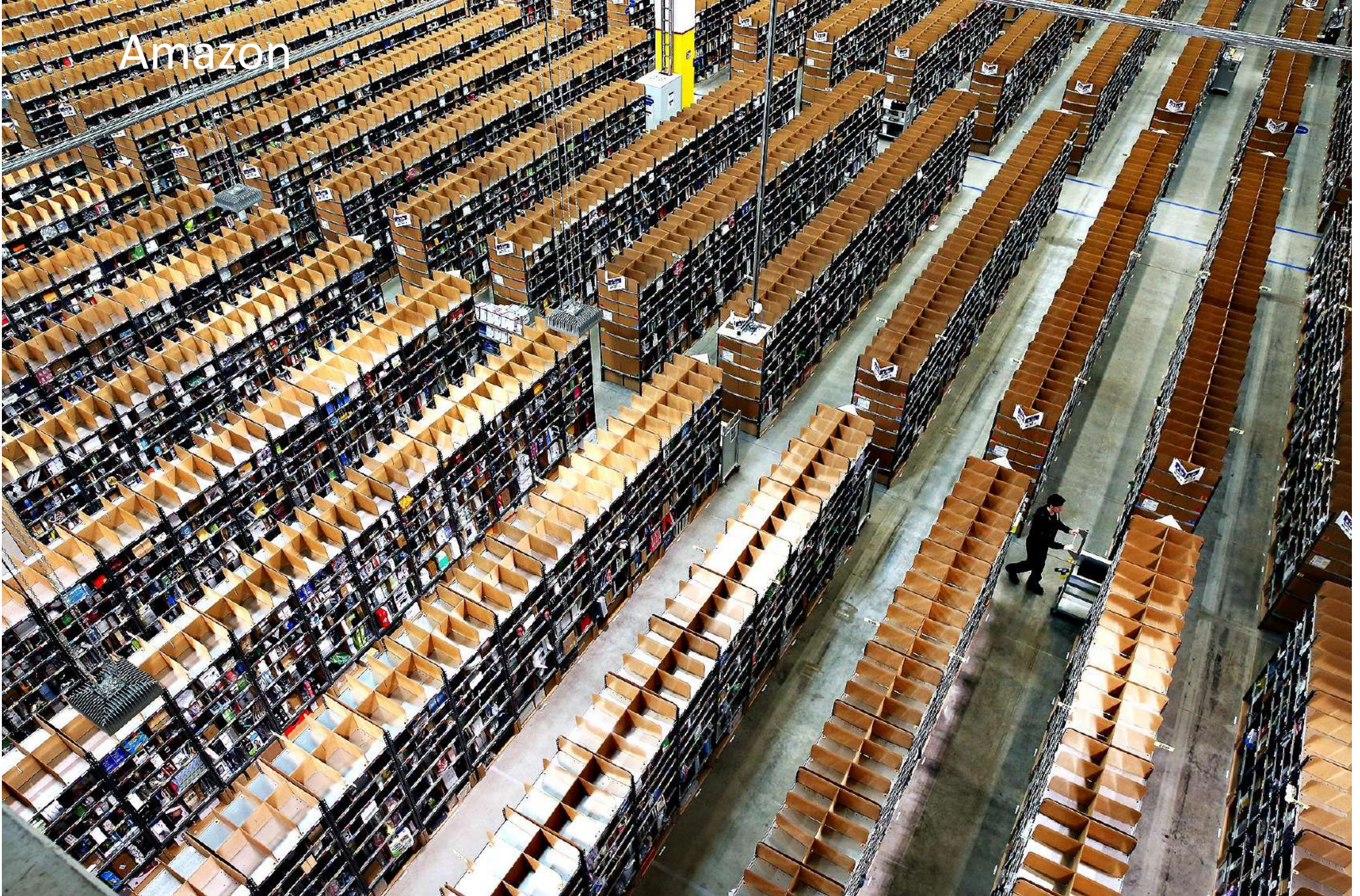
## ❑ Slotting

- Volume based
- Volume based + family grouping
- Family grouping
- Family grouping + Batch-pick

Activity of determining the most appropriate storage location for each item in your warehouse:

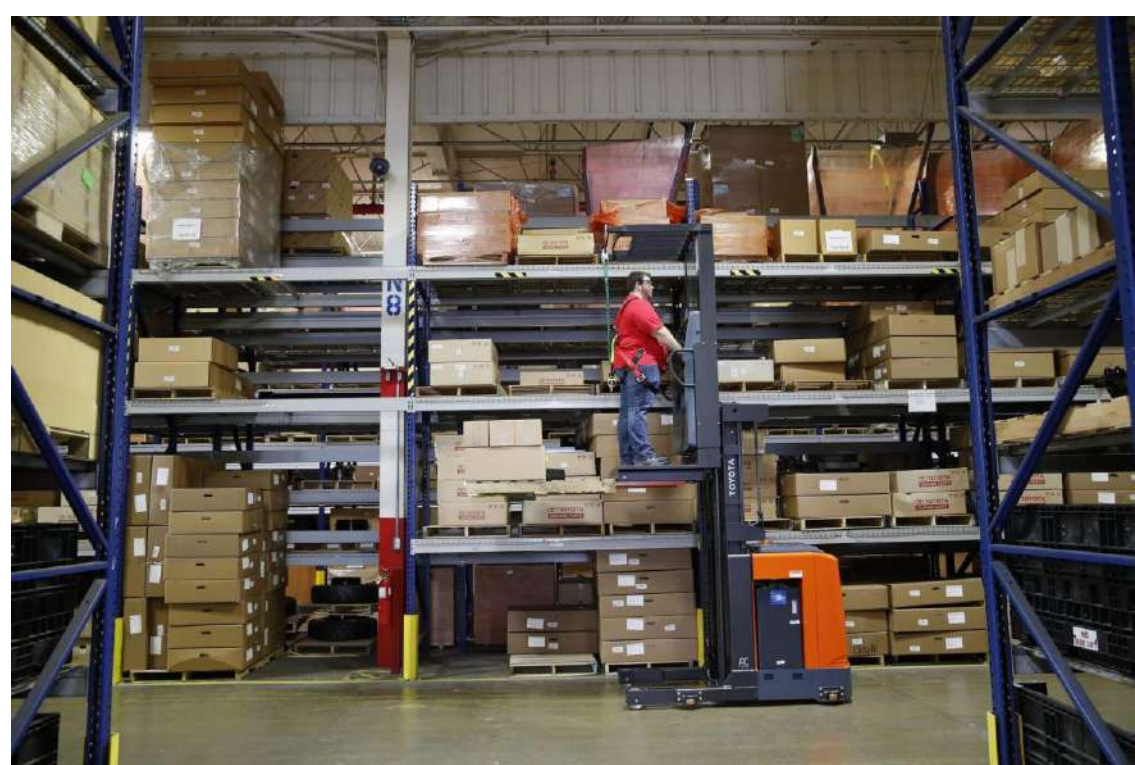
- Space utilization
- Material handling productivity

Amazon



Amazon









## Pallet racks:

- ❑ Selective rack (single-deep rack)
- ❑ Double-deep rack (Deep-Reach)
- ❑ Push-back rack
- ❑ Drive-In or drive-through rack
- ❑ Gravity and powered flow rack
- ❑ Radio-shuttle
- ❑ Sliding pallet-rack
- ❑ Self-carrying racking construction

## Special racking systems:

- ❑ Cantilever rack
- ❑ Automatic racks (horizontal and vertical)
- ❑ Specialized constructions
- ❑ Combined racking constructions for storage and picking

## Racking for cases and containers:

- ❑ Bin-shelving (light)
- ❑ Attachments for pallet racks
- ❑ Racks for plastics containers (Miniload)
- ❑ Gravity flow rack
- ❑ Sliding case-rack
- ❑ Carousels (horizontal and vertical)
- ❑ Mezzanines and platforms
- ❑ Combined constructions

Other (for bulk/loose/liquid/gas materials)

# Storage equipment



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## Pallet racks:

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# Storage equipment

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- ❑ **Drive-In or drive-through rack**
- ❑ Gravity and powered flow rack
- ❑ Radio-shuttle
- ❑ Sliding pallet-rack
- ❑ Self-carrying racking construction



# Storage equipment

## Pallet racks:

- ❑ Selective rack (single-deep rack)
- ❑ Double-deep rack (Deep-Reach)
- ❑ Push-back rack
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# Storage equipment



Co-funded by the  
Erasmus+ Programme  
of the European Union

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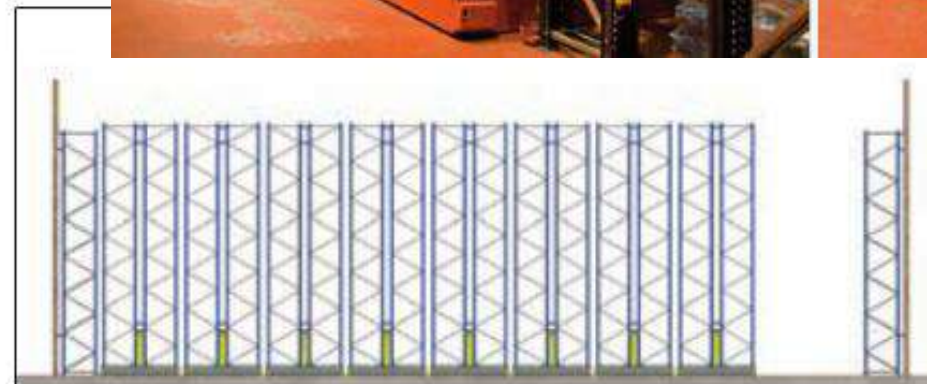
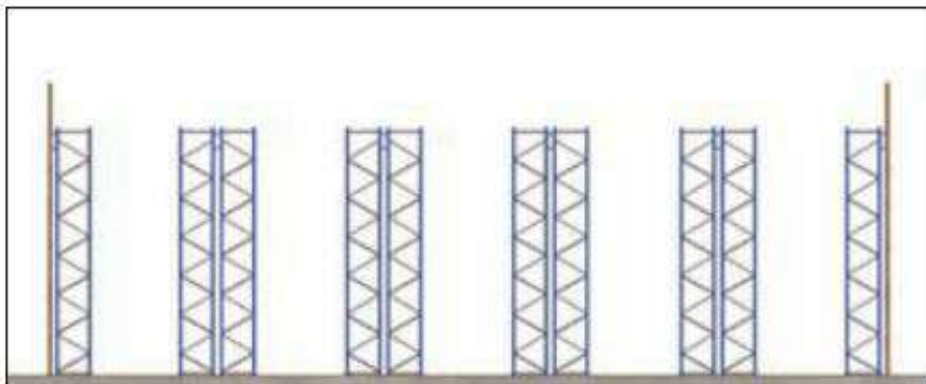
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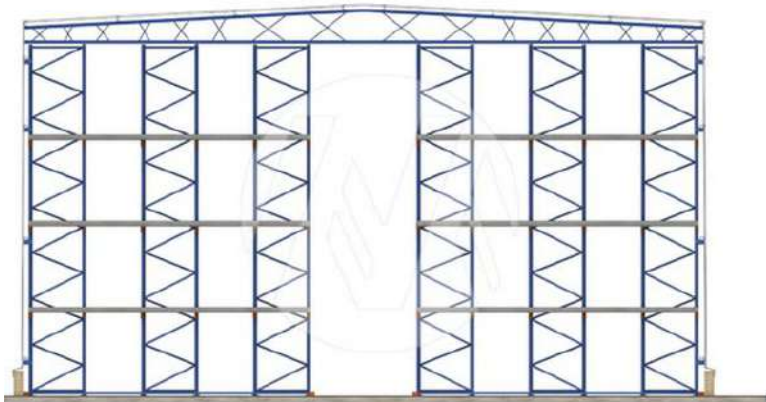




# Storage equipment

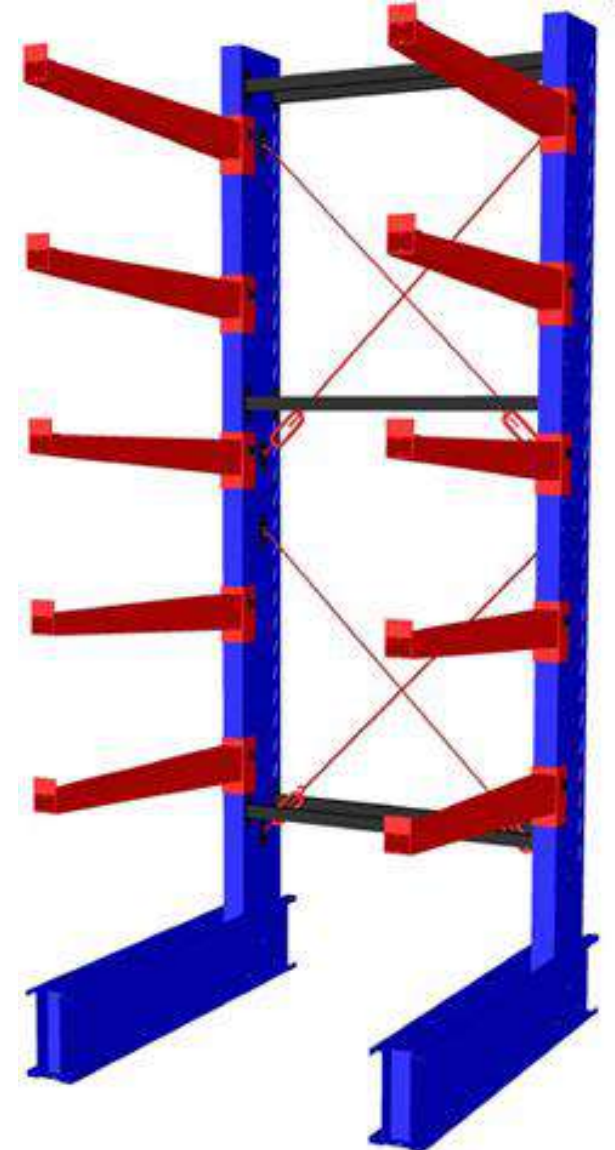
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## Special racking systems:

- ❑ Cantilever rack
- ❑ Automatic racks  
(horizontal and vertical)
- ❑ Specialized constructions  
(controlled atmosphere,  
ASRS and other)
- ❑ Combined racking  
constructions for storage  
and picking



# Storage equipment



Co-funded by the  
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[www.promag.pl](http://www.promag.pl)

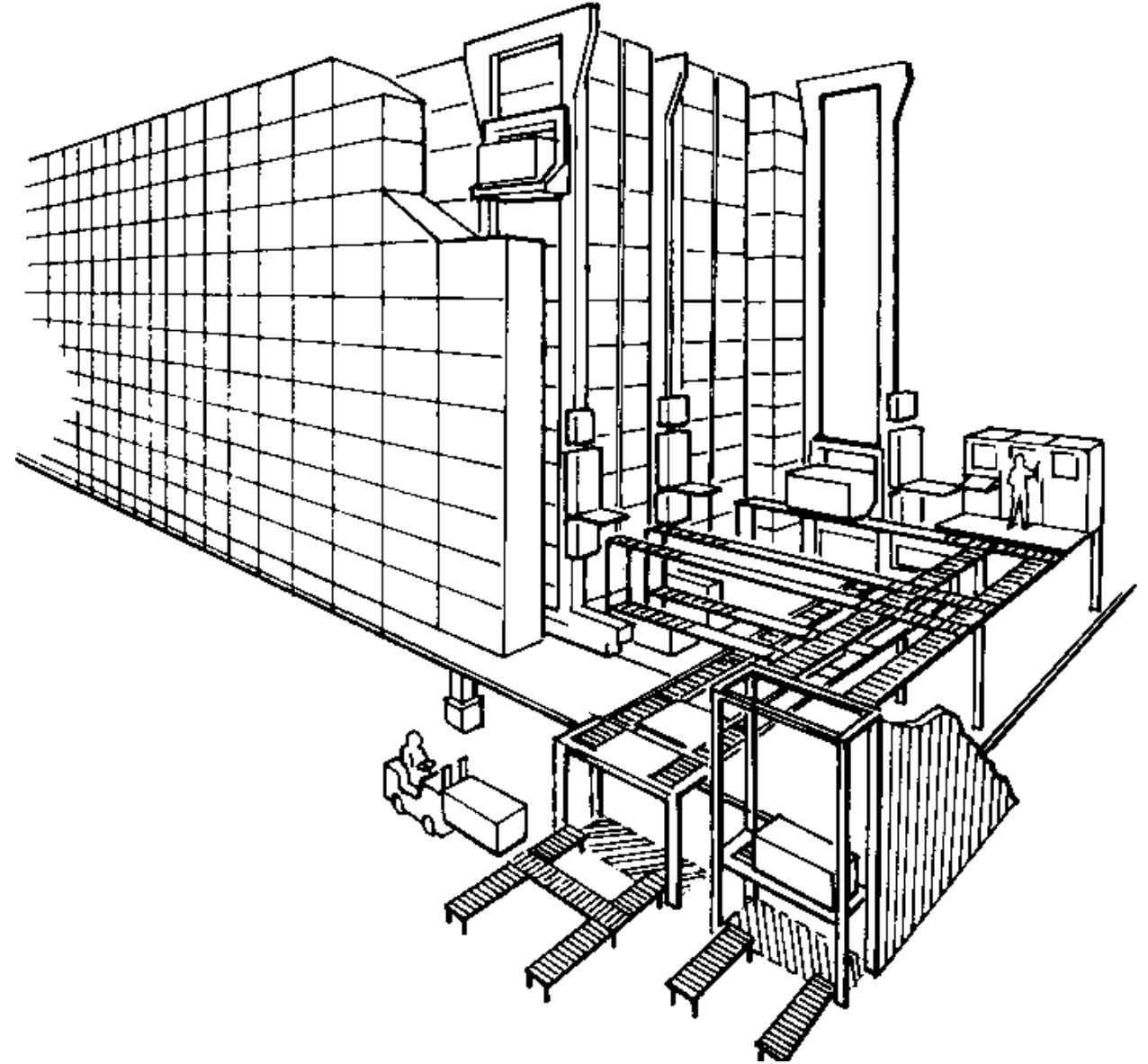
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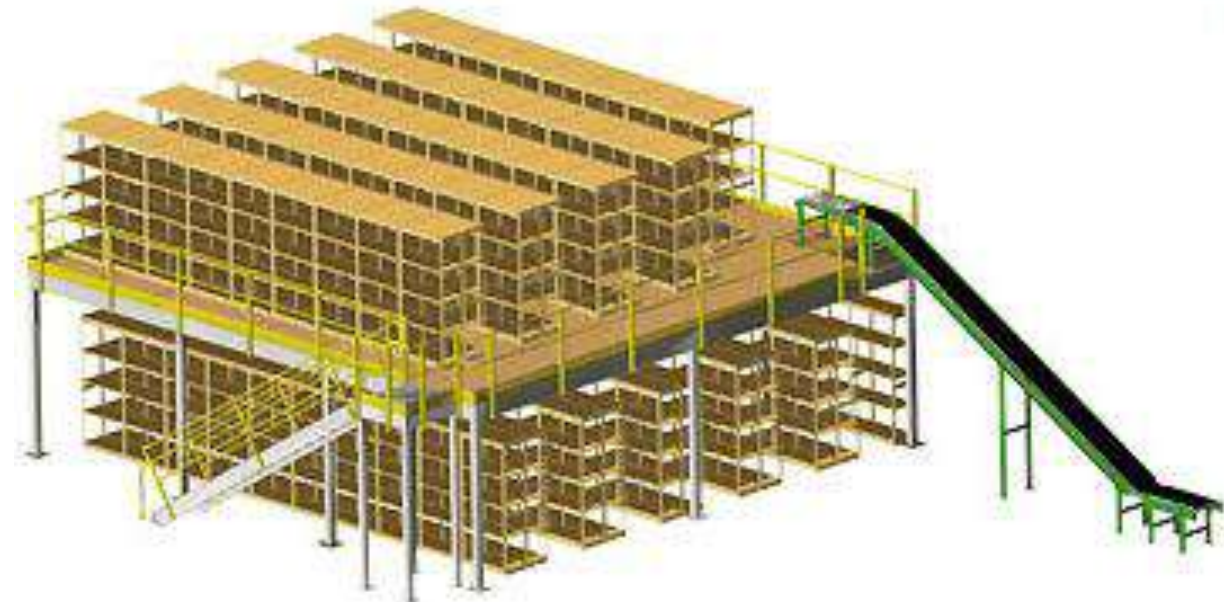
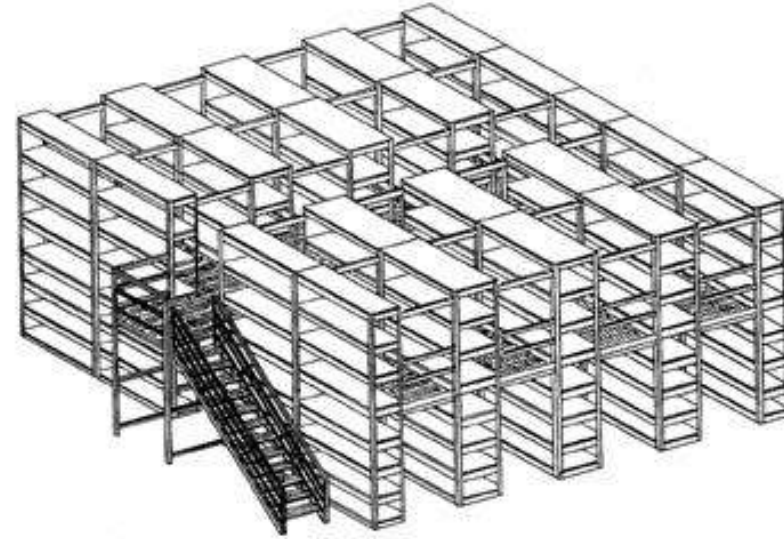
# Storage equipment



Co-funded by the  
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## Special racking systems:

- ❑ Space partitioning - mezzanines



# Material handling equipment



Co-funded by the  
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- ❑ Workstation systems: balancers, pneumatic manipulators etc.
  - ❑ Equipment for manual conveying
  - ❑ Transport trolleys (rail and road)
  - ❑ Tractors + trailers
  - ❑ Forklift trucks
  - ❑ Conveyors and flow-directing components
  - ❑ Cranes (overhead cranes)
  - ❑ Automatic Guided Vehicles (AGV's), robocars, intelligent forklift trucks
  - ❑ Mobile robots, cobots
  - ❑ Auxiliary equipment
  - ❑ Automatic Storage/Retrieval Systems (AS/RS)
  - ❑ Carousels
- ❑ Intermittent operation
    - cranes
    - forklifts
    - mobile robots
  - ❑ Continuous operation
    - Conveyors

# Material handling equipment – forklift trucks

PW



Co-funded by the  
Erasmus+ Programme  
of the European Union

## Basic operations:

- ❑ Lifting
- ❑ High lifting (reaching)

## Drive:

- ❑ Electric drive
- ❑ Gas drive (LPG)
- ❑ Diesel
- ❑ Manually guided

## Way of controlling:

- ❑ Guided
- ❑ Driven

## Construction:

- ❑ Counterbalanced
- ❑ Supported

## Operator position:

- ❑ No operators place
- ❑ Standing operator
- ❑ Sitting operator

## Unit take:

- ❑ Frontal
- ❑ Bilateral
- ❑ Sideway





# Material handling equipment – forklift trucks

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- Sitting operator

## Unit take:

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- Bilateral
- Sideway



# Material handling equipment – cranes



Co-funded by the  
Erasmus+ Programme  
of the European Union

## STANDARD PARAMETERS:

### lifting capacity:

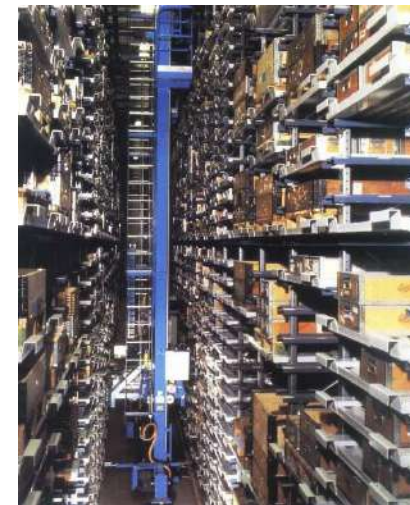
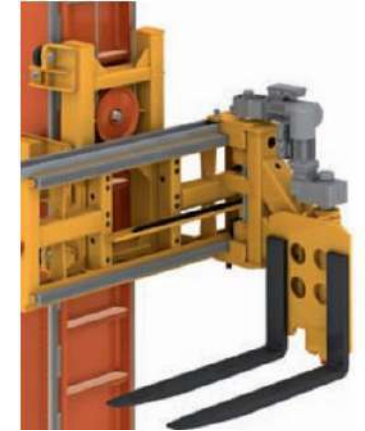
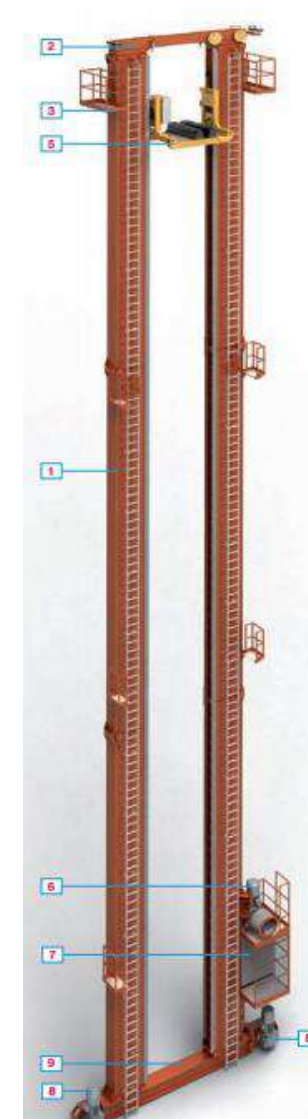
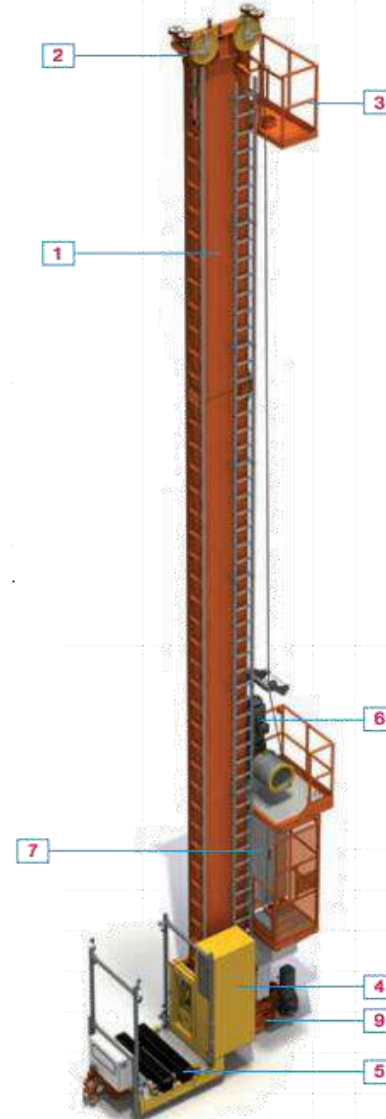
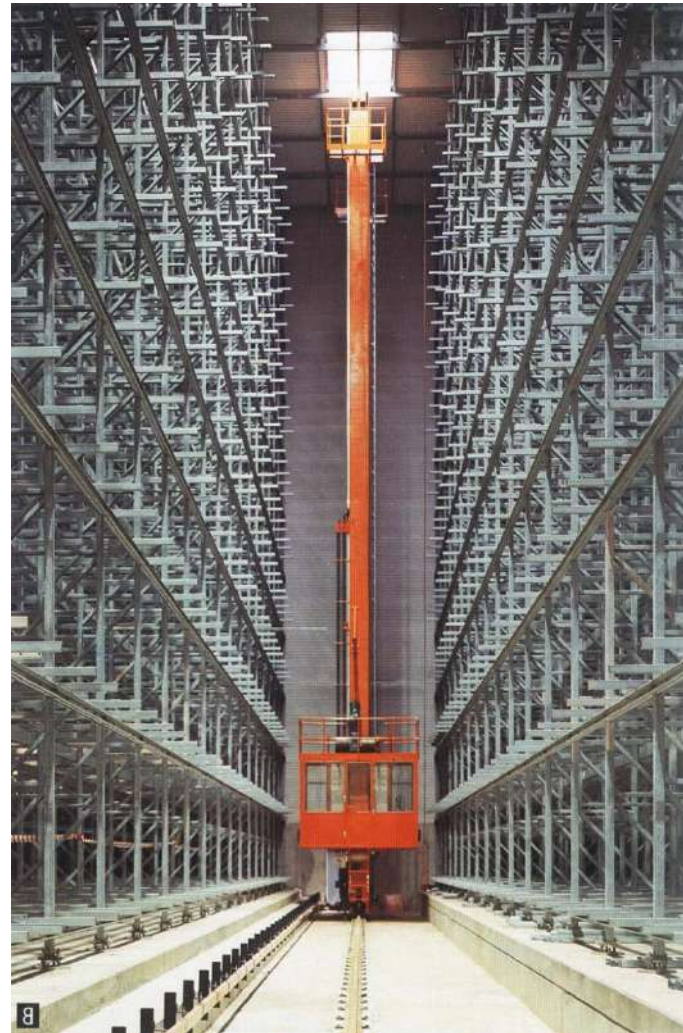
- up to 1000 - 1500 kg (single column - AS/RS);
- up to 1500 - 3000 kg (two-column - AS/RS);
- up to 100 kg (single column - cartons);
- up to 200 kg (two-column - cartons);

### Lifting height:

- up to approx. 12-15m (pl. container);
- up to approx. 45m (pallet) - the highest 54m;

### Minimum corridor width:

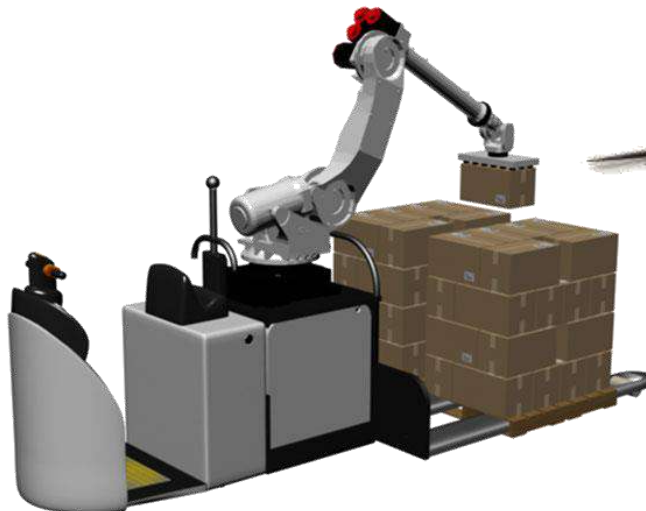
- approx. 870 mm (pl. container)
- about 1300-1400mm (pallet)



# Material handling equipment – AGV and RPA



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- mobile robots capable of independent perception and interpretation of the environment,
- operator determines only the purpose of operation, required boundary conditions and environmental parameters,
- traffic planning, identification of the environment, control of motion mechanisms, etc. are implemented by the system without operator participation,
- autonomous action systems (artificial intelligence and image recognition)

# Material handling equipment – AGV



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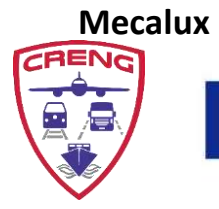
## Guiding mechanisms:

- ❑ Inductive (wire)
- ❑ Magnetic track
- ❑ Inertial (gyroscopic)
- ❑ Point-wise (transponders)
- ❑ Optical (reflective line)
- ❑ Laser
- ❑ Other (i.e. GPS)
- ❑ Monorails

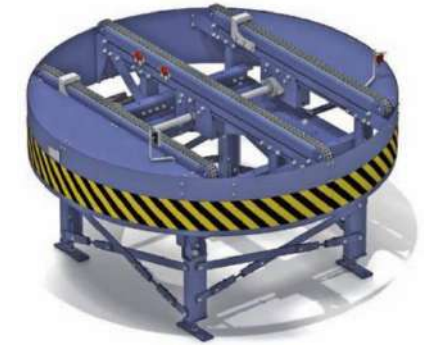
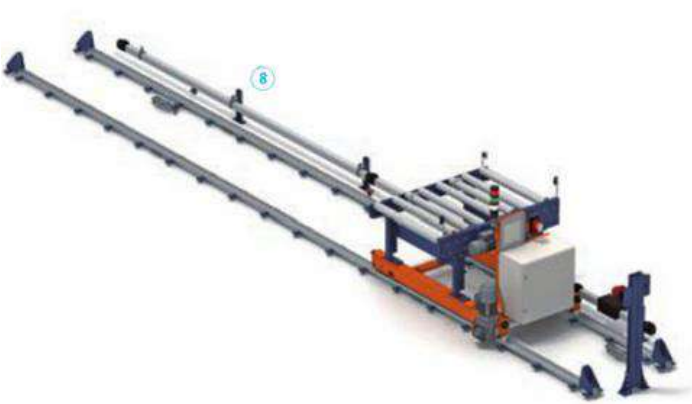


# Material handling equipment – conveyors

PW

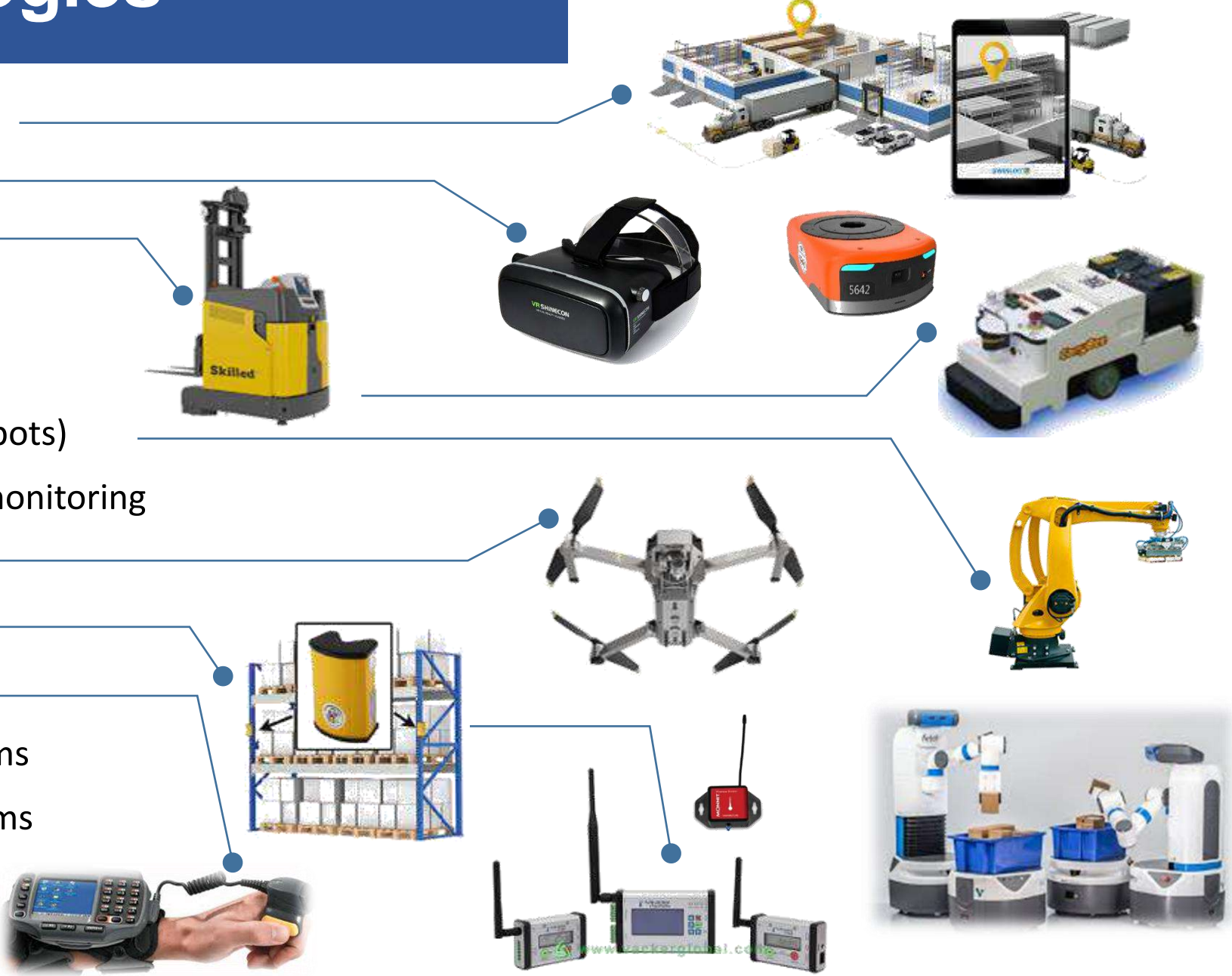


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# Emerging technologies

- Location systems in the facility space
- Virtual Reality (VR)
- Intelligent forklifts
- AGV Automated Guided Vehicles
- Automatic conveyor systems
- Robotized systems (autonomous, cobots)
- Intelligent building, environmental monitoring
- Industrial drones
- Sensor systems (IoT) and DWS
- Wearables and smartphones
- Speech and image recognition systems
- Biometric features recognition systems
- The people-technology connection



## 3. Information systems in warehousing and WAP

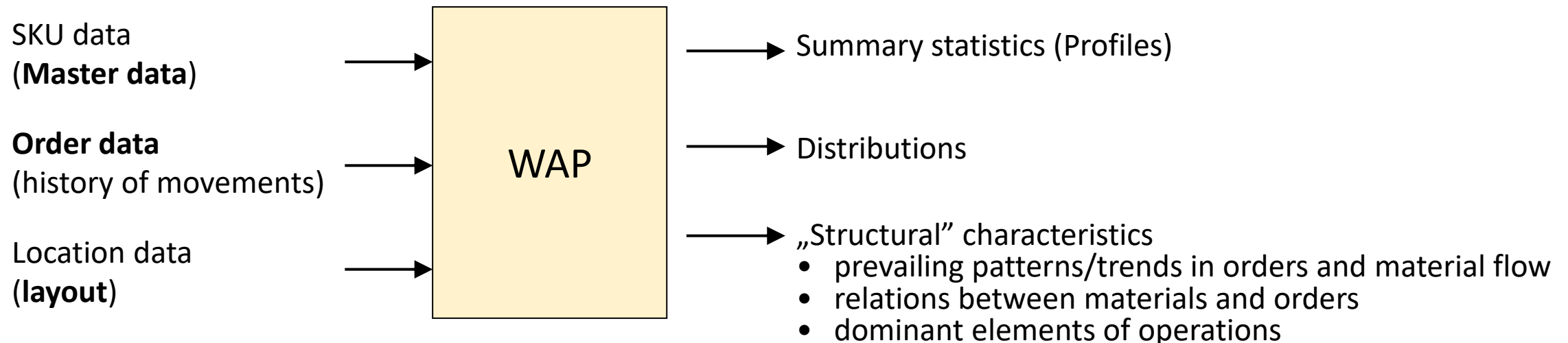


# Warehouse Activity Profiling (WAP)



Co-funded by the  
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of the European Union

- ❑ Measurement and statistical analysis of warehouse activity (items activity and order activity)
- ❑ ...to understand customers' orders that drive the system
- ❑ Sifting through historical data for opportunities and insights that might confer advantage
- ❑ Profiling is designed to readily identify root causes of material flow problems and information flow problems
- ❑ **Investigating labor consumption**



# Warehouse Activity Profiling (WAP)



Co-funded by the  
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of the European Union

(basic summary statistics)

- Order-related
  - average number of SKU's involved (work and storage complexity)
  - average number of orders shipped per day (volume of activity)
  - average number of lines (SKU's) per order (picking complexity)
  - average number of units per line
  - seasonality
- Facility-related data
  - area of the warehouse
  - average number of shipments received per day
  - average rate of introduction of new SKU's (operational stability)
  - average number of SKU's in the warehouse (volume and scope of operations)
  - distribution of the personnel to the various activities (labor-related costs and opportunities)

(basic profiles)

- Order mix distributions
    - Family mix distribution
    - Handling units mix distribution
    - Order increment distribution
  - Lines/Order distribution
  - Cubes (Weight)/Order distribution
  - Lines & Cubes/ Order distribution
  - Other
- 
- **Pareto Effect:** a small percentage of entities account for the largest fraction of the activity (20/80 rule)
  - **ABC/XYZ analysis:** exploit the Pareto effects in order to classify the considered entities into categories
  - **Slotting:** determining the most appropriate storage location for each item in the warehouse:
    - Space utilization
    - Material handling productivity
    - Process reliability
  - **Routing:** constructing picking paths
  - **Picking organization:**
    - Batchpicking / Multiorderpicking
    - Zonepicking
    - Wavepicking
    - Other
  - Task interleaving
  - Logics used in determining actual locations and sequences

# Warehouse Management System (WMS)



Co-funded by the  
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of the European Union

- ...software to track and manage warehouse activities.
- Built around an **industrial strength relational database**
- The most fundamental capability of a WMS is to **record receipt** of inventory into the warehouse and to **register its shipment out**.
- *Driving financial transactions*: receipt drives the paying of bills to suppliers upstream; and shipping drives the sending of invoices downstream to the consignee.
- The **core of a WMS is a database** of **skus** and a **stock locator system** so that one can manage both the *inventory of skus* and the *inventory of storage locations*.
- The database is updated simultaneously from multiple sources (purchasing, receiving, picking, shipping, etc.).
- WMS should **track the inventory** of storage locations in the warehouse.

# Logistics information flows



Co-funded by the Erasmus+ Programme of the European Union

## I. Logistics chain (logistics network) general management

- Multidirectional information flows in supply chain

- Planning and decision making
- Contact with clients and partners
- Coordination of the supply chain
- Business information

## II. Operational level

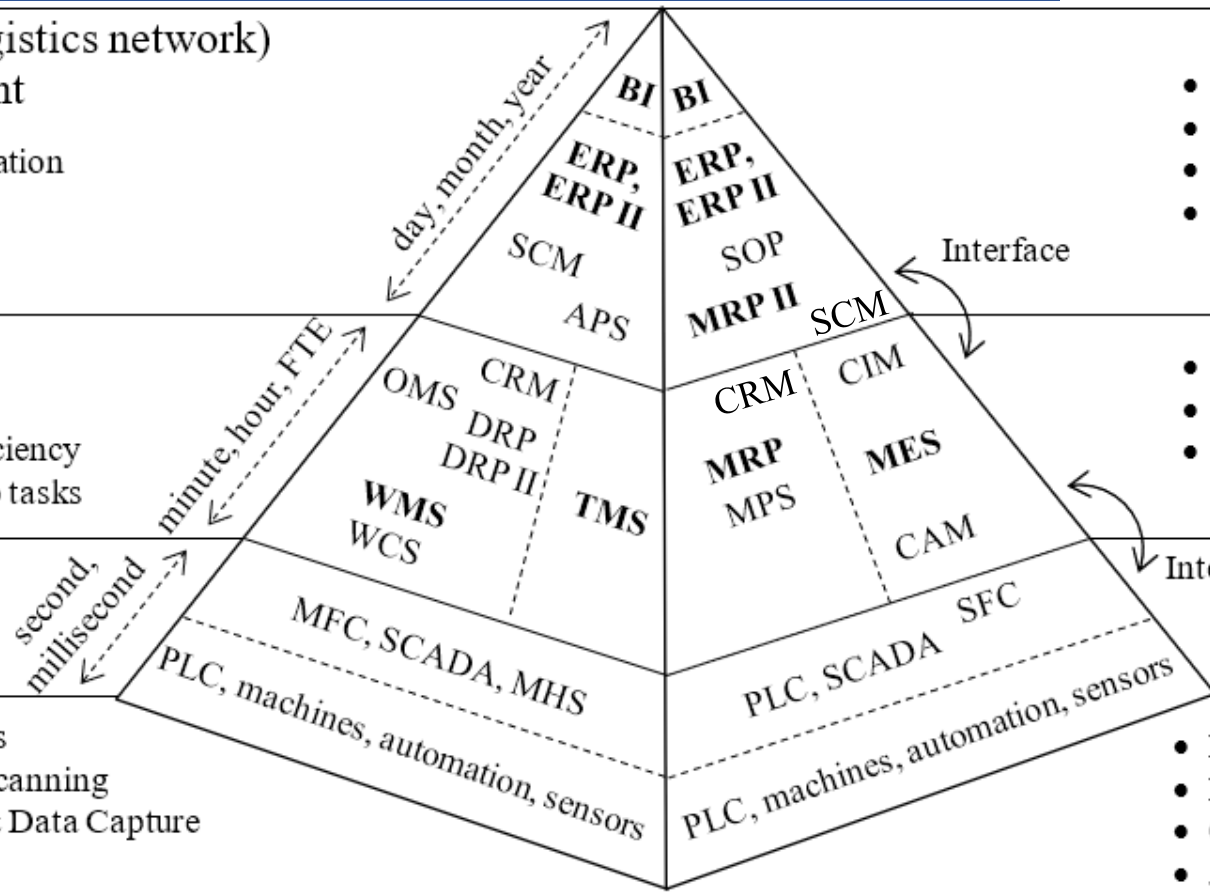
- Inventory control
- Maintaining systems' efficiency
- Allocation of resources to tasks

- Product engineering
- Product life cycle
- Maintaining production efficiency

## III. Machine (control) level

- Material Handling Systems
- Dimensioning & Weight Scanning
- Automatic Identification & Data Capture
- Warehouse automation

- Production execution systems
- Production automation
- Control and identification systems
- Job shop control



APS – Advanced Planning System  
 BI – Business Intelligence  
 CAM – Computer Aided Manufacturing  
 CIM – Computer Integrated Manufacturing  
 CRM – Customer Relationship Management  
 DRP – Distribution Requirements Planning  
 DRP II – Distribution Resources Planning  
 ERP – Enterprise Resource Planning

MES – Manufacturing Execution System  
 MFC – Material Flow Control  
 MPS – Master Production Schedule  
 MRP II – Manufacturing Resources Planning  
 MRP – Material Requirements Planning  
 OMS – Order Management System  
 PLC – Programmable Logic Controller  
 SCADA – Supervisory Control and Data Acquisition

SFC – Shop Floor Control  
 SCM – Supply Chain Management  
 SOP – Sales and Operation Planning  
 TMS – Transport Management System  
 WCS – Warehouse Control System  
 WMS – Warehouse Management System

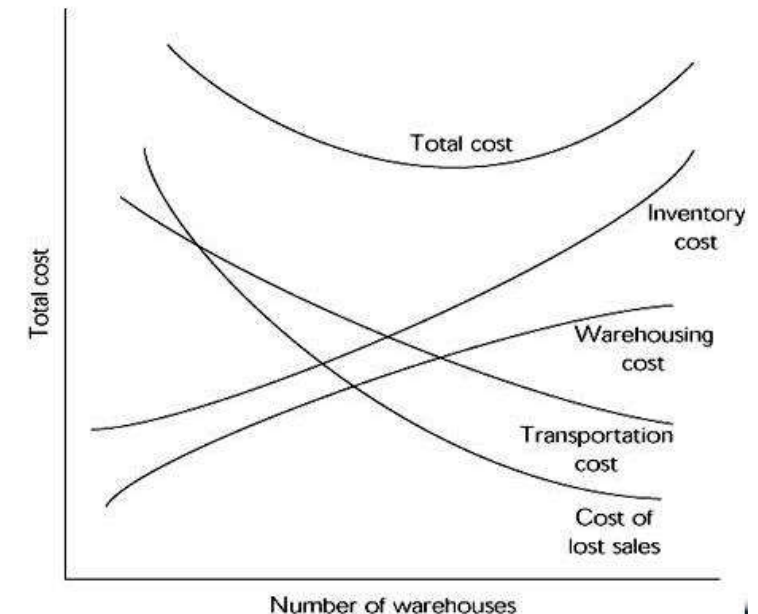
## 4. Teaching warehousing in WUT

# Teaching warehousing



## I. Supply chain analysis

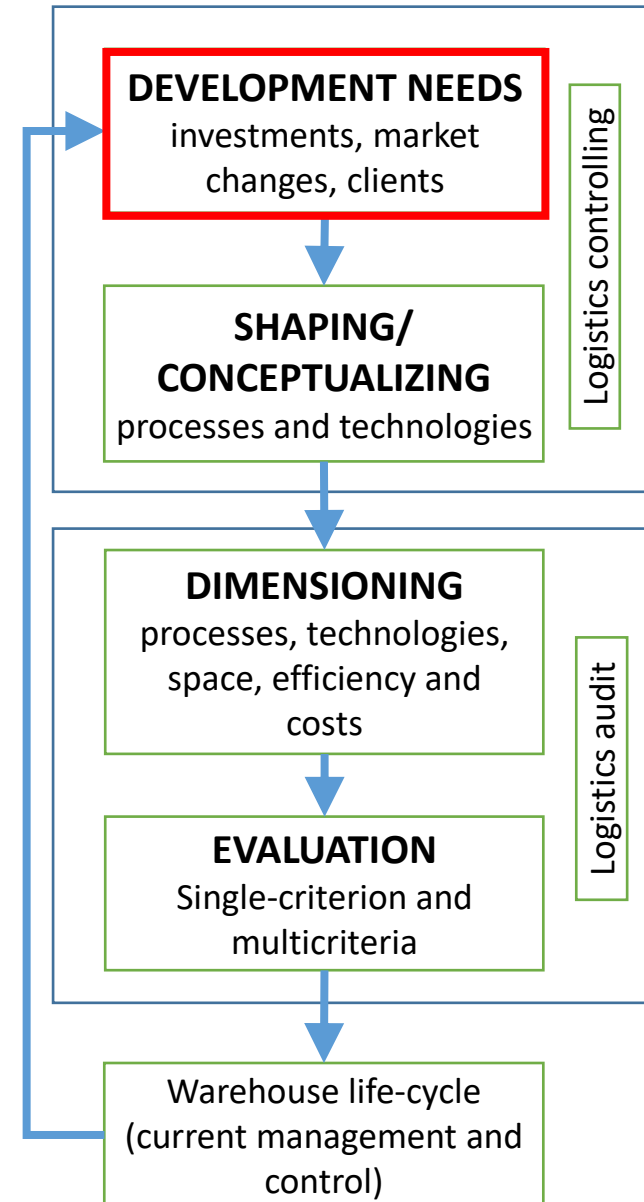
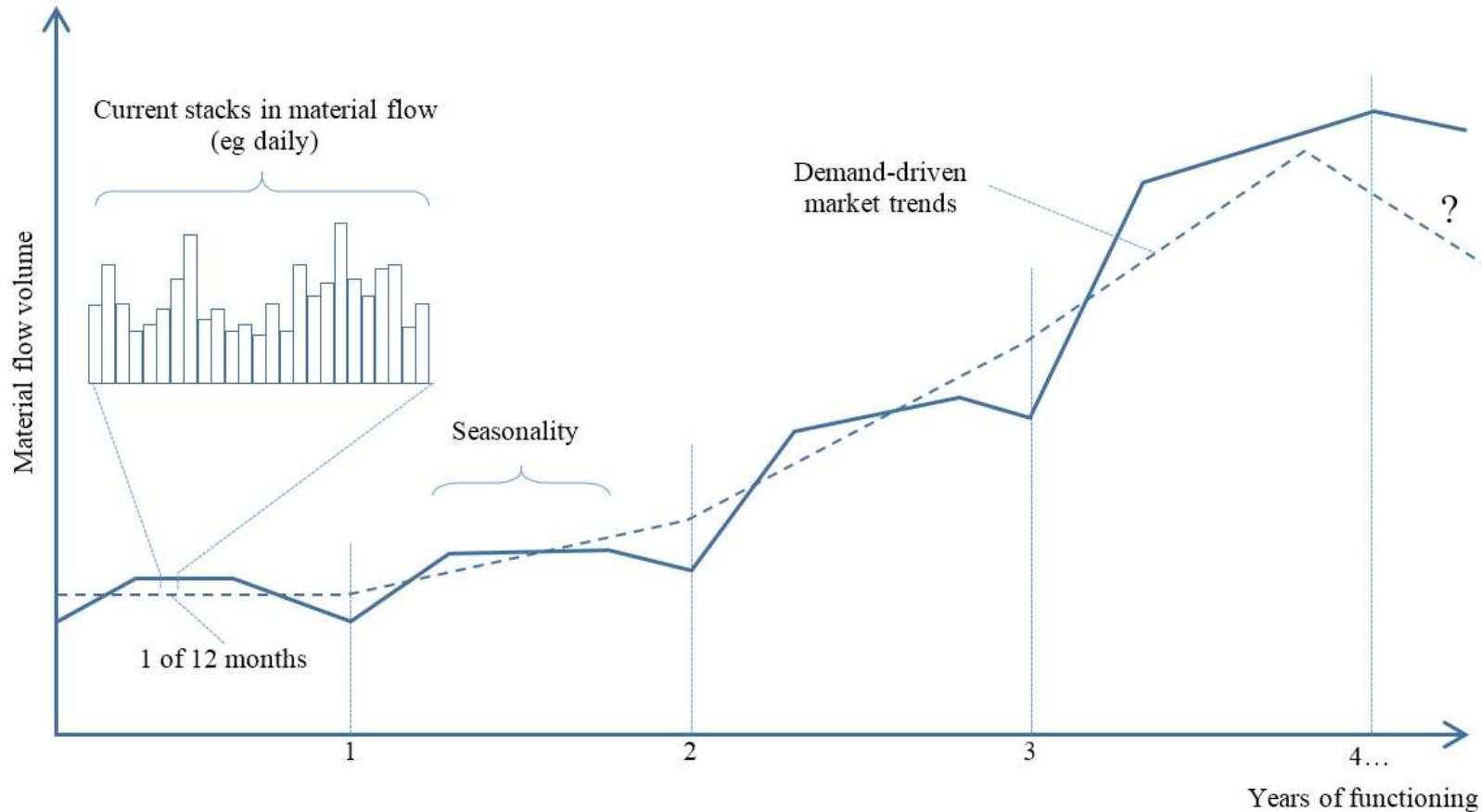
1. Continuous tracking of trends and challenges in global warehousing
2. The structure of the logistic network (hierarchical, centralized)
3. Introducing warehouse in the supply chain
4. Strategic planning of warehouses - investments in infrastructure
5. Ownership structure (outsourcing, external warehouse, rental, own buildings)
6. Physical localisation
7. Inventory analysis and forecasting
8. Stock control system



# Teaching warehousing

## II. Formulating a logistics task

1. Warehouse Activity Profiling
2. Input and output flow volumes (average and reliable, pile-up coefficients)

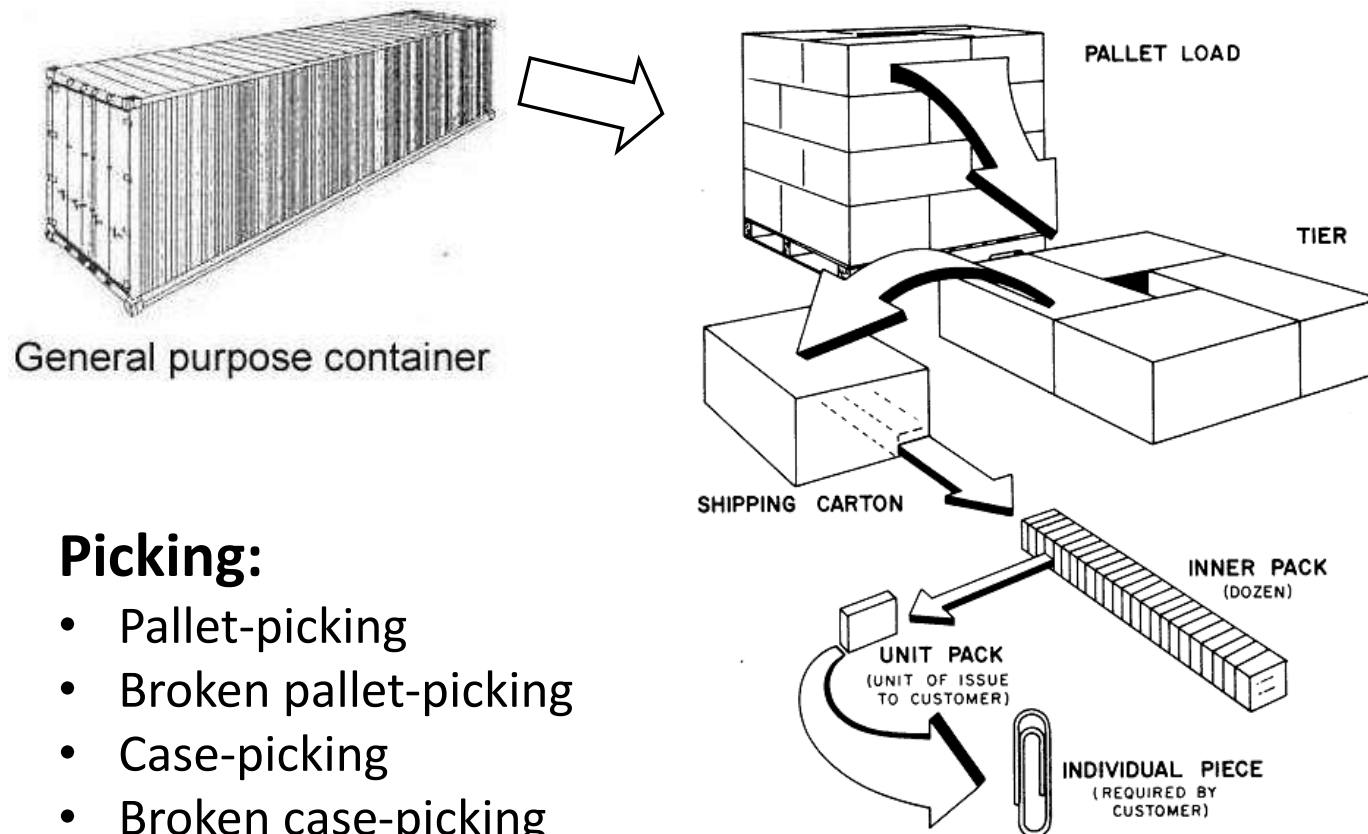




# Teaching warehousing

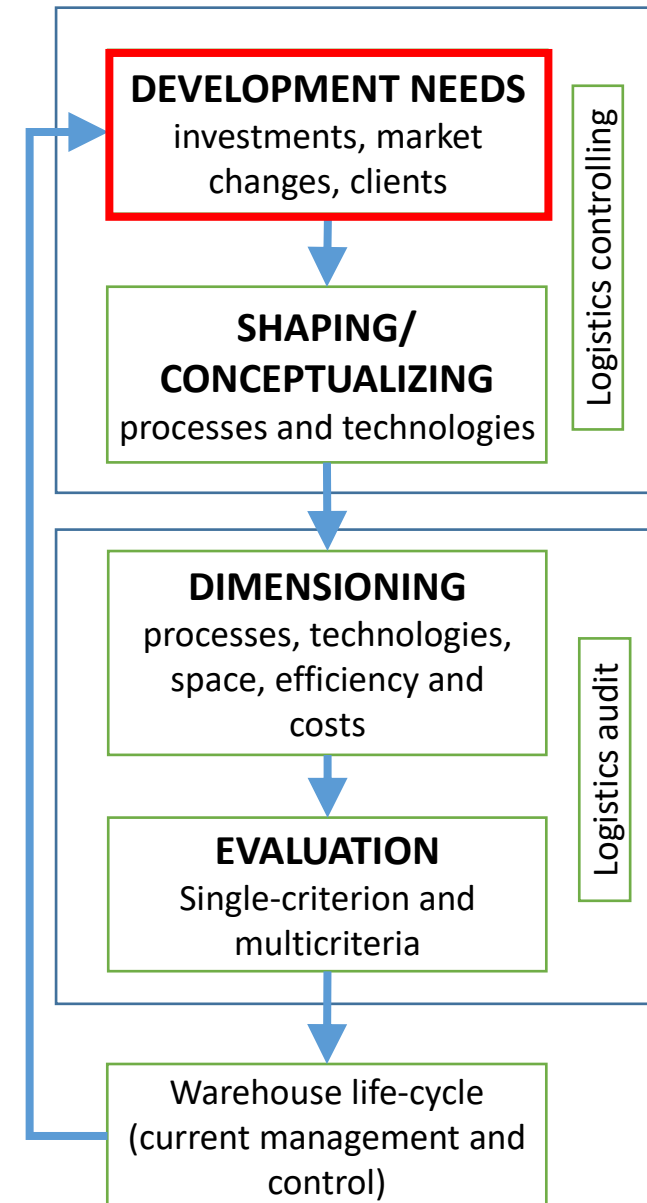
## II. Formulating a logistics task

### 3. Physical flow structure and special requirements



### Picking:

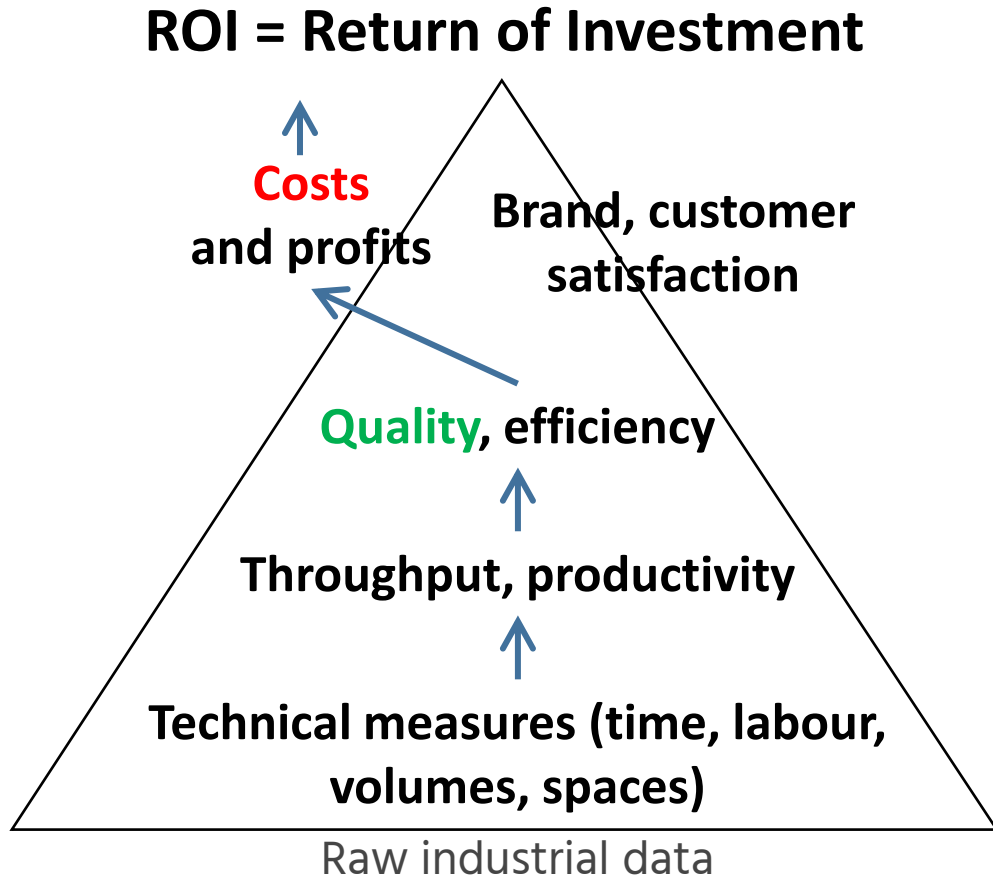
- Pallet-picking
- Broken pallet-picking
- Case-picking
- Broken case-picking



# Teaching warehousing

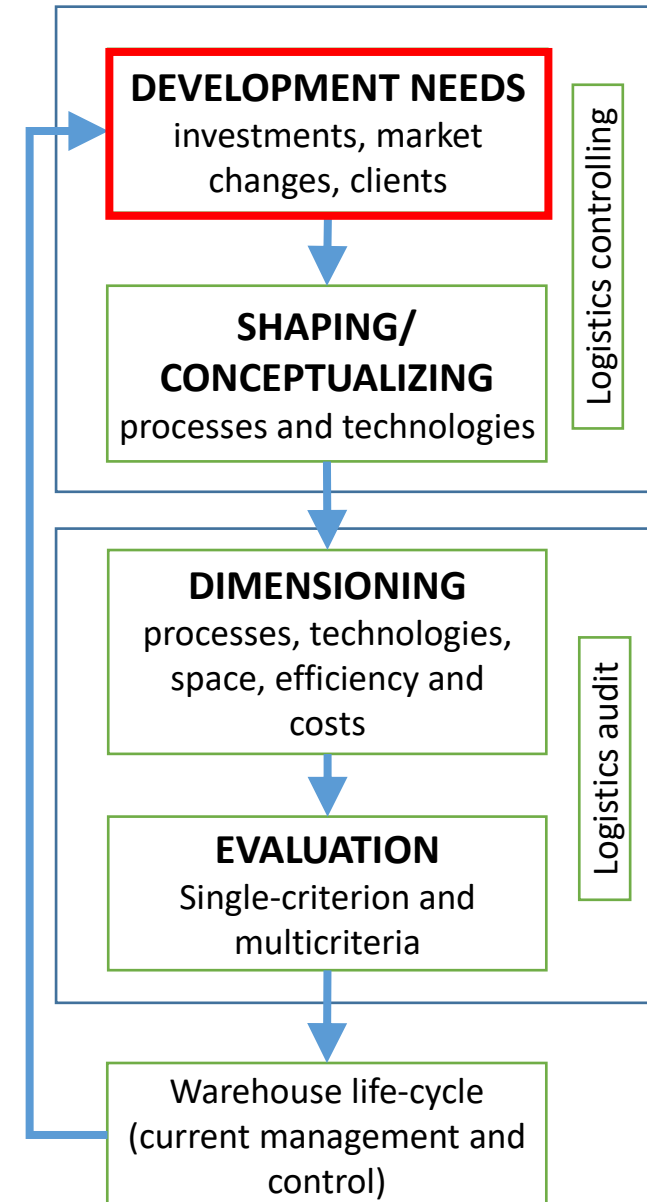
## II. Formulating a logistics task

### 4. Evaluation criteria (KPIs) for warehouse design



Quality of warehouse services:  
(*OTIFEF – on-time, in-full, error-free*)

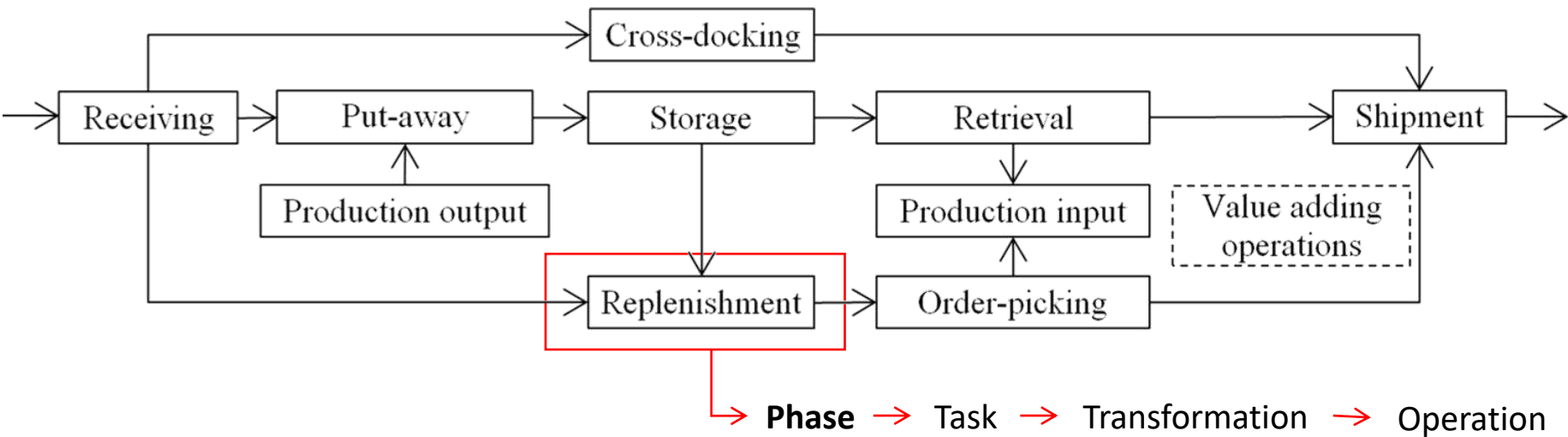
$$OTIFEF = \frac{LZ_{otifef} \cdot 100\%}{LZ}$$



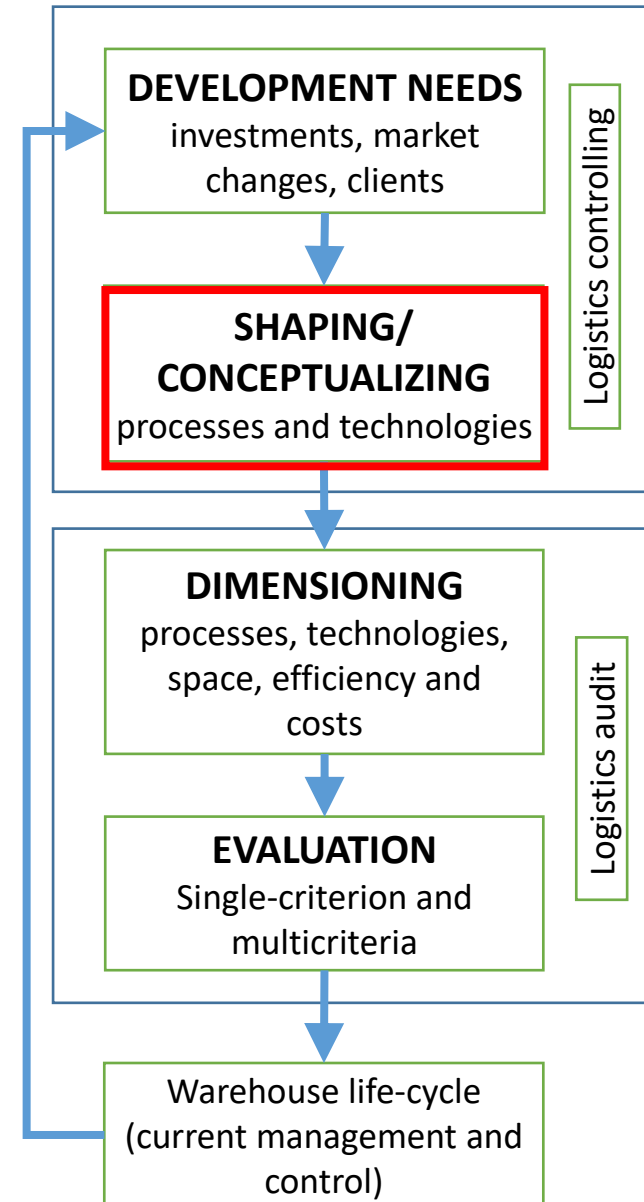
# Teaching warehousing

## III. Conceptualization of technological variants of the warehouse

### 1. Warehouse process (material flow) concept

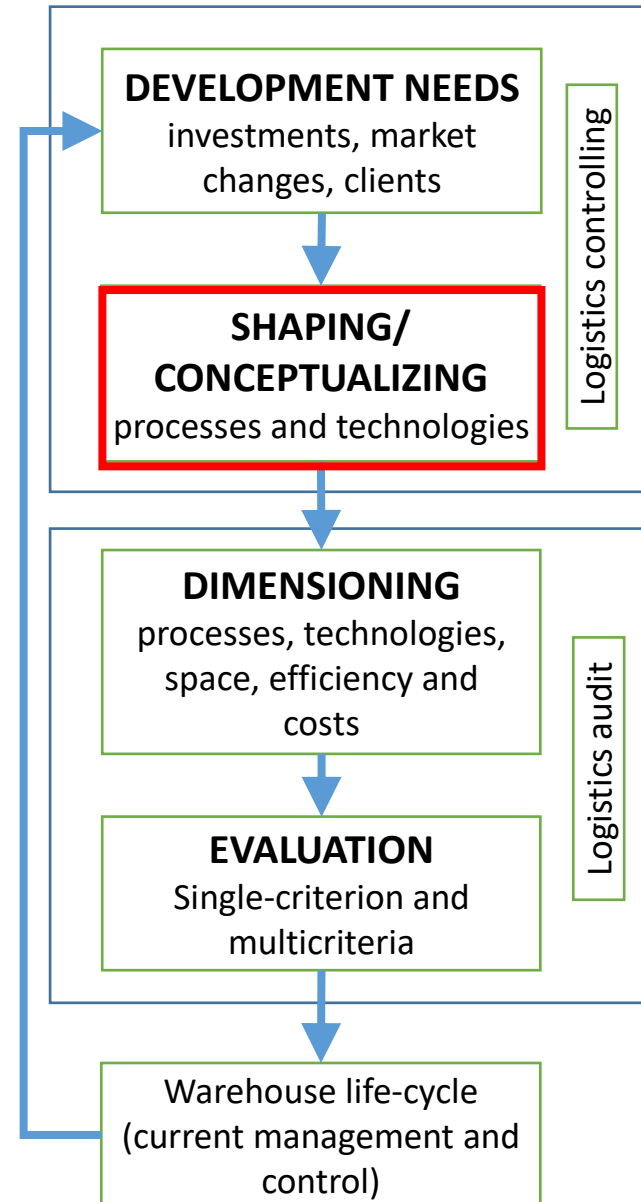
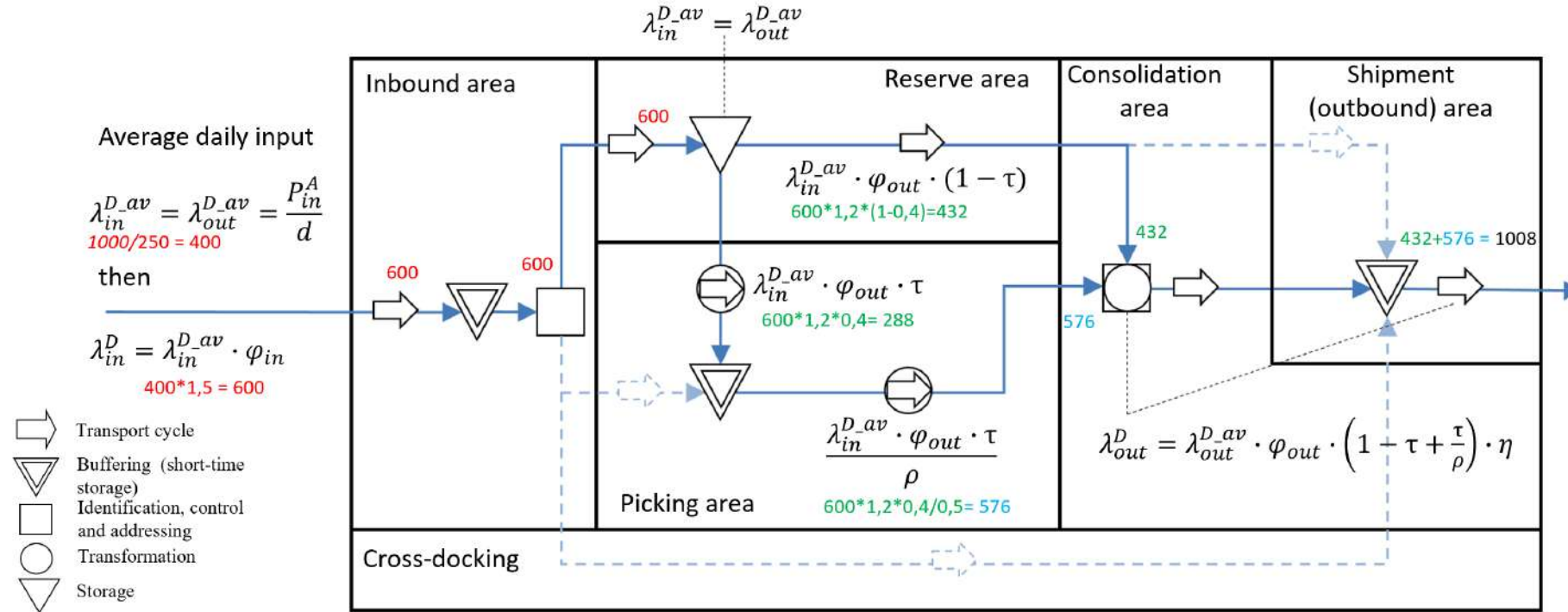


Simple flow  
 Standard flow  
 Complex flow



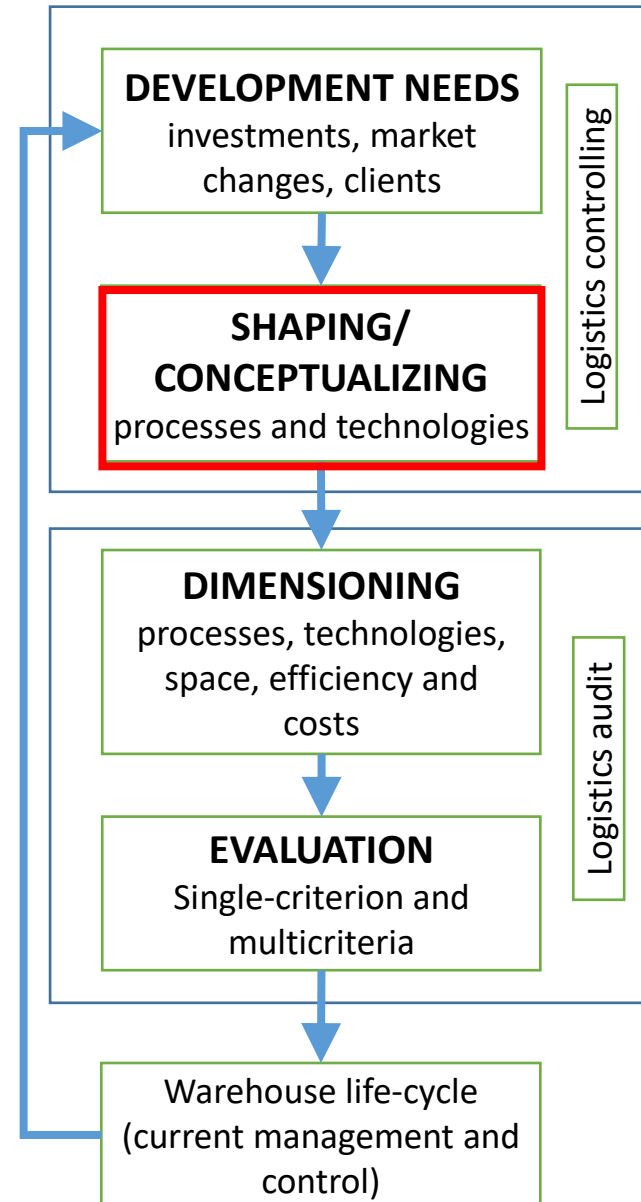
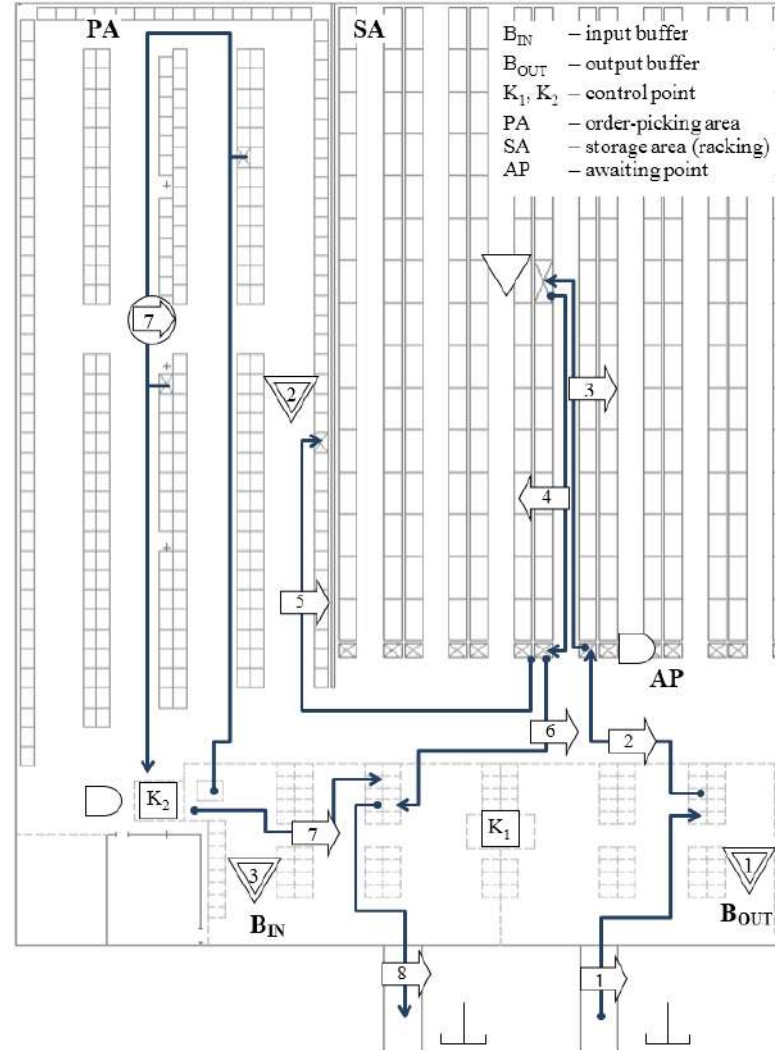
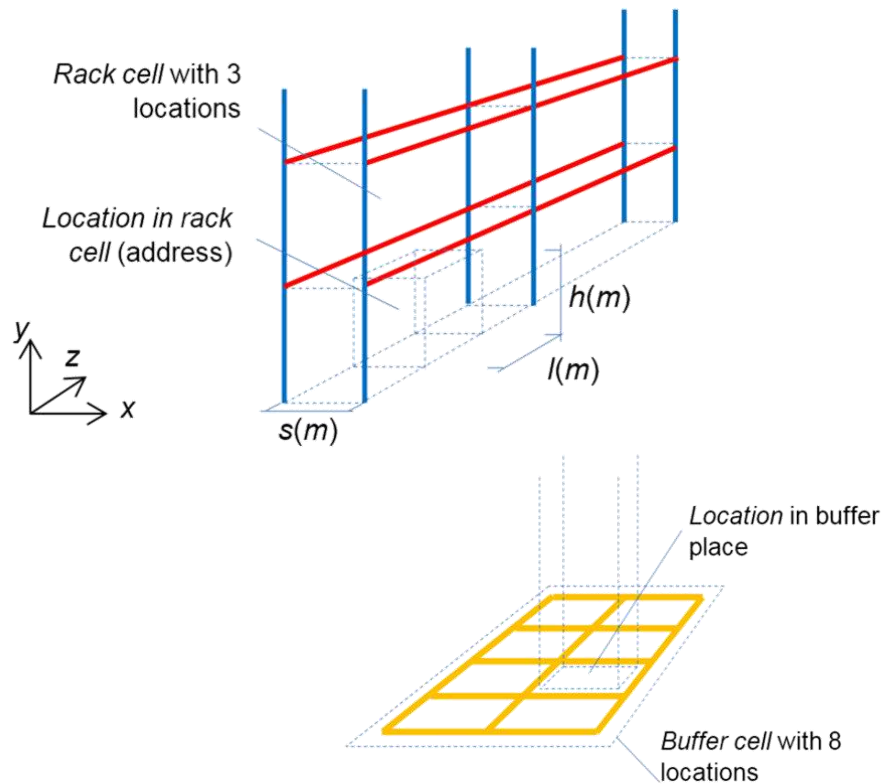
## III. Conceptualization of technological variants of the warehouse

### 1. Warehouse process (material flow) concept



## III. Conceptualization of technological variants of the warehouse

2. Functional layout of the facility
3. Building structure (arrangement of construction pillars, floor parameters)



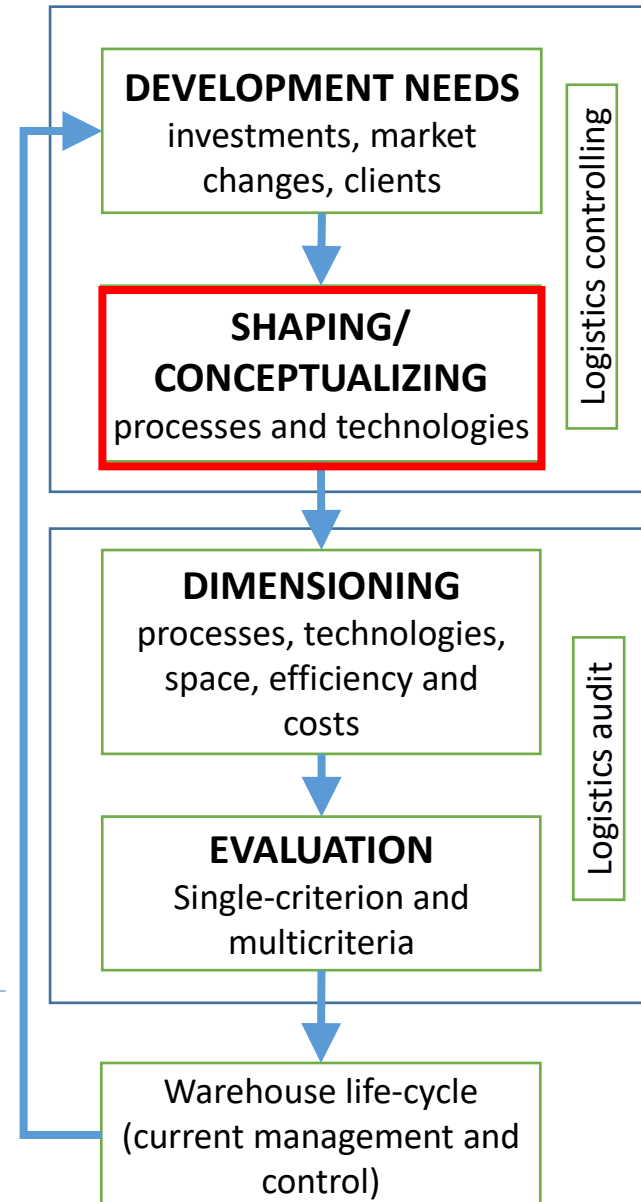
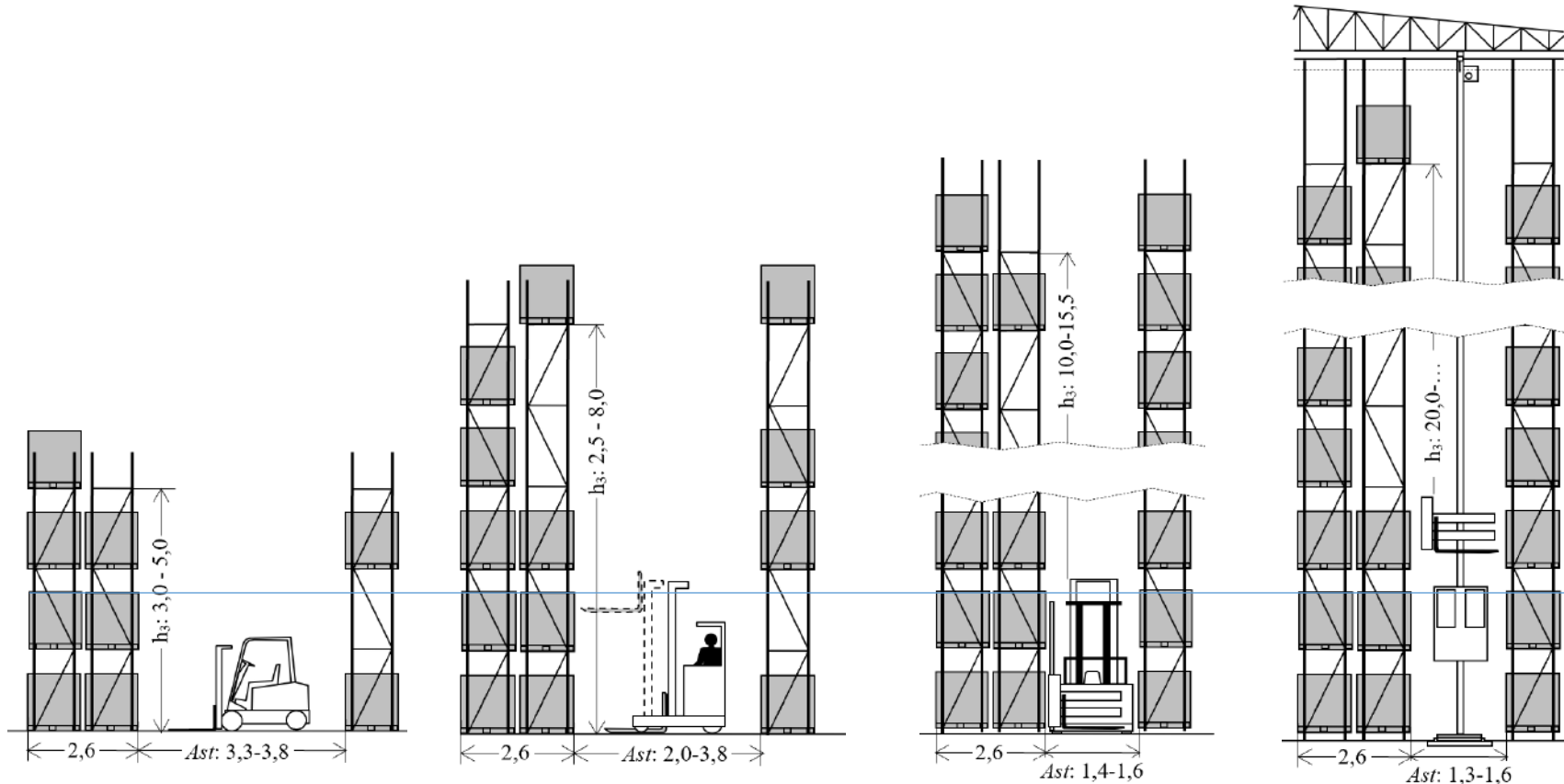
# Teaching warehousing



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## III. Conceptualization of technological variants of the warehouse

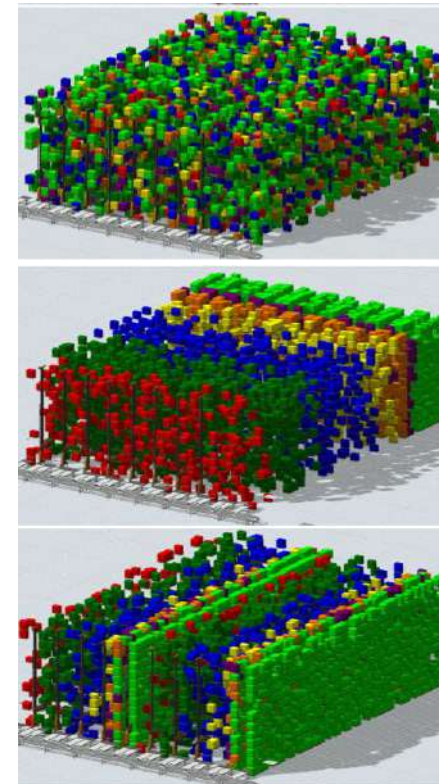
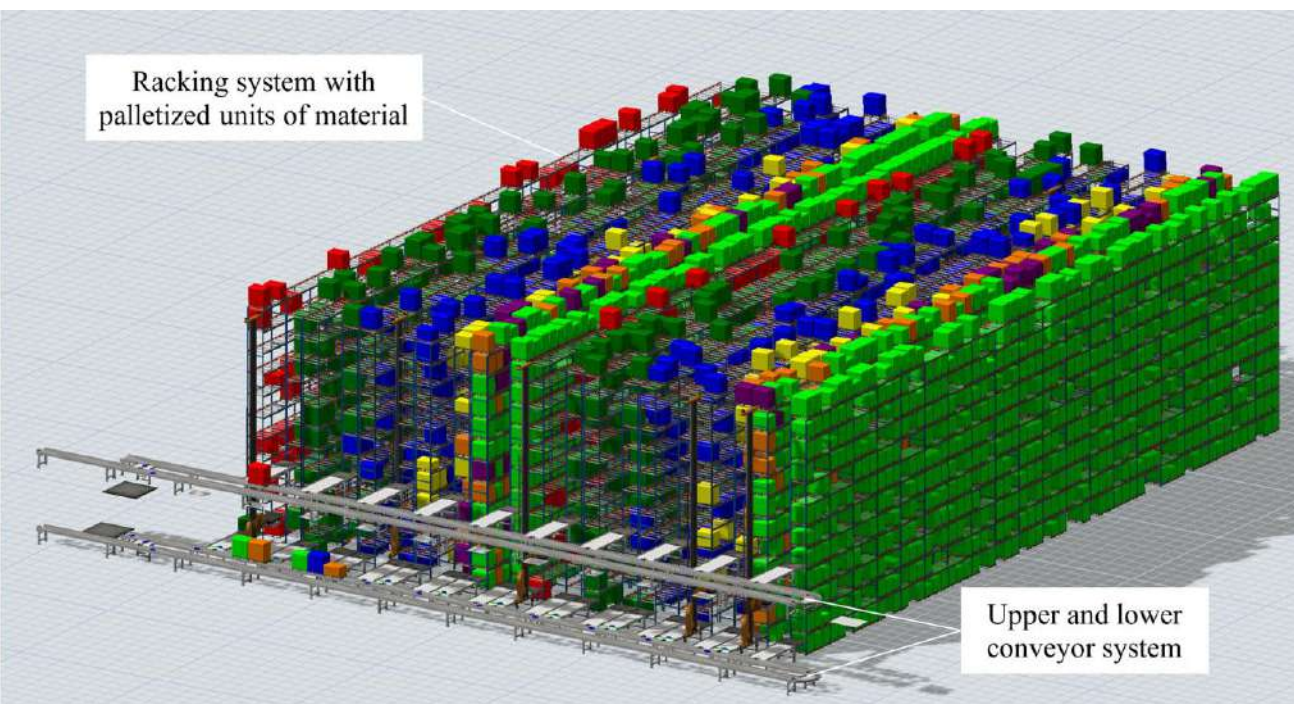
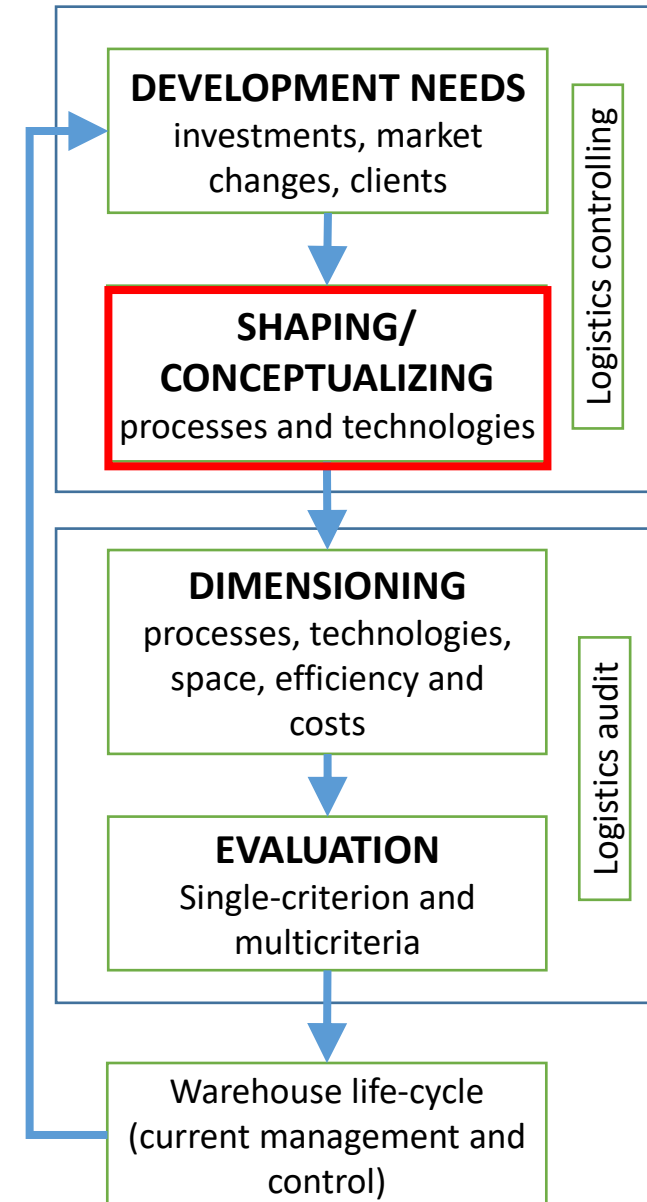
- 4. Storage systems (racking),
- 5. Internal transport (equipment, labour, mechanization, automation)
- 6. Picking, sorting and packing technologies



# Teaching warehousing

## III. Conceptualization of technological variants of the warehouse

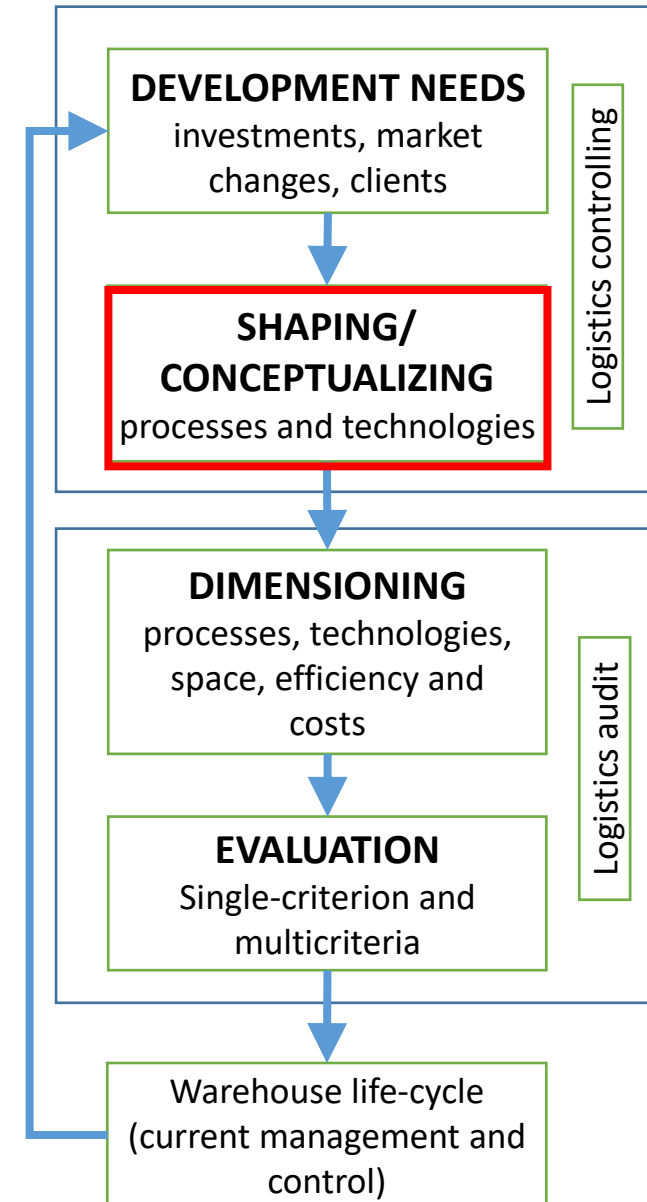
4. Storage systems (racking),
5. Internal transport (equipment, labor, mechanization, automation)
6. Picking, sorting and packing technologies
7. Loading subsystems
8. Pedestrian traffic



# Teaching warehousing

## III. Conceptualization of technological variants of the warehouse

9. Allocation of resources (employees and equipment) to the proces tasks
10. Warehouse logic and slotting patterns
11. WMS functionalities and relation to superior and subordinated systems
12. Automatic Identification and Data Capture (AIDC) and Dimension & Weight Scanning (DWS)
13. Security systems (e.g. fire protection)

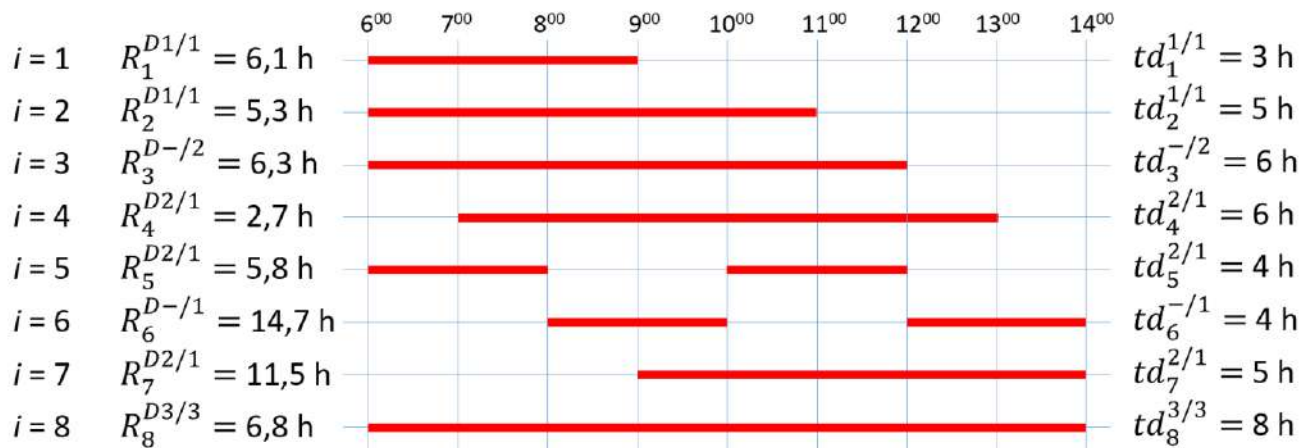




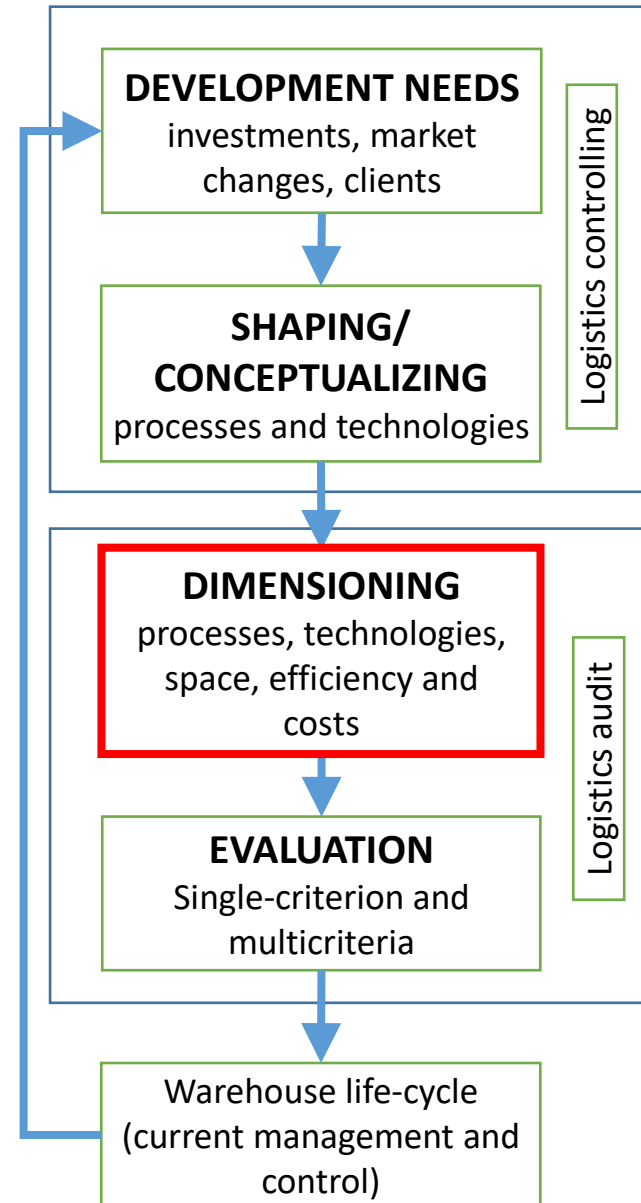
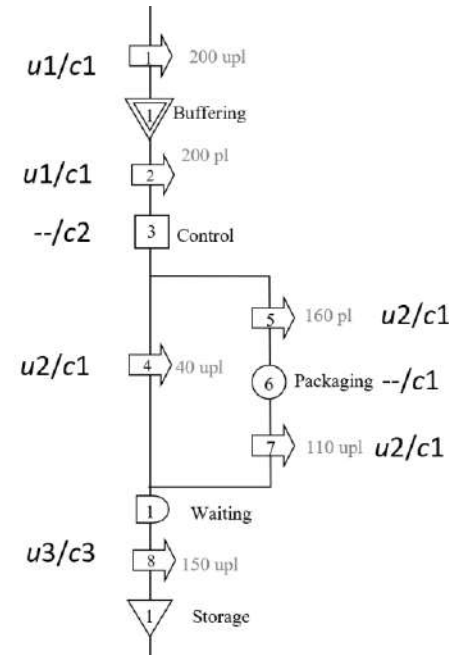
# Teaching warehousing

## IV. Dimensioning of a warehouse facility

### 1. Scheduling the warehouse process (time windows)



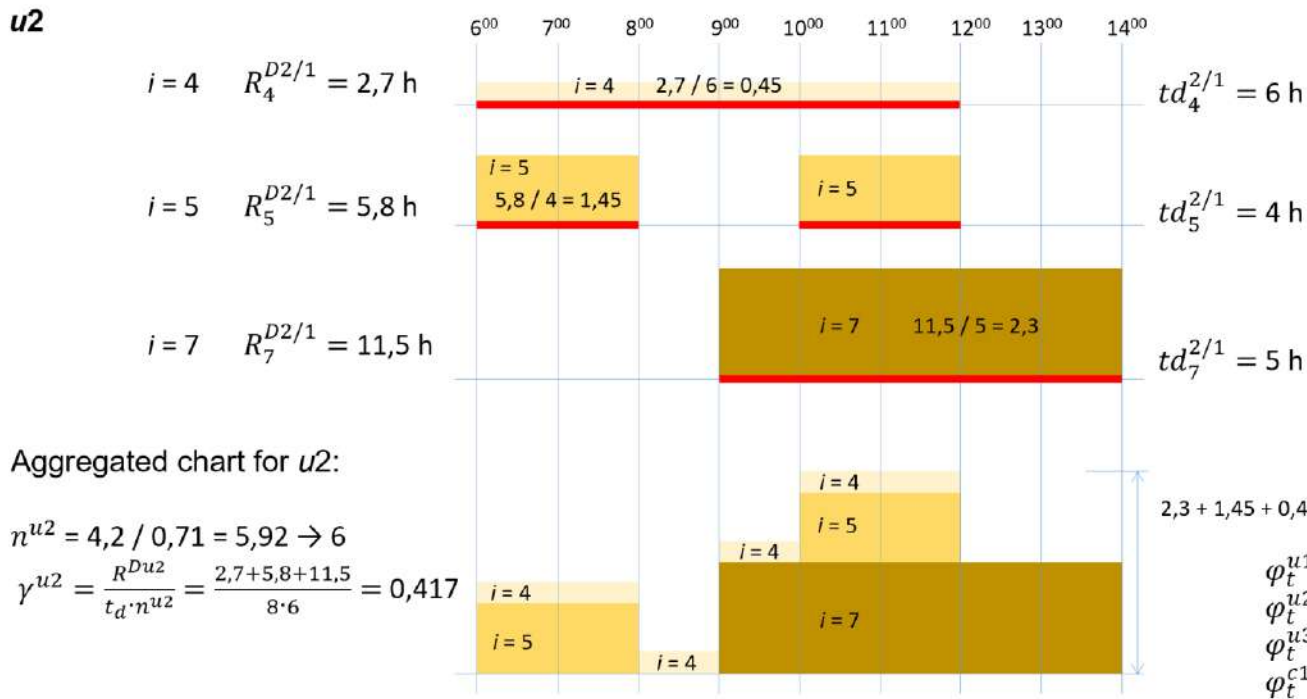
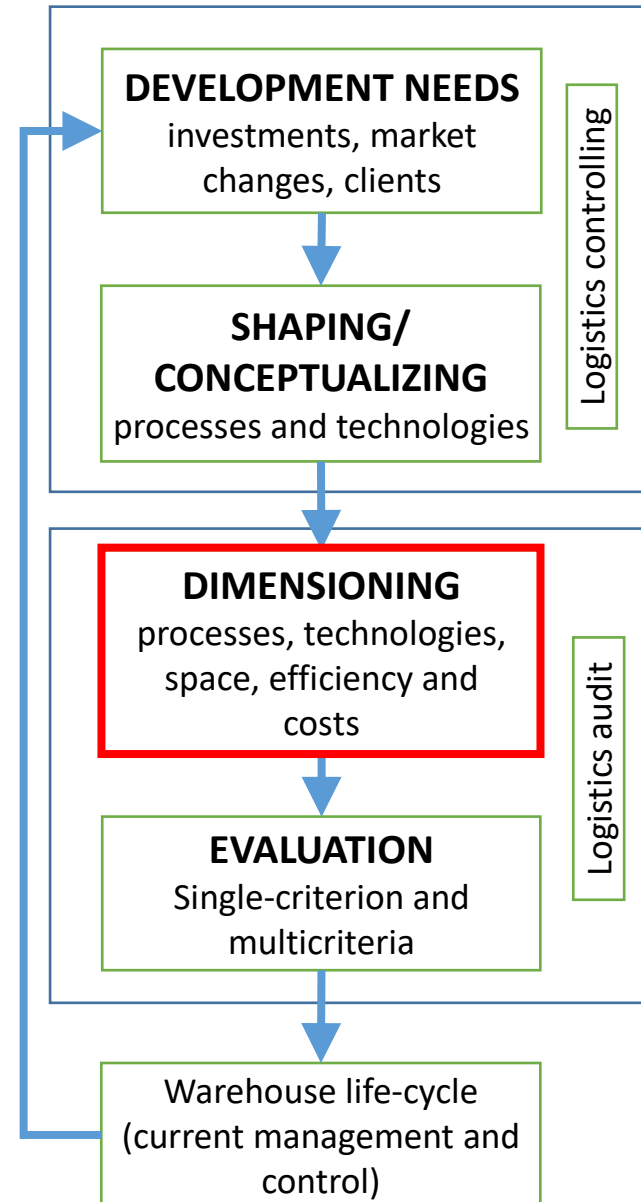
The tasks have different disposed times for realization



# Teaching warehousing

## IV. Dimensioning of a warehouse facility

2. Calculation of the unit times of warehouse operations
3. Setting time utilization coefficients
4. Determining the labour consumption of warehouse activities
5. Calculation of the number of resources (people and devices)



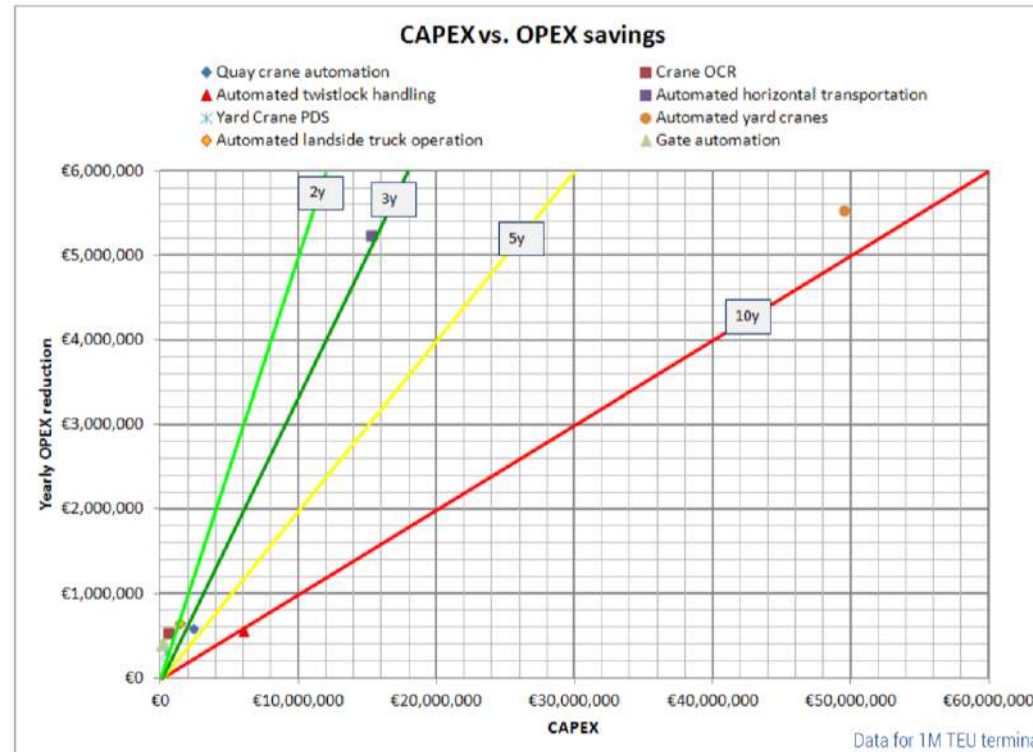
$$n^u = \left[ \frac{\sum_{i \in I} R_i^{Du}}{td^u \cdot \varphi_t^u} \right]$$

$$n^c = \left[ \frac{\sum_{i \in I} R_i^{Dc}}{td^c \cdot \varphi_t^c} \right]$$

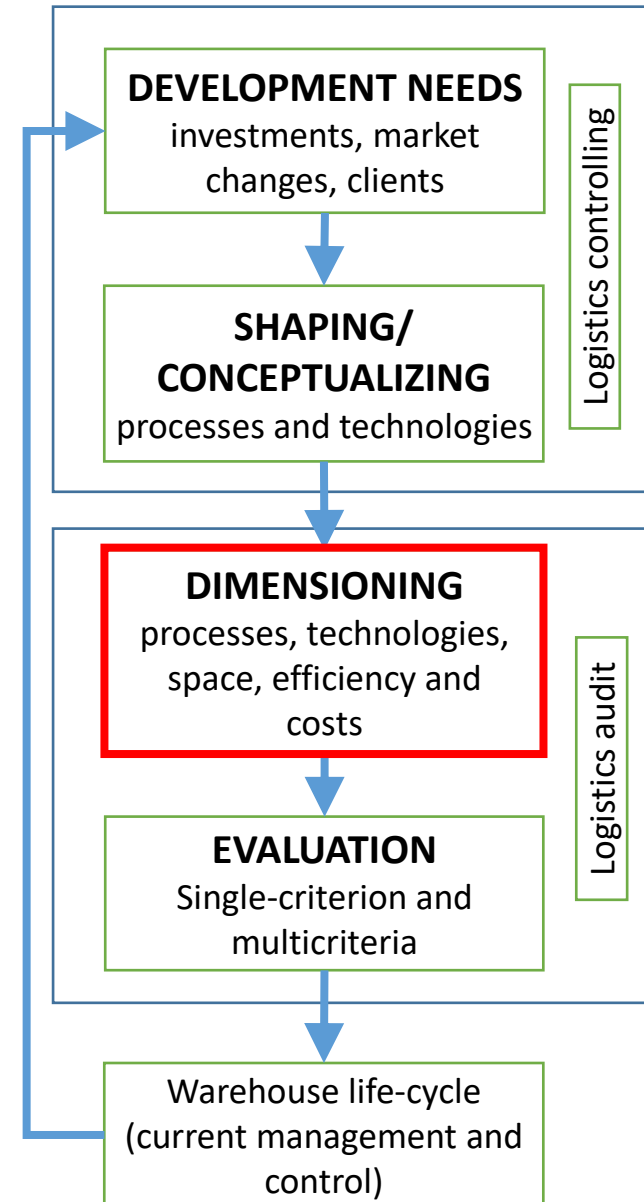
# Teaching warehousing

## IV. Dimensioning of a warehouse facility

6. Calculation of investment outlays
7. Calculation of operating costs (CAPEX, OPEX)
8. ABC / ACB
9. Calculation of selected key performance indicators
10. Determining the ROI



Automation: Experiences & Lessons learnt / (c) TBA



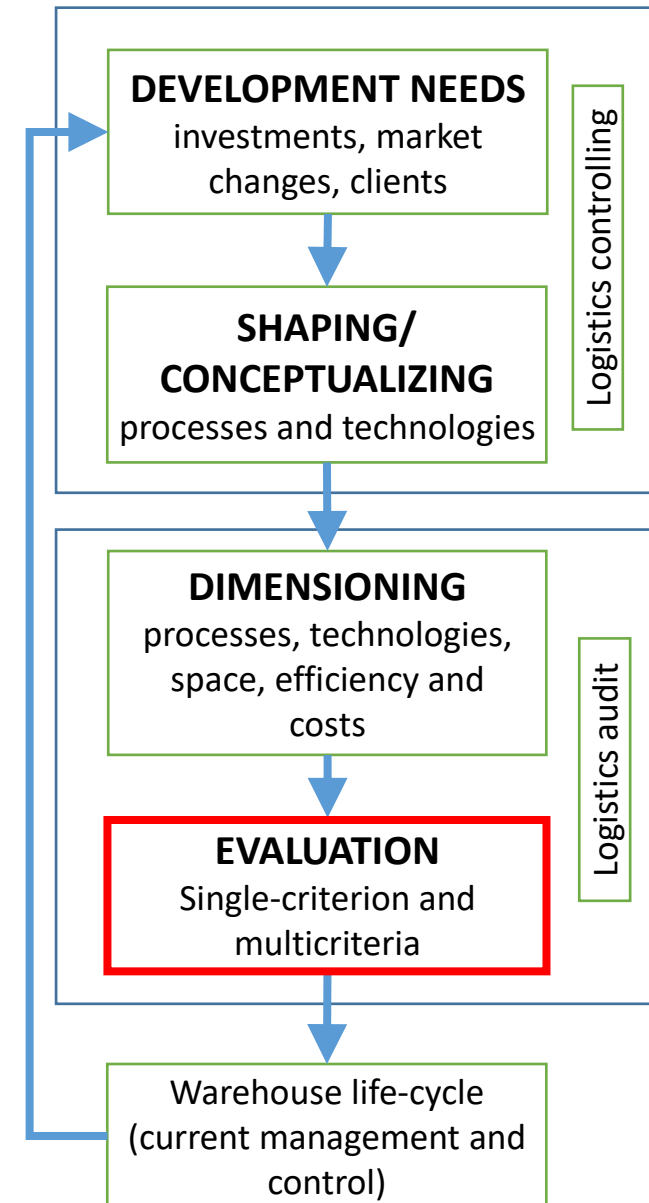
# Teaching warehousing

## V. Assessment and selection of the preferred solution

1. Key performance indicators pannels for warehouse options
2. Benchmarking
3. Single-criterion assessment
4. Multi-criteria assessment

## VI. Additional activities

1. Preliminary simulation
2. Digital twin or digital shadow planning and implementation



# Teaching warehousing



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## Design / teaching support

1. Simulation (FlexSim)
2. Virtual Reality
2. Data processing (WAP) – VBA, SQL
3. Analytical procedures
4. BPMN (Business Process Modelling Notation)
5. Logistics audit procedures
6. Optimization methods

## Laboratory of Warehouse Process Management



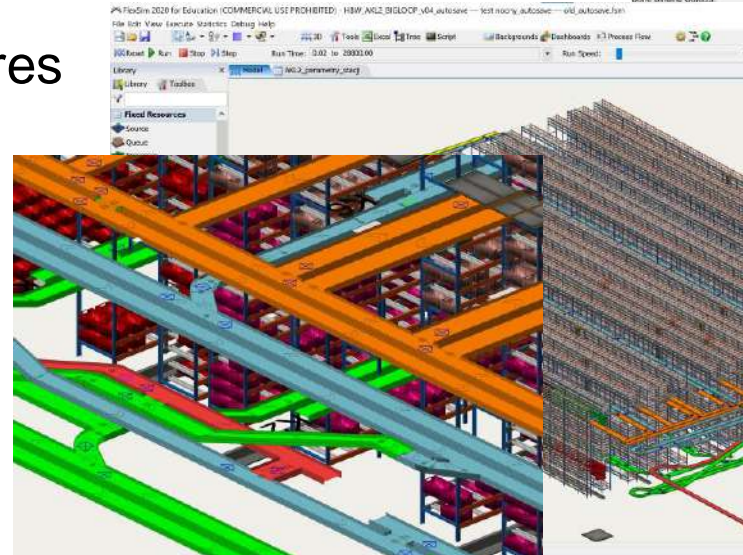
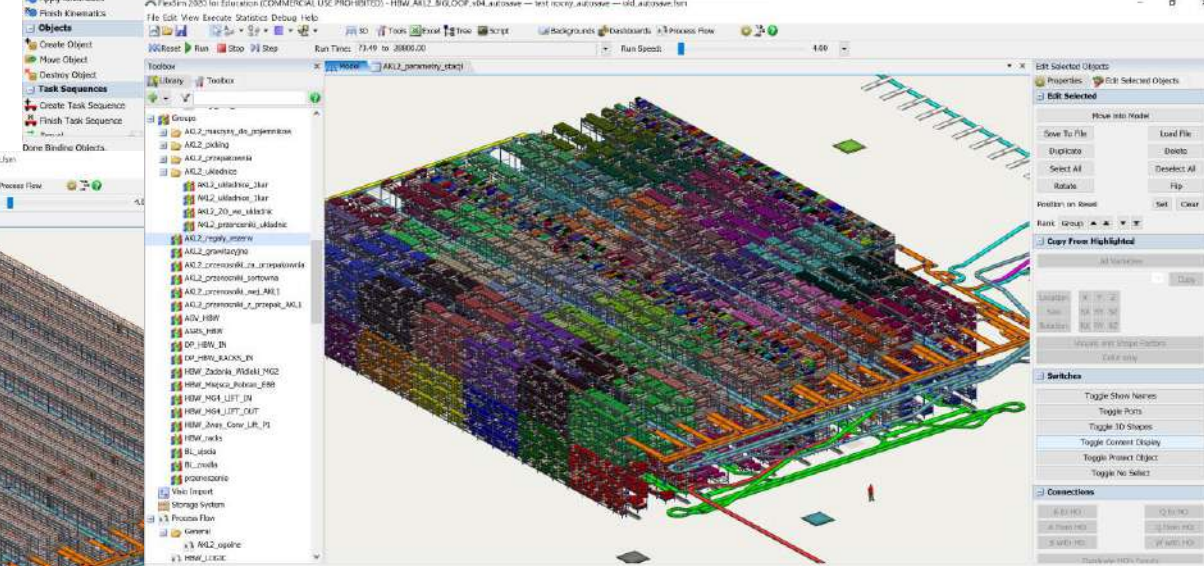
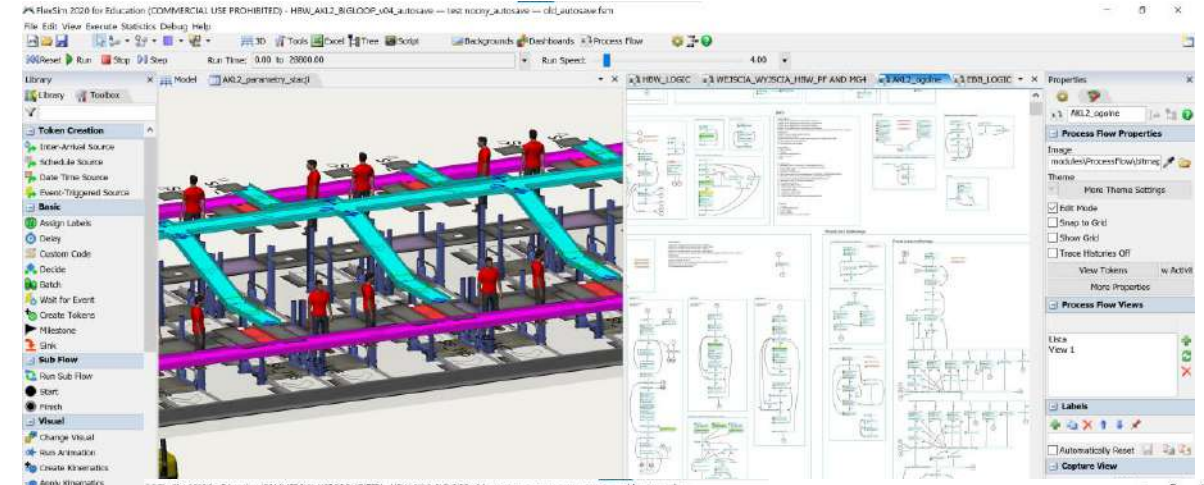
# Teaching warehousing



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# Teaching warehousing



## Design / teaching support

1. Simulation (FlexSim)
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- 4. BPMN (Business Process Modelling Notation)**
5. Logistics audit procedures
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BPMN

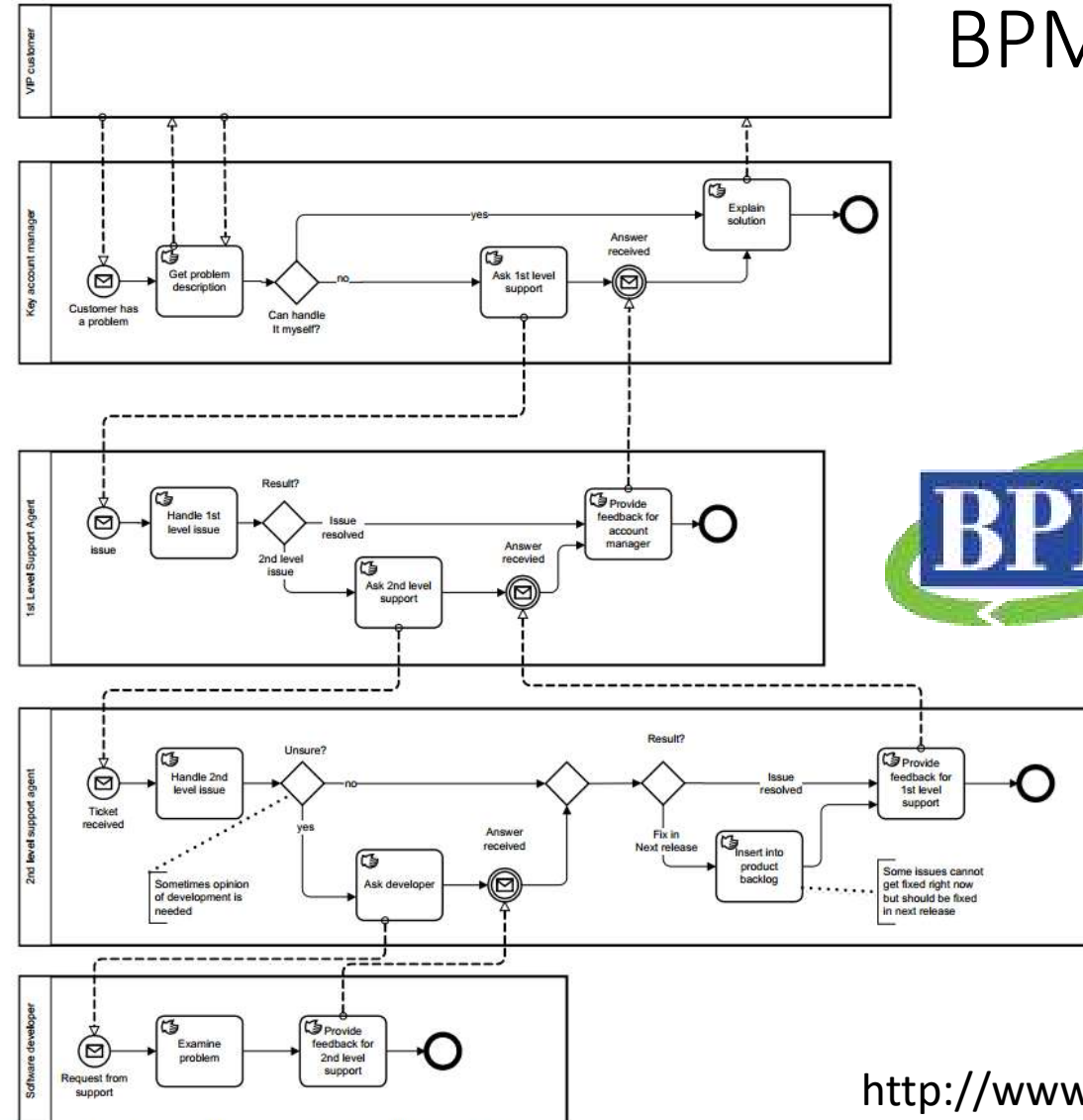


Figure 6.2: Incident Management as detailed collaboration

## Design / teaching support

1. Simulation (FlexSim)
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3. Analytical procedures
4. BPMN (Business Process Modelling Notation)
5. Logistics audit procedures
6. **Optimization methods**

Warehouse logics are based on the **optimization tasks**, (often NP-difficult) :

- Traveling salesman and n-traveling salesmens problem
- Backpack problem
- The allocation of resources to tasks
- Scheduling problems
- Minimization of empty runs
- Mass service theory (queue theory)
- Mechanics and structure durability



Master Classes Feb 16, 2022



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CBHE ERASMUS+ 2018: Crisis and Risk Engineering for Transport Services

**Thank you for attention!**

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