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Session 7: Warehouse operations

35E00750 Logistics Systems and Analytics

Dr. Tri M. Tran
Assistant Professor of Operations Management
University of Groningen
https://www.rug.nl/staff/tri.tran/

Distribution centers in the supply chain

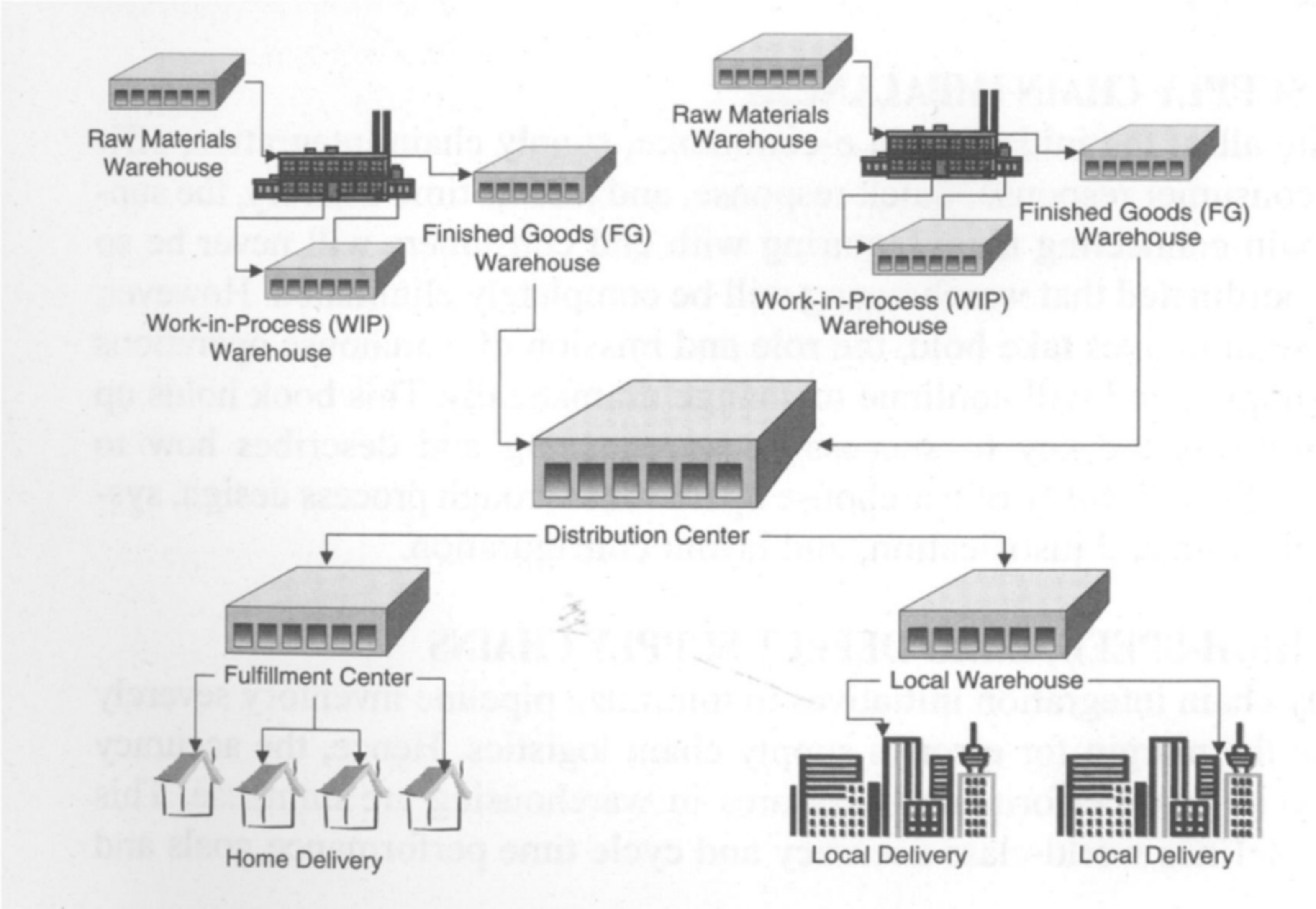
The role of the warehouse includes activities beyond product storage and shipment.

Warehouses could also do:

- coordinate the material and information flows among multiple supply chain participants
- The warehouses modify the materials and conduct several value-added processing (VAP) tasks

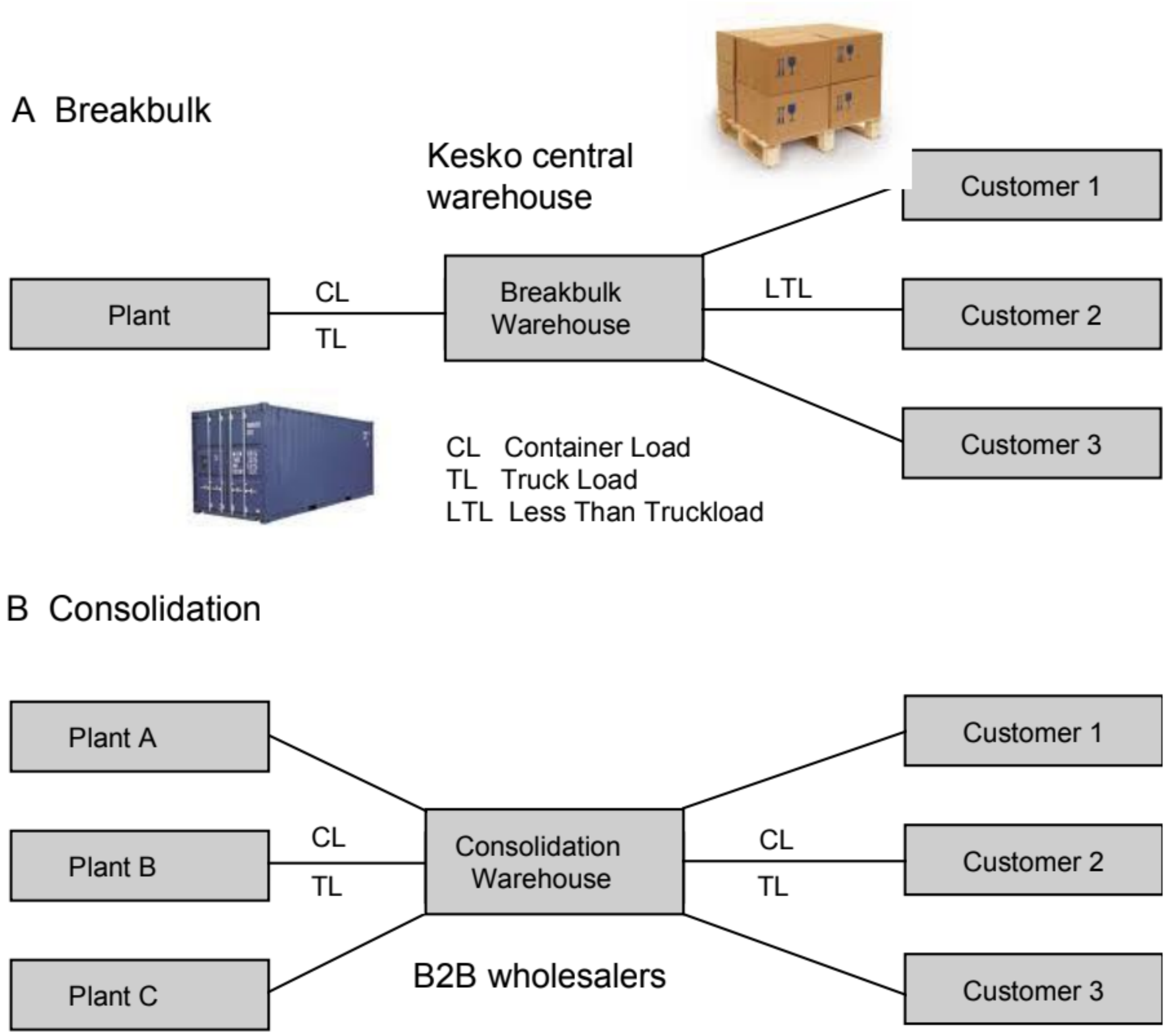
Distribution centers in the supply chain

Warehouse types



Distribution centers in the supply chain

Warehouse functions



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Distribution centers in the supply chain

- **The pressure on warehouses to be cost effective and responsive has increased over the years.**

- **Advances in technology have also profoundly affected warehouses.**

Distribution center in the supply chain

Numerous objectives

- Shorter cycle times
- Lower inventory
- Lower costs
- Improved customer service levels
- And added value

Need for advanced technologies

- **New redesign and/or increased automation to achieve order processing and cost goals**

- **Relocation of facilities to achieve overall supply chain service goals**

See how Amazon is using new robots to deliver orders even faster

https://www.youtube.com/watch?v=2IldVQbDmXM

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DC-related decisions

Ownership of warehouses

Ownership

- Public versus contract versus private

Centralized or Decentralized Warehousing

- How many
- Location
- Size
- Layout
- What products where

Factors to consider

- Throughput volume
- Stability of demand
- Density of market area to be served
- Security and control needs
- Customer service needs
- Multiple use needs of the firm

Private or Public Distribution Center?

- **Combing public and private warehousing because**
  - of varying regional market conditions
  - customer volumes and requirements
  - and other factors (e.g., seasonality)
- **Private warehouse/DCs**
  - Stable demand:
    - *many larger firms have multiple product lines, and this helps stabilize the DC throughput to build the volume necessary for an economical, private DC*
  - Dense market area
    - *dense market areas relatively close to the warehouse or numerous vendors relatively close to physical supply DCs*
  - Control:
    - *Physical control (e.g., security or refrigeration)*
    - *Service control (e.g., customers and/or plants)*

Public warehouses? (not publicly owned)

- **Financial investment:**
  - require no, or limited, capital investment
- **Flexibility**
  - space needed for shorter or longer periods
  - location flexibility
    - *immediately launch in, expand in, or pull out of new, untried markets without fixed distribution costs*
- **Third-party operators may provide**
  - different services for manufacturers and suppliers
  - different distribution management service and integrate these services within a total logistics system

Centralized vs. Decentralized?

- **How many DCs the organization should have?**
  - The answer is relatively simple
    - *Small- and medium-sized firms with a regional market will need only one or a few DCs*
    - *Larger firms with many national or international market areas need more*

- **Reasons for centralizing decisions**
  - Firms' supply and demand conditions
  - Close coordination with transportation alternatives

Size and location

Factors affecting the location of facilities

- Availability of transportation
- Proximity to markets and customers
- Supplier network
- Land costs and utilities
- Centralization/decentralization of DCs

Basic Warehouse Operations

Movement

- Receiving
- Put-away
- Order picking
- Shipping

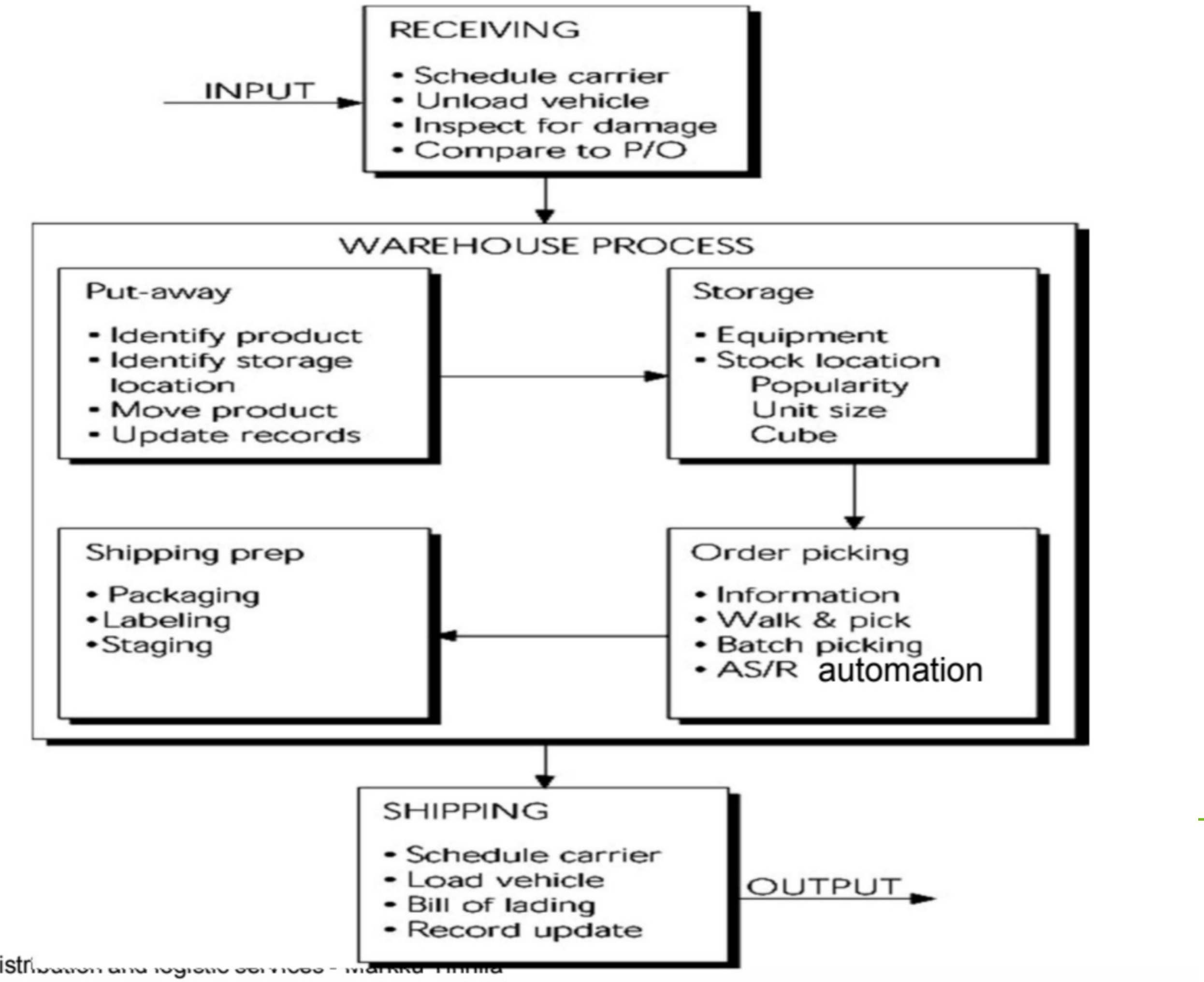
Storage

- Stock location
- Warehouse Management Systems (WMS)

WMS are a key part of the supply chain and primarily aim to control the movement and storage of materials within a warehouse and process the associated transactions, including shipping, receiving, putaway and picking.

The systems also direct and optimize stock putaway based on real-time information about the status of bin utilization.

Basic Warehouse Operations



Transportation problems

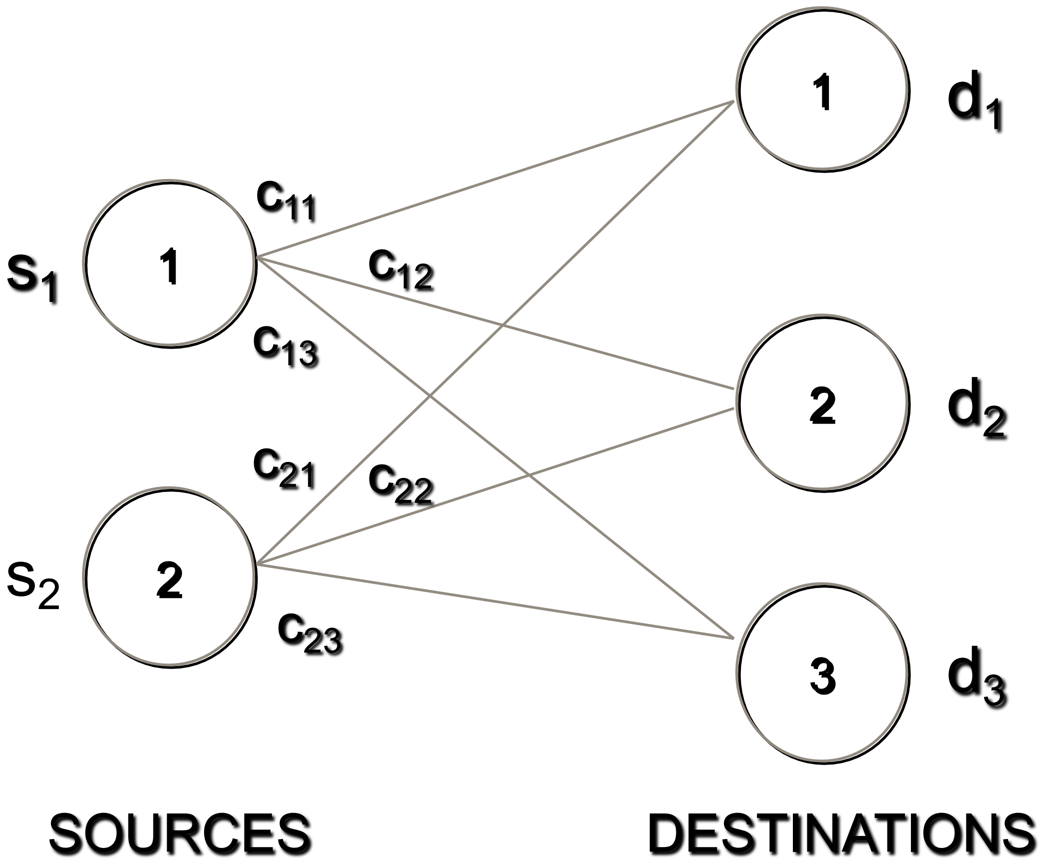
A common problem in logistics is how to transport goods from a set of sources (e.g., plants, warehouses, etc.) to a set of destinations (e.g., warehouses, customers, etc.) at the minimum possible cost.

Given

- a set of sources, each with a given supply,
- a set of destinations, each with a given demand,
- a cost table (cost/unit to ship from each source to each destination)

Problem: ***How much should be shipped from each supply point to each demand point to minimize total transportation costs?***

Transportation problems



Transportation problems: LP Formulation

Define x_{ij}: the amount shipped from supply point i to the demand point j.

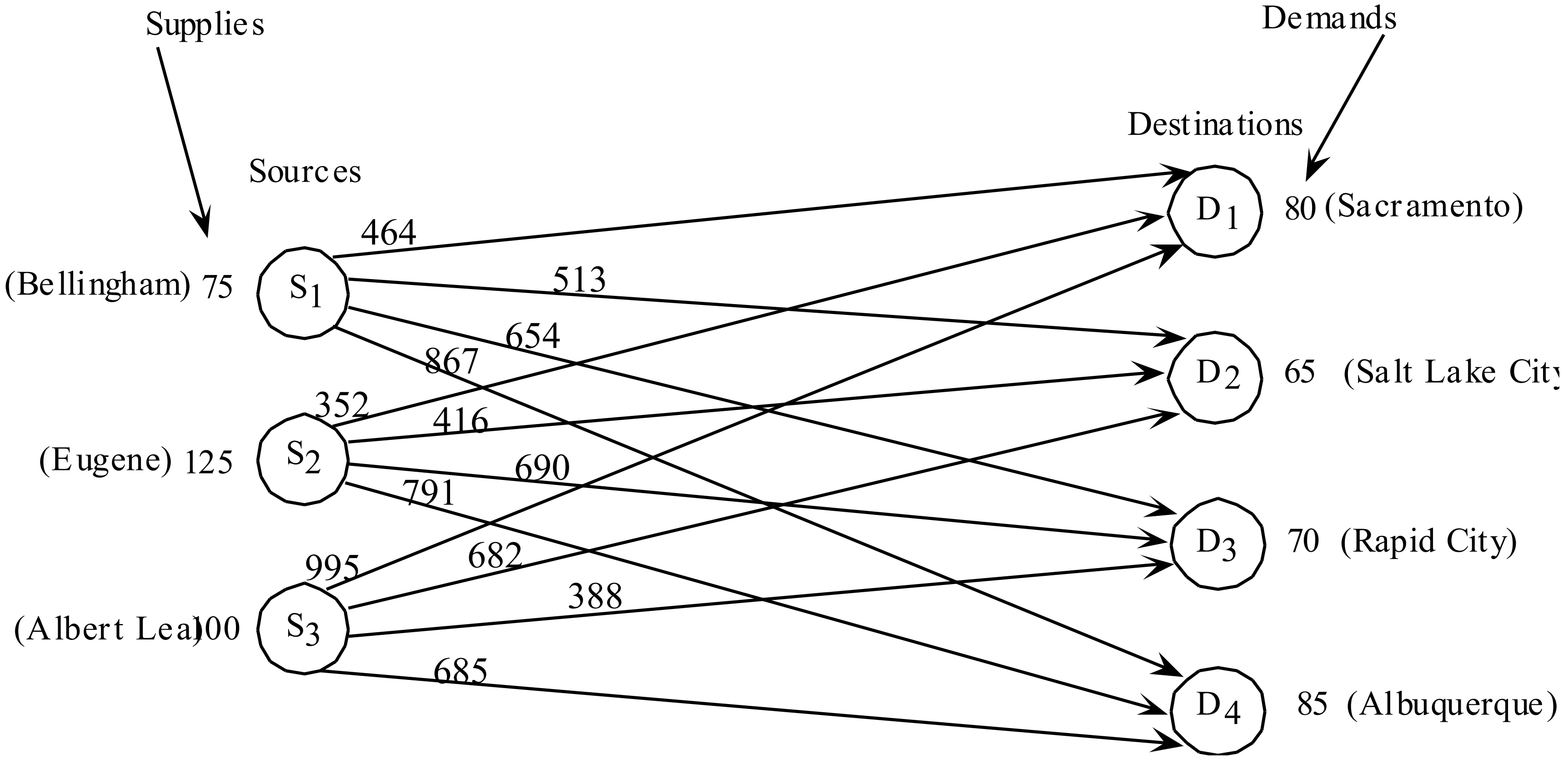
$$\text{Min} \quad \sum_i \sum_j c_{ij} x_{ij}$$

$$\text{s.t.} \quad \sum_j x_{ij} \leq s_i \quad \text{for each origin } i$$

$$\sum_i x_{ij} = d_j \quad \text{for each destination } j$$

$$x_{ij} \geq 0 \quad \text{for all } i \text{ and } j$$

Transportation problems: Excel



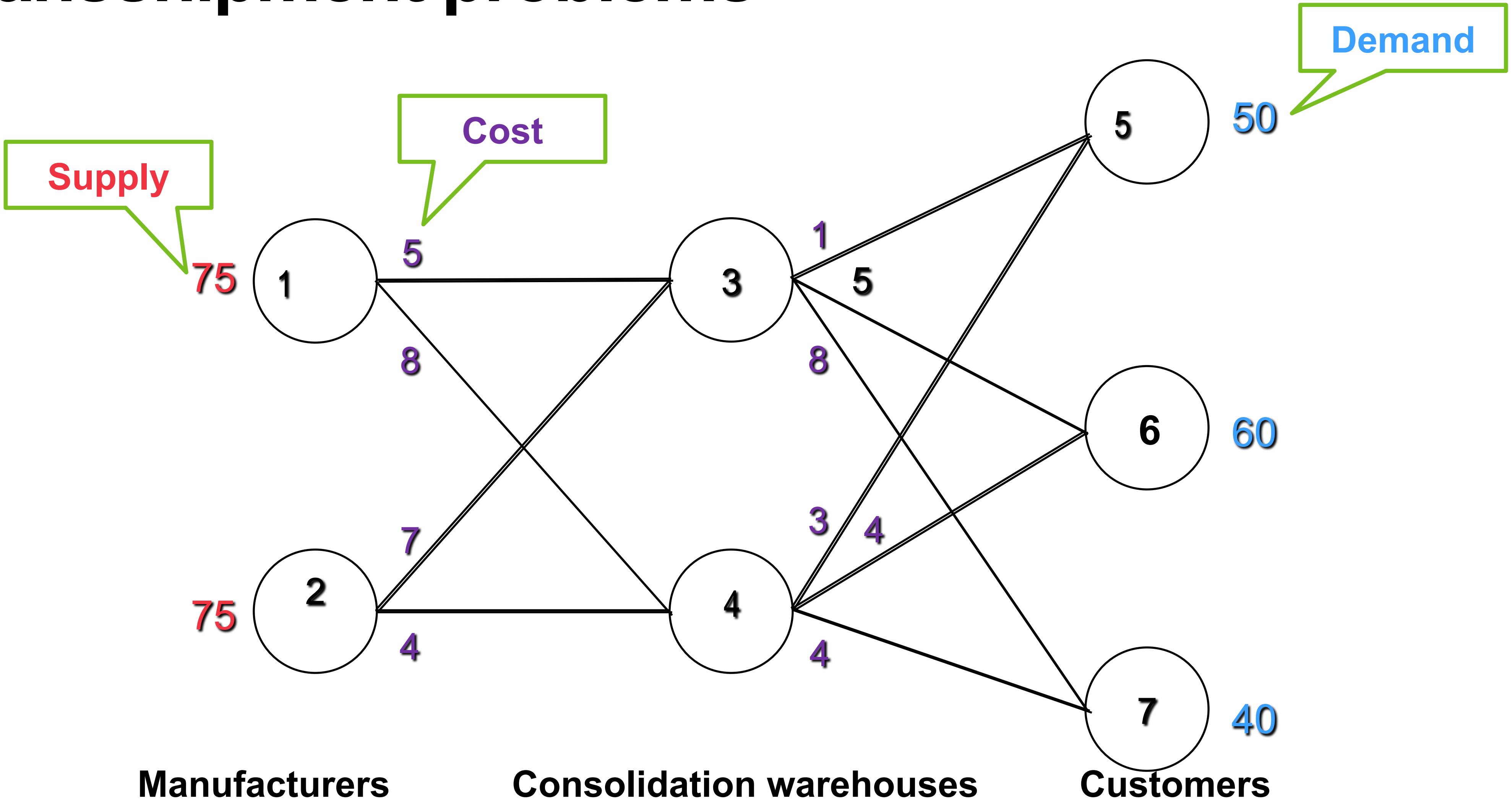
Transportation problems: Excel

	B	C	D	E	F	G	H	I	J
3	**Unit Cost**		Destination (Warehouse)						
4			Sacramento	Salt Lake City	Rapid City	Albuquerque			
5	Source	Bellingham	$464	$513	$654	$867			
6	(Cannery)	Eugene	$352	$416	$690	$791			
7		Albert Lea	$995	$682	$388	$685			
8									
9									
10	**Shipment Quantity**		Destination (Warehouse)						
11	**(Truckloads)**		Sacramento	Salt Lake City	Rapid City	Albuquerque	Total Shipped		Supply
12	Source	Bellingham	0	20	0	55	75	=	75
13	(Cannery)	Eugene	80	45	0	0	125	=	125
14		Albert Lea	0	0	70	30	100	=	100
15		Total Received	80	65	70	85			
16			=	=	=	=			Total Cost
17		Demand	80	65	70	85			$152,535

Transshipment problems

- Transshipment problems are transportation problems in which a shipment may move through **intermediate nodes** (*transshipment nodes*) before reaching a particular destination node.
  - Transshipment nodes do not have any supply or demand.
  - Transshipment problems can be converted to larger transportation problems and solved by a special transportation program.
  - Transshipment problems can also be solved by general purpose linear programming codes.

Transshipment problems



Transshipment problems – LP Formulation

x_{ij} represents the shipment from node *i* to node *j*

$$\text{Min} \ \sum_{i}\sum_{k} c_{ik}x_{ik} + \sum_{j}\sum_{k} c_{kj}x_{kj}$$

s.t.

$$\sum_{k} x_{ik} \leq s_i$$ for each origin *i to all transshipment points*

amount shipped away cannot be higher than amount supplied

$$\sum_{i} x_{ik} - \sum_{j} x_{kj} = 0$$ for each transshipment node *k*

in = out

$$\sum_{k} x_{kj} = d_j$$ for each destination *j*

amount received = demand

$$x_{ik}, x_{kj} \geq 0$$ for all *i* and *j*

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Transshipment problems – LP formulation (1/2)

- Decision Variables

x_{ij} = amount shipped from manufacturer i to warehouse j

x_{jk} = amount shipped from warehouse j to customer k

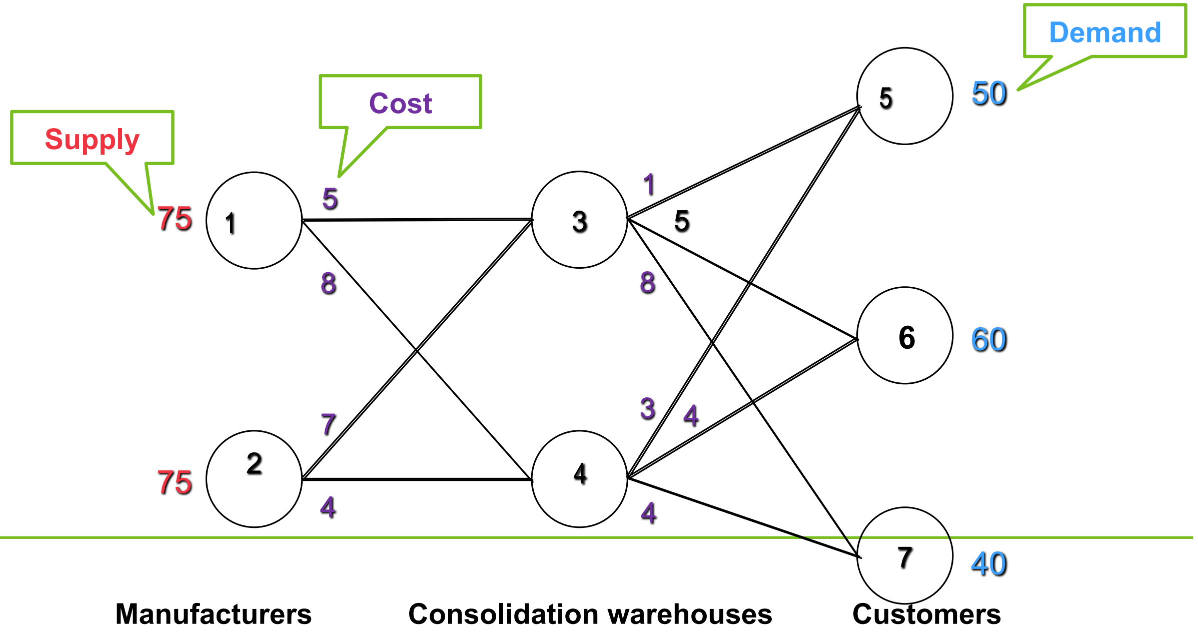
where i = 1, 2

j = 3, 4

k = 5, 6, 7

- Objective Function

Minimize Overall Shipping Costs:



Transshipment problems – LP formulation (2/2)

Constraints Defined

- **Amount Out of 1** : cannot be more than supply
- **Amount Out of 2**
- **Amount Through 3** : in = out
- **Amount Through 4**
- **Amount Into 5**
- **Amount Into 6**
- **Amount Into 7**

- **Non-negativity of Variables**

Transshipment problems – Excel

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1		x13	x14	x23	x24	x35	x36	x37	X45	X46	X47			**Total cost**
2		75	0	0	75	50	25	0	0	35	40			1150
3	Cost	5	8	7	4	1	5	8	3	4	4			
4														
5	**Constraints**													
6	Manufacturer 1	1	1									75	<=	75
7	Manufacturer 2			1	1							75	<=	75
8	Warehouse 3	1		1		-1	-1	-1				0	=	0
9	Warehouse 4		1		1				-1	-1	-1	0	=	0
10	Customer 5					1			1			50	=	50
11	Customer 6						1			1		60	=	60
12	Customer 7							1			1	40	=	40
13														

Facility Layout

The objectives of the design and layout

- Optimum use of space
- Smooth flow
- Labor productivity
- Adequate protection of goods

Layout planning parameters

- Aisle space
- Shelving
- Racking
- Handling equipment
- All other physical dimensions of the interior

Efficient use of space and an effective flow of goods in DC

- Cubic utilization and capacity
- Product protection
- Level of mechanization
- Safety
- Product physical characteristics
- Productivity/performance
- Shifts and staffing levels (Assignment problem)

Assignment Problem with LP

	Backstroke	Breaststroke	Butterfly	Freestyle
Carl	37.7	43.4	33.3	29.2
Chris	32.9	33.1	28.5	26.4
David	33.8	42.2	38.9	29.6
Tony	37	34.7	30.4	28.5
Ken	35.4	41.8	33.6	31.1

Question: How should the swimmers be assigned to make the fastest relay team?

Assignment Problem: LP Formulation

Let x_{ij} = 1 if swimmer *i* swims stroke *j*; 0 otherwise
t_{ij} = best time of swimmer *i* in stroke *j*

Minimize Time = $\sum_i \sum_j t_{ij} x_{ij}$

subject to

(each stroke swum) $\sum_i x_{ij} = 1$ for each stroke *j*

(each swimmer swims 1) $\sum_j x_{ij} \leq 1$ for each swimmer *i*

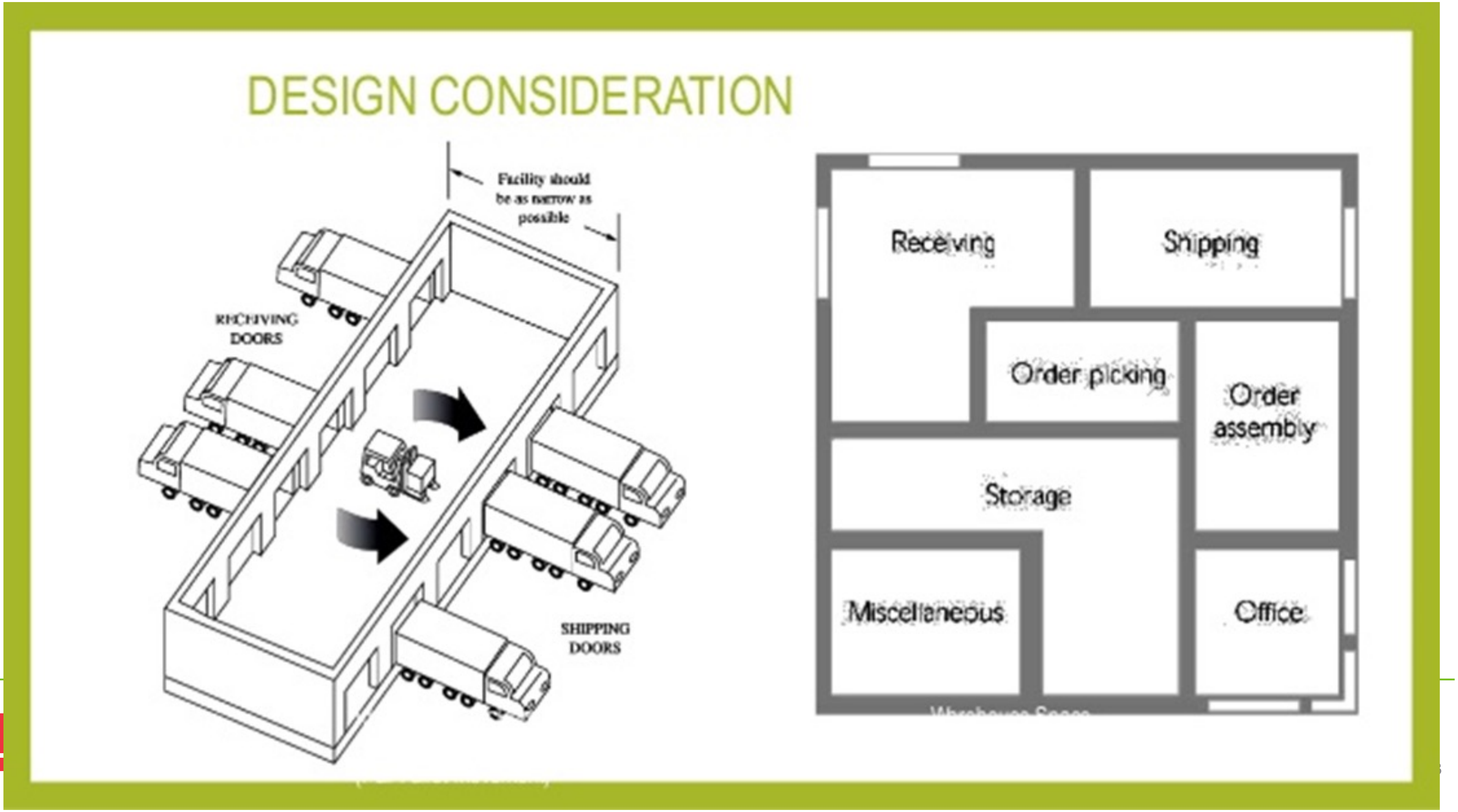
$x_{ij} \geq 0$ for all *i* and *j*.

Assignment Problem: LP Formulation

See the attached Excel

	B	C	D	E	F	G	H	I
3	**Best Times**	Backstroke	Breastroke	Butterfly	Freestyle			
4	Carl	37.7	43.4	33.3	29.2			
5	Chris	32.9	33.1	28.5	26.4			
6	David	33.8	42.2	38.9	29.6			
7	Tony	37.0	34.7	30.4	28.5			
8	Ken	35.4	41.8	33.6	31.1			
9								
10								
11	**Assignment**	Backstroke	Breastroke	Butterfly	Freestyle			
12	Carl	0	0	0	1	1	<=	1
13	Chris	0	0	1	0	1	<=	1
14	David	1	0	0	0	1	<=	1
15	Tony	0	1	0	0	1	<=	1
16	Ken	0	0	0	0	0	<=	1
17		1	1	1	1	Time	=	126.2
18		=	=	=	=			
19		1	1	1	1			

Functions of Distribution Operations



Order picking principles (1/4)

1. Encourage and design for **full-pallet** as opposed to loose case picking and **full-cases** as opposed to broken case picking

2. Pick from storage

- One of the most effective means for improving picking productivity and accuracy is to bring the storage locations to the picker

3. Eliminate and combine order picking tasks when possible

- Traveling, Extracting, Reaching and bending,
- Documenting, Sorting, Packing, Searching

Order picking principles (2/4)

4. Batch orders to reduce total travel time

- By increasing the number of orders picked by an order picker during a picking tour, the travel time per pick can be reduced.
  - Single order picking – each order picker completes one order at a time. Major advantage is that order integrity is never jeopardized. Consequently, the walking time per line item is high.
  - Batch Picking – order pickers take responsibility for retrieving a batch of several orders during a picking tour. Major advantage is a reduction in travel time per line item.
  - Zone Picking – an order picker is dedicated to pick the line items in his or her assigned zone. One advantage of zone picking is travel time savings. Since each picker's coverage has been reduced from the entire warehouse to a smaller area.

Order picking principles

5. Establish separate forward and reverse picking areas.

- A **condensed picking area**, containing some of the inventory of popular items should be established.

6. Assign the most popular items to the most easily accessed locations in the warehouse.

- By assigning the most popular items close to the front of the warehouse, an order picker's travel time can be significantly reduced.

7. Balance picking activity across picking locations to reduce congestion

- Care must be taken to distribute picking activity over large enough areas to reduce congestion yet, not over so great an area as to significantly increase travel times.
- This is often achieved in horseshoe configurations of walk-and-pick systems

Order picking principles

8. Assign items that are likely to be **requested together** to the same or nearby locations.

- Suggest that items be clustered into **families** containing items that are likely to requested together and then assigning the families to warehouse locations on the basis of the pick frequency and space occupied associated with cluster

9. Sequence pick location visits **to reduce travel time**

10. Organize **picking documents** and displays to minimize search time and errors – electronic devices in trucks or handheld

11. Design picking vehicles to minimize sorting time and errors and to enhance the picker's comfort.- specialization requires volumes

12. **Eliminate paperwork** from the order picking activity.

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Supply Chain Execution Systems

SCES Impact Areas

- **Fulfillment**
- **Delivery**

- **Visibility**
- **Responsiveness**

Typical modules and applications include:

- **Warehouse Management Systems (WMSs)**
  - Labor management systems
  - Yard/dock management
  - Returns management
  - Inventory control
- **Transportation Management Systems (TMSs):**
  - Domestic transportation management software
  - Global multimodal transportation management (managing transportation around multimodal processes)
- **Global Trade Management (GTM) systems:**
  - Trade compliance
  - International/global logistics
  - Global order management
  - Global trade financial management

Source: https://www.gartner.com/en/information-technology/glossary/sce-supply-chain-execution#:~:text=Supply%20chain%20execution%20(SCE)%20is,for%20example%2C%20dynamic%20routing%20and

Fulfillment and Delivery

- **Material handling and controls**
  - Right condition
- **AutoID and data collection**
  - Right material
- **Supply chain execution systems**
  - Right time
- **People**
  - Necessary for all of the above

Responsiveness

- **Best decision-making is executed on the basis of events as or before, not after they occur**

- **Responsive logistics systems provide discipline and control that is based not only upon plans and performance goals but also upon the dynamics of actual operations**

SCES components

- Warehouse and labor management
- Transportation management
- Yard management
- International trade logistics
- Supply chain visibility and event management

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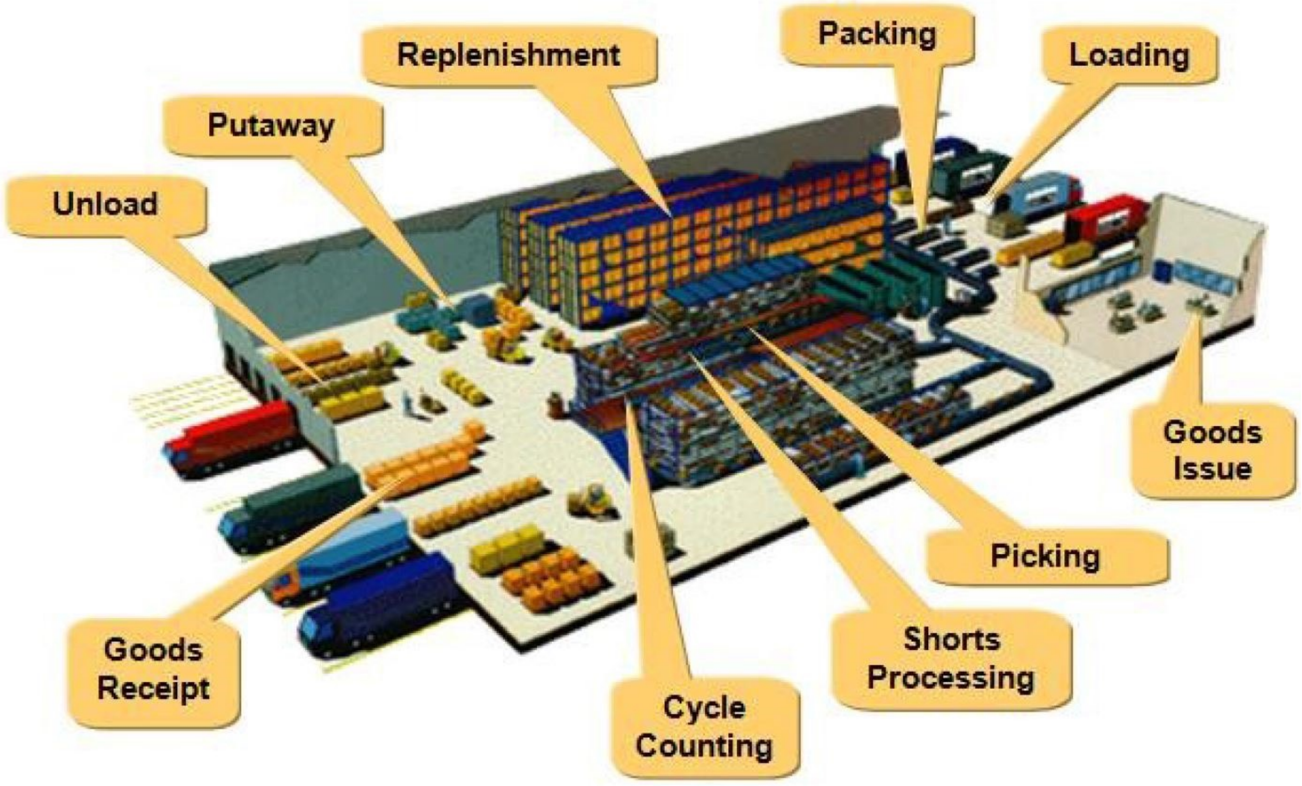
Warehouse management systems

Warehouse management systems (WMSs)

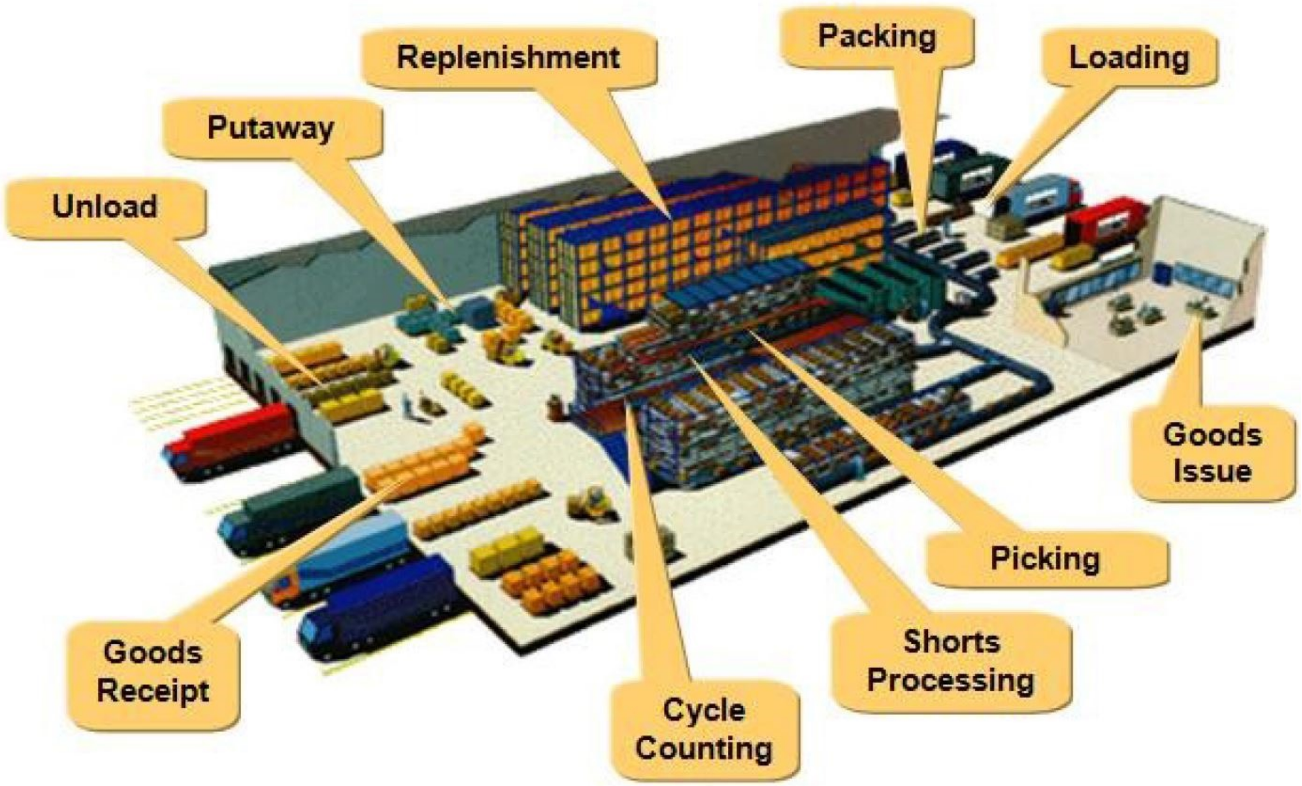
Manages warehouse inventory, space, equipment, and labor resources to direct the flow of materials and information from receiving and putaway to light assembly, order picking, value-added processing and shipment

Warehouse management systems



WMS Functions

- **Receiving**
  - Blind
  - Advance shipping notice (ASN)/Electronic Data Interchange (EDI)
  - Conventional or automatic
- **Putwaway**
  - Dedicated, random, or hybrid
  - Location selection: system or operator
  - Put confirmation
- **Picking and shipping**
  - Pick by order, batch, wave
  - Pick confirmation
  - Shipping checklists
  - Manifests, bills of lading



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Now we’re going to talk about each of them…

WMS setup

Product files

- Descriptions
- Dimensions
- Units of measure
- Bills of materials
- Substitutions

Location files

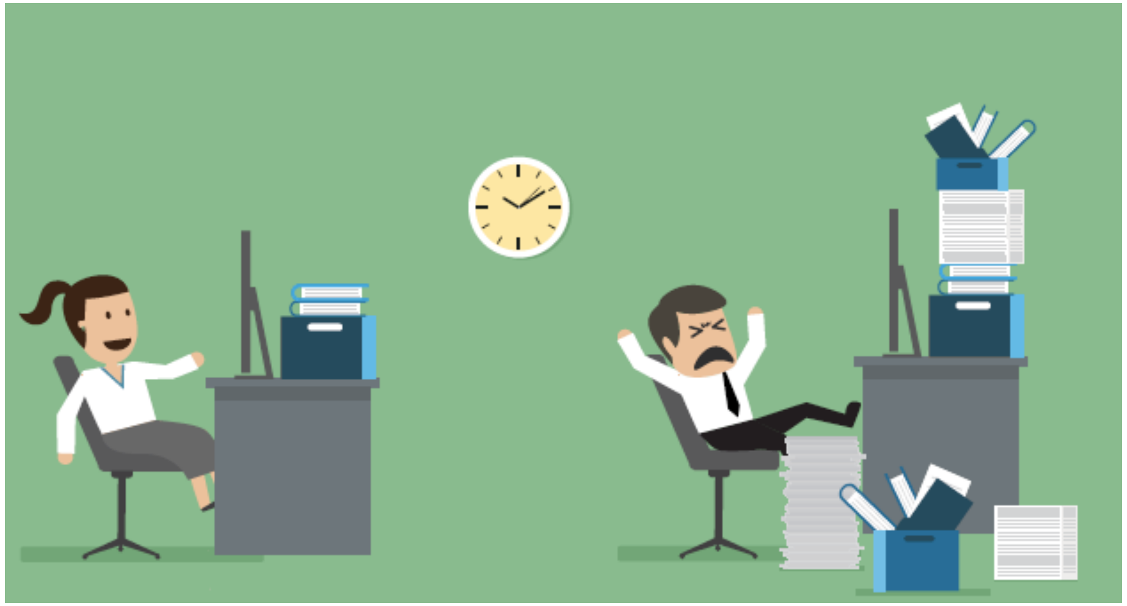
- Numbering/ sequencing
- Dimensions/capacity

Equipment files

Employee files

Workload management

- Equipment profiles
- Material profiles
- Location profiles
- Operator/equipment matrices
- Operator/task priorities
- Labor standards



Material handling interfaces

- Conveyor
- Sortation
- Palletizer
- Automatic guided vehicles (AGVs)
- Pick (Pack)-to-Light
- Carousel
- Automated storage and retrieval system (ASRS or AS/RS)

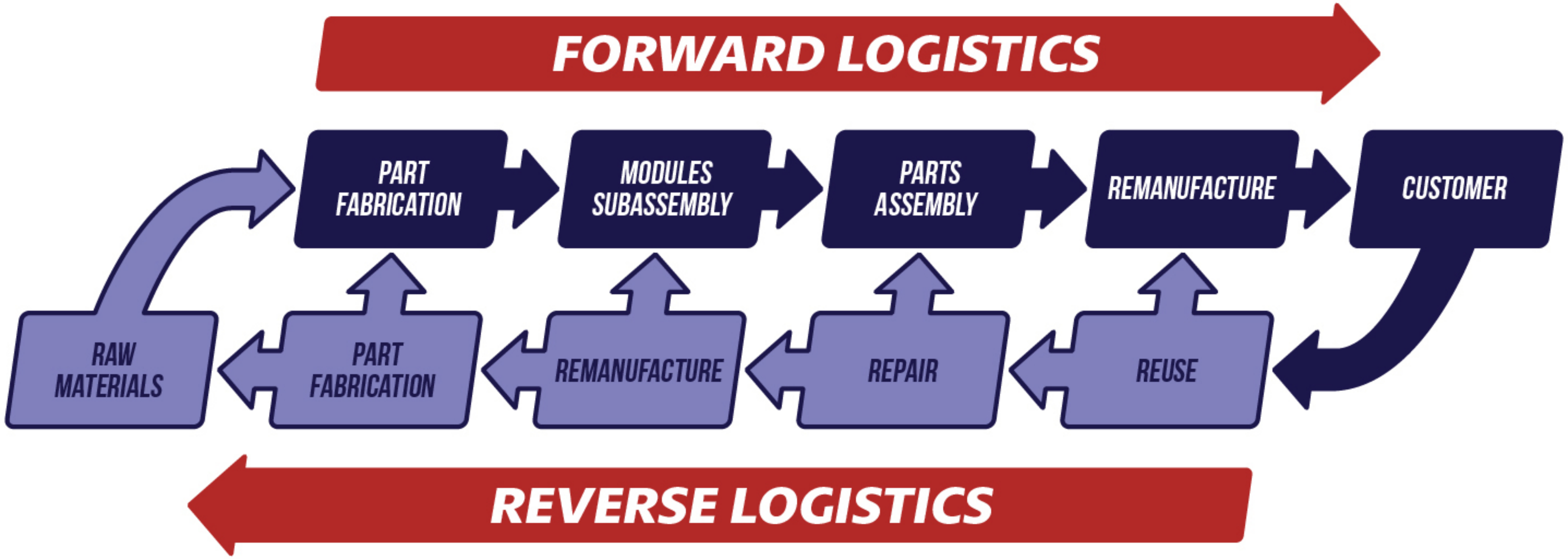
System interfaces

- **Purchasing**
- **Order management**
- **MRP / Manufacturing Execution System (MES)**

Receiving

- ASNs / Purchase Order Receiving
- Carrier Appointment Scheduling
- Pre-tagged Receipts
- Blind (unanticipated) receipts
- Load tagging/labeling
- Quality assurance
- Returns

Reverse logistics



Storage and Putaway

- Location selection
- Override
- Location confirmation
- Crossdocking
- Relocation
- Consolidation

Inventory management

- Lot, Date Code, and Serial Number Tracking
- Shelf-life Monitoring and Rotation
- Catch Weighing
- Routine and Exception Cycle Counting
- Full Physical

Pick planning

- **Host download format and frequency**
- **Wave and batch planning**
- **Material allocation**
- **Order/shipment release**
- **Changes and cancellations**

Wave picking:
https://www.youtube.com/watch?app=desktop&v=6swvr-J_bJE

Staging and shipping

- Trailer scheduling/processing
- Staging location management
- Staged load confirmation
- Door/trick verification
- Shipping labels
- Manifests/bills of lading
- Shipping confirmation

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Thank you!

Questions?

Dr. Tri M. Tran
tri.tran@aalto.fi