

Supply Chain Management

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MGM 660

Lecture 8



Transportation in a supply chain

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Course Agenda

Chapter

1. Understand the role of transportation in a supply chain.
2. Evaluate the strengths and weaknesses of different modes of transportation.
3. Discuss the role of infrastructure and policies in transportation.
4. Identify the relative strengths and weaknesses of various transportation network design options.
5. Identify trade-offs that shippers need to consider when designing a transportation network.
6. Application of Artificial Intelligence on Transportation

The Role of Transportation in a Supply Chain

- **Transportation** refers to the movement of product from one location to another as it makes its way from the beginning of a supply chain to the customer.
- **Transportation** is an important supply chain driver because products are rarely produced and consumed in the same location.
- **Transportation** is a significant component of the costs incurred by most supply chains.
- The role of transportation is even more significant in global supply chains.
- Any supply chain's success is closely linked to the appropriate use of transportation.
- One objective of transportation management is to balance cost and service

The Role of Transportation in a Supply Chain

- **Example,**
- **IKEA** home furnishings retailer, has built a global network, with about 350 stores in 42 countries, primarily on the basis of effective transportation.
- **IKEA's** sales for the year ending August 2013 reached 29.2 billion euros. Its strategy is built around providing good-quality products at low prices.
- Its goal is to cut prices by 2 to 3 percent each year. As a result, **IKEA** works hard to find the least expensive global source for each of its products. Modular design of its furniture allows IKEA to transport its goods worldwide much more cost effectively than a traditional furniture manufacturer.

• Seven-Eleven Japan

- Is another firm that has used transportation to achieve its strategic goals. The company has a goal of carrying products in its stores to match the needs of customers as they vary by geographic location or time of day.
- To help achieve this goal, Seven-Eleven Japan uses a responsive transportation system that replenishes its stores several times a day so the products available match customers' needs.
- Products from different suppliers are aggregated on trucks according to their required temperature to help achieve frequent deliveries at a reasonable cost.

The Role of Transportation in a Supply Chain

- Supply chains also use responsive transportation to centralize inventories and operate with fewer facilities.
- **For example,**
- **Amazon** relies on package carriers and the postal system to deliver customer orders from centralized warehouses.
- **McMaster-Carr** uses ground transportation and package carriers to provide next-day delivery of a wide variety of MRO products to about 90 percent of U.S. businesses from five distribution centers.
- The location of its distribution centers along with an effective transportation network allows McMaster to be very responsive while using a low-cost mode of transportation.

Transportation Infrastructure and Policies

- Governments generally take full responsibility or played a significant role in building and managing infrastructure elements.
- Without a monopoly, deregulation and market forces help create an effective industry structure.
- Pricing should reflect the marginal impact on the cost to society.

Transportation Infrastructure and Policies

- **Transportation infrastructures** often require government ownership or regulation because of their inherently monopolistic nature.
- In the absence of a monopoly, deregulation and market forces help create an effective industry structure.
- When the infrastructure is publicly owned, it is important to price usage to reflect the marginal impact on the cost to society.
- If this is not done, overuse and congestion result because the cost borne by a user is less than the user's marginal impact on total cost.

Design Options for a Transportation Network

- **The design** of a transportation network affects the performance of a supply chain by establishing the infrastructure within which operational transportation decisions regarding scheduling and routing are made.
- A well-designed transportation network allows a supply chain to achieve the desired degree of responsiveness at a low cost.

- **When designing a transportation network**

1. Should transportation be direct or through an intermediate site?
2. Should the intermediate site stock product or only serve as a cross-docking location?
3. Should each delivery route supply a single destination or multiple destinations (milk run)?

- **Based on the answers to these questions, the supply chain ends up with a variety of transportation networks.**

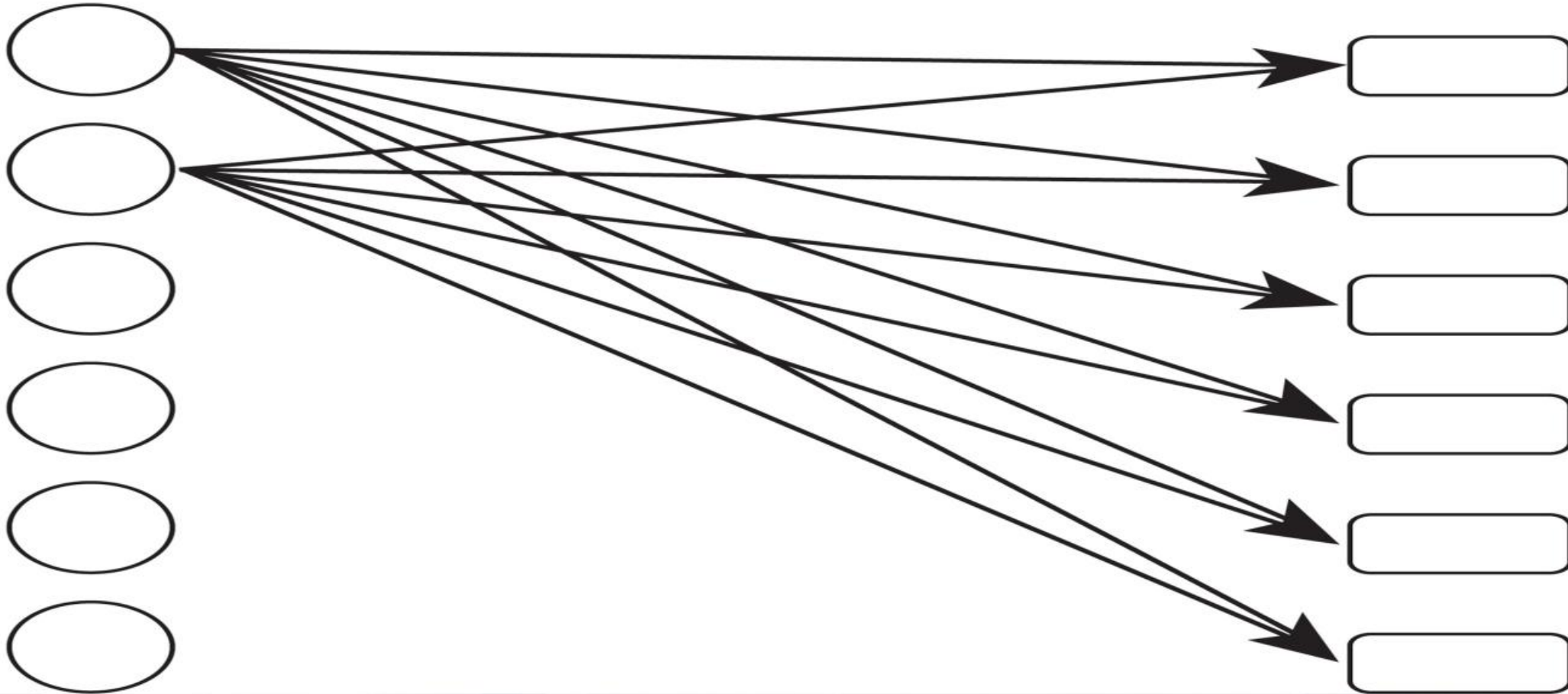
Direct Shipment Network to Single Destination

- With the direct shipment network to a single destination option, the buyer structures the transportation network so that all shipments come directly from each supplier to each buyer location.
- With a direct shipment network, the routing of each shipment is specified, and the supply chain manager needs to decide only the quantity to ship and the mode of transportation to use.
- The major advantage of a direct shipment transportation network is the elimination of intermediate warehouses and its simplicity of operation and coordination. The shipment decision is completely local, and the decision made for one shipment does not influence others.

Direct Shipment Network to Single Destination

Suppliers

Buyer Locations



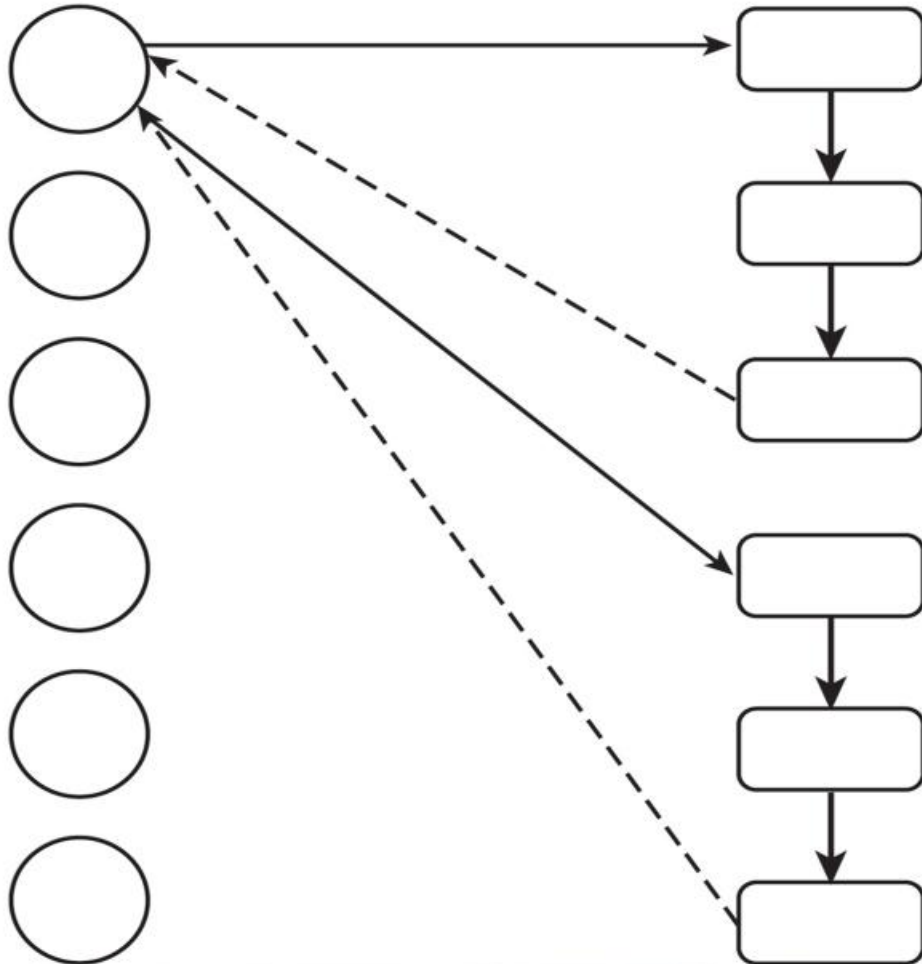
Direct Shipping with Milk Runs

- **A milk run** is a route on which a truck either delivers product from a single supplier to multiple retailers or goes from multiple suppliers to a single buyer location.
- **Milk runs** involve multiple pickups or deliveries during a single transportation route.
- In direct shipping with milk runs, a supplier delivers directly to multiple buyer locations on a truck or a truck picks up deliveries destined for the same buyer location from many suppliers.
- When using this option, a supply chain manager has to decide on the routing of each milk run.

Direct Shipping with Milk Runs

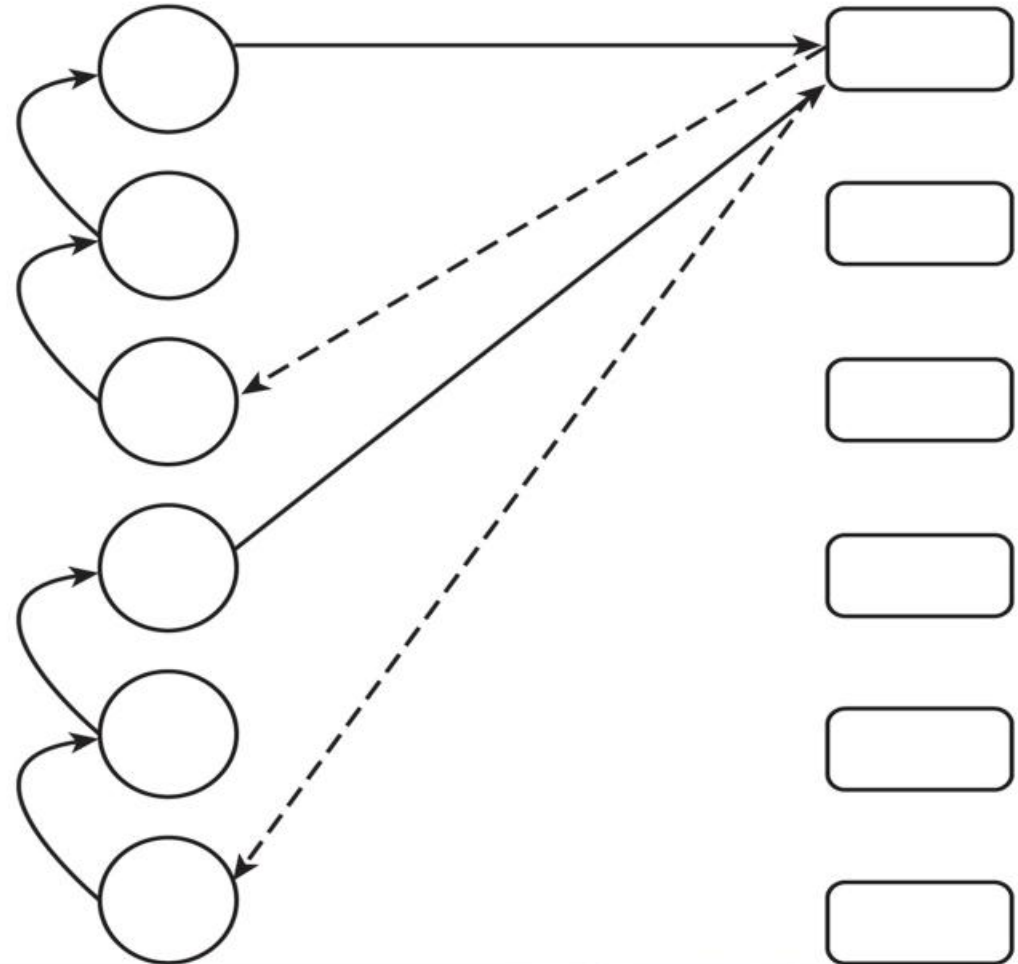
Suppliers

Buyer Locations



Suppliers

Buyer Locations



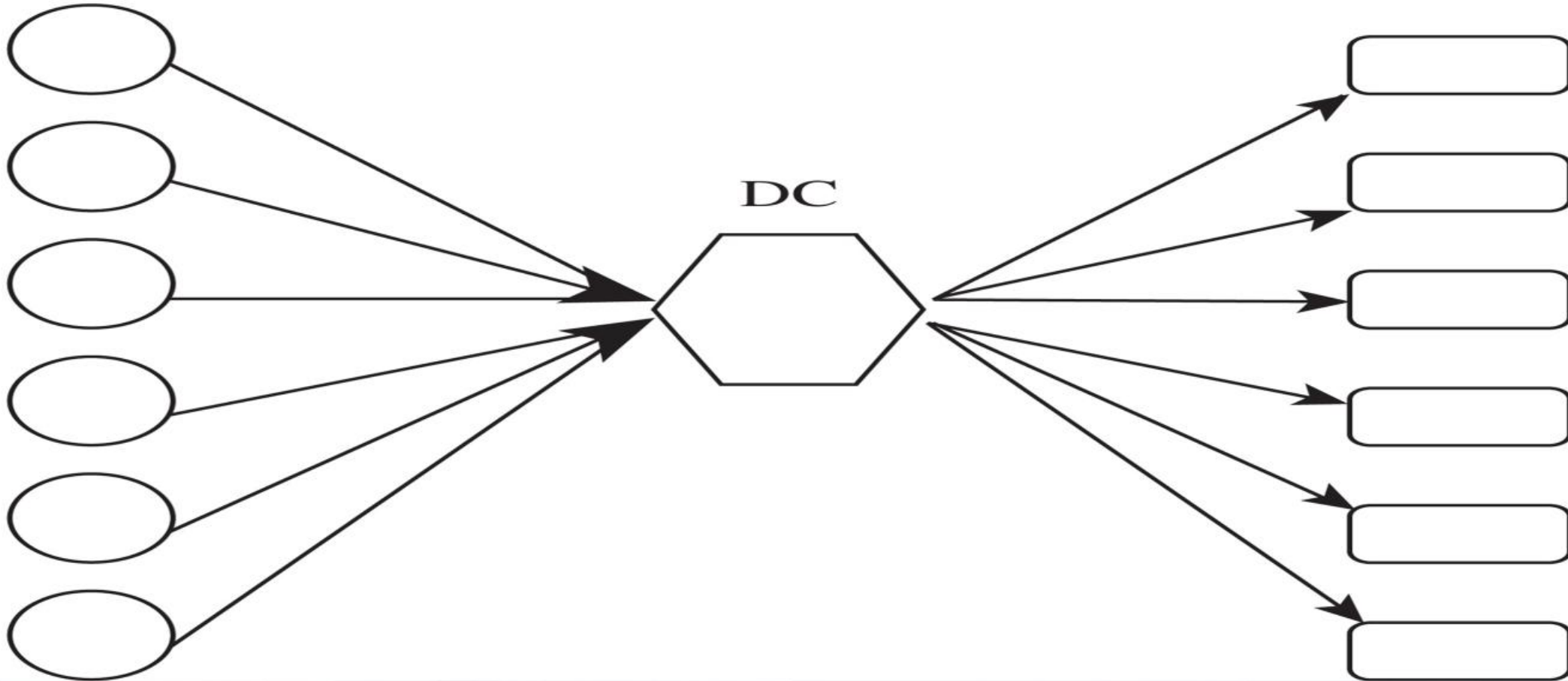
All Shipments via Intermediate Distribution Center with Storage

- **Under this option**, product is shipped from suppliers to a central distribution center, where it is stored until needed by buyers when it is shipped to each buyer location.
- Storing product at an intermediate location is justified if transportation economies require large shipments on the inbound side or shipments on the outbound side cannot be coordinated.
- In such a situation, product comes in large quantities into a DC, where it is held in inventory and sent to buyer locations in smaller replenishment lots when needed.

All Shipments via Intermediate Distribution Center with Storage

Suppliers

Buyer Locations



All Shipments via Intermediate Transit Point with Cross-Docking

- **Under this option**, suppliers send their shipments to an intermediate transit point (which could be a DC), where they are cross-docked and sent to buyer locations without storing them.
- The product flow is similar to the previous Figure except that there is no storage at the intermediate facility.
- When a DC cross-docks product, each inbound truck contains product from suppliers for several buyer locations, whereas each outbound truck contains product for one buyer location from several suppliers.

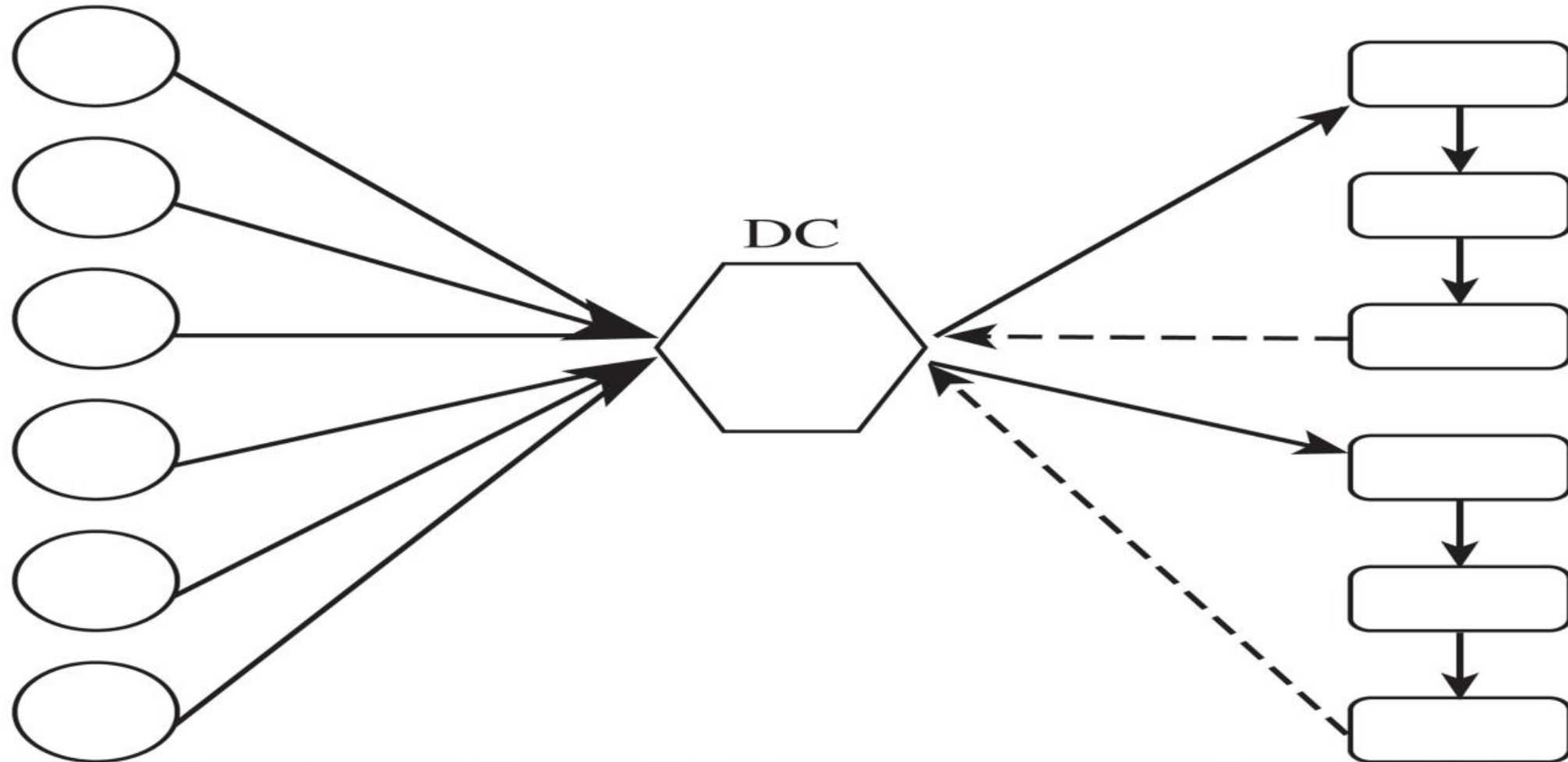
Shipping via DC Using Milk Runs

- **Milk runs** reduce outbound transportation costs by consolidating small shipments.
- **For example**, Seven-Eleven Japan cross-docks deliveries from its fresh-food suppliers at its DCs and sends out milk runs to the retail outlets because the total shipment to a store from all suppliers does not fill a truck.
- The use of cross-docking and milk runs allows Seven- Eleven Japan to lower its transportation cost while sending small replenishment lots to each store.
- The use of cross-docking with milk runs requires a significant degree of coordination and suitable routing and scheduling.

Shipping via DC Using Milk Runs

Suppliers

Buyer Locations



Tailored Network

Network Structure	Pros	Cons
Direct shipping	No intermediate warehouse Simple to coordinate	High inventories (due to large lot size) Significant receiving expense
Direct shipping with milk runs	Lower transportation costs for small lots Lower inventories	Increased coordination complexity
All shipments via central DC with inventory storage	Lower inbound transportation cost through consolidation	Increased inventory cost Increased handling at DC
All shipments via central DC with cross-dock	Low inventory requirement Lower transportation cost through consolidation	Increased coordination complexity
Shipping via DC using milk runs	Lower outbound transportation cost for small lots	Further increase in coordination complexity
Tailored network	Transportation choice best matches needs of individual product and store	Highest coordination complexity

Selecting a Transportation Network

- Eight stores, four supply sources
- Truck capacity = 40,000 units
- Cost \$1,000 per load, \$100 per delivery
- Holding cost = \$0.20/year

Selecting a Transportation Network

Annual sales = 960,000/store **Direct shipping**

Batch size shipped from each supplier to each store = 40,000 units

Number of shipments/yr from each supplier to each store = $960,000 / 40,000 = 24$

Annual trucking cost for direct network = $24 \times 1,100 \times 4 \times 8 = \$844,800$

Average inventory at each store for each product = $40,000 / 2 = 20,000$ units

Annual inventory cost for direct network = $20,000 \times 0.2 \times 4 \times 8 = \$128,000$

Total annual cost of direct network = $\$844,800 + \$128,000 = \$972,800$

Selecting a Transportation Network

Annual sales = 960,000/store **Milk runs**

Batch size shipped from each supplier to each store = $40,000/2 = 20,000$ units

Number of shipments/yr from each supplier to each store = $960,000/20,000 = 48$

Transportation cost per shipment per store (two stores/truck) = $1,000/2 + 100 = \$600$

Annual trucking cost for direct network = $48 \times 600 \times 4 \times 8 = \$921,600$

Average inventory at each store for each product = $20,000/2 = 10,000$ units

Annual inventory cost for direct network = $10,000 \times 0.2 \times 4 \times 8 = \$64,000$

Total annual cost of direct network = $\$921,600 + \$64,000 = \$985,600$

Selecting a Transportation Network

Annual sales = 120,000/store **Direct shipping**

Batch size shipped from each
supplier to each store = 40,000 units

Number of shipments/yr from
each supplier to each store = $120,000/40,000 = 3$

Annual trucking cost
for direct network = $3 \times 1,100 \times 4 \times 8 = \$105,600$

Average inventory at each
store for each product = $40,000/2 = 20,000$ units

Annual inventory cost
for direct network = $20,000 \times 0.2 \times 4 \times 8 = \$128,000$

Total annual cost of
direct network = $\$105,600 + \$128,000 = \$233,600$

Selecting a Transportation Network

Annual sales = 120,000/store **Milk runs**
 Batch size shipped from each
 supplier to each store $= 40,000/4 = 10,000$ units
 Number of shipments/yr from
 each supplier to each store $= 120,000/10,000 = 12$
 Transportation cost per shipment
 per store (two stores/truck) $= 1,000/4 + 100 = \$350$
 Annual trucking cost
 for direct network $= 12 \times 350 \times 4 \times 8 = \$134,400$
 Average inventory at each
 store for each product $= 10,000/2 = 5,000$ units
 Annual inventory cost
 for direct network $= 5,000 \times 0.2 \times 4 \times 8 = \$32,000$
 Total annual cost of
 direct network $= \$134,400 + \$32,000 = \$166,400$

Trade-offs in Transportation Design

- All transportation decisions made by shippers in a supply chain network must take into account their impact on inventory costs, facility and processing costs, the cost of coordinating operations, and the level of responsiveness provided to customers.
- **For example,**
- **Amazon's** use of package carriers to deliver products to customers increases transportation cost but allows Amazon to centralize its facilities and reduce inventory costs.
- If Amazon wants to reduce its transportation costs, the company must either sacrifice responsiveness to customers or increase the number of facilities and resulting inventories to move closer to customers.

Trade-offs in Transportation Design

Mode	Cycle Inventory	Safety Inventory	In-Transit Cost	Transportation Time	Transportation Cost
Rail	5	5	5	2	5
TL	4	4	4	3	3
LTL	3	3	3	4	4
Package	1	1	1	6	1
Air	2	2	2	5	2
Water	6	6	6	1	6

Trade-offs When Selecting Transportation Mode

Demand = 120,000 motors, Cost = \$120/motor,
Weight = 10 lbs/motor, Lot size = 3,000,
Safety stock = 50% ddlt

Carrier	Range of Quantity Shipped (cwt)	Shipping Cost (\$/cwt)
AM Railroad	200+	6.50
Northeast Trucking	100+	7.50
Golden Freightways	50–150	8.00
Golden Freightways	150–250	6.00
Golden Freightways	250+	4.00

Cycle inventory= $Q/2 = 2,000/2 = 1,000$ motors

Safety inventory= $L/2$ days of demand
 $= (6/2)(120,000/365) = 986$ motors

In-transit inventory= $120,000(5/365) = 1,644$ motors

Total average inventory $= 1,000 + 986 + 1,644$
 $= 3,630$ motors

Annual holding cost using AM Rail $= 3,630 \times \$30 = \$108,900$

Annual transportation cost using AM Rail $= 120,000 \times 0.65 = \$78,000$

The total annual cost for inventory and transportation using AM Rail= \$186,900

Trade-offs When Selecting Transportation Mode

Alternative	Lot Size (Motors)	Transportation Cost	Cycle Inventory	Safety Inventory	In-Transit Inventory	Inventory Cost	Total Cost
AM Rail	2,000	\$78,000	1,000	986	1,644	\$108,900	\$186,900
Northeast	1,000	\$90,000	500	658	986	\$64,320	\$154,320
Golden	500	\$96,000	250	658	986	\$56,820	\$152,820
Golden	1,500	\$96,000	750	658	986	\$71,820	\$167,820
Golden	2,500	\$86,400	1,250	658	986	\$86,820	\$173,220
Golden	3,000	\$80,000	1,500	658	986	\$94,320	\$174,320
Golden (old proposal)	4,000	\$72,000	2,000	658	986	\$109,320	\$181,320
Golden (new proposal)	4,000	\$67,000	2,000	658	986	\$109,320	\$176,820

Tradeoffs When Aggregating Inventory

Inventory aggregation decisions must account for inventory and transportation costs.

Inventory aggregation decreases supply chain costs if the product has a high value-to-weight ratio, high demand uncertainty, low transportation cost, and customer orders are large.

If a product has a low value-to-weight ratio, low demand uncertainty, large transportation cost, or small customer orders, inventory aggregation may increase supply chain costs.

- **Option A.** Keep the current structure but replenish inventory once a week rather than once every four weeks
- **Option B.** Eliminate inventories in the territories, aggregate all inventories in a finished-goods warehouses, and replenish the warehouse once a week

Tradeoffs When Aggregating Inventory

	Aggregate	Disaggregate
Transport cost	Low	High
Demand uncertainty	High	Low
Holding cost	High	Low
Customer order size	Large	Small

Trade-off Between Transportation Cost and Responsiveness

- The transportation cost a supply chain incurs is closely linked to the degree of responsiveness the supply chain aims to provide.
- If a firm has high responsiveness and ships all orders within a day of receipt from the customer, it will have small outbound shipments, resulting in a high transportation cost.
- If it decreases its responsiveness and aggregates orders over a longer time horizon before shipping them out, it will be able to exploit economies of scale and incur a lower transportation cost because of larger shipments.

Trade-off Between Transportation Cost and Responsiveness

- Temporal aggregation is the process of combining orders across time.
- Temporal aggregation decreases a firm's responsiveness because of shipping delay but also decreases transportation costs because of economies of scale that result from larger shipments.
- Thus, a firm must consider the trade-off between responsiveness and transportation cost when designing its transportation network

Trade-off Between Transportation Cost and Responsiveness

Day	Demand	Two-Day Response		Three-Day Response		Four-Day Response	
		Quantity Shipped	Cost (\$)	Quantity Shipped	Cost (\$)	Quantity Shipped	Cost (\$)
1	19,970	19,970	299.70	0		0	
2	17,470	17,470	274.70	37,440	474.40	0	
3	11,316	11,316	213.16	0		48,756	586.56
4	26,192	26,192	361.92	37,508	475.08	0	
5	20,263	20,263	302.63	0		0	
6	8,381	8,381	183.81	28,644	386.44	54,836	648.36
7	25,377	25,377	353.77	0		0	
8	39,171	39,171	491.71	64,548	745.48	0	
9	2,158	2,158	121.58	0		66,706	767.06
10	20,633	20,633	306.33	22,791	327.91	0	
11	23,370	23,370	333.70	0		0	
12	24,100	24,100	341.00	47,70	574.70	68,103	781.03
13	19,603	19,603	296.03	0		0	
14	18,442	18,442	284.42	38,045	480.45	38,045	480.45
			\$4,164.46			3,464.46	3,264.46

- The use of different transportation networks and modes based on customer and product characteristics
- **Factors affecting tailoring**
 - Customer density and distance
 - Customer size
 - Product demand and value

Tailored Transportation

	Short Distance	Medium Distance	Long Distance
High density	Private fleet with milk runs	Cross-dock with milk runs	Cross-dock with milk runs
Medium density	Third-party milk runs	LTL carrier	LTL or package carrier
Low density	Third-party milk runs or LTL carrier	LTL or package carrier	Package carrier

Tailored Transportation

Product Type	High Value	Low Value
High demand	Disaggregate cycle inventory. Aggregate safety inventory. Inexpensive mode of transportation for replenishing cycle inventory and fast mode when using safety inventory.	Disaggregate all inventories and use inexpensive mode of transportation for replenishment.
Low demand	Aggregate all inventories. If needed, use fast mode of transportation for filling customer orders.	Aggregate only safety inventory. Use inexpensive mode of transportation for replenishing cycle inventory.

- The complexity of transportation decisions demands use of IT systems.
- **IT software can assist in:**
 - Identification of optimal routes by minimizing costs subject to delivery constraints
 - Optimal fleet utilization
 - GPS applications

- **Three main risks to be considered in transportation are**
 1. Risk that the shipment is delayed
 2. Risk of disruptions
 3. Risk of hazardous material
- **Risk mitigation strategies**
 - Decrease the probability of disruptions
 - Alternative routings
 - In case of hazardous materials the use of modified containers, low-risk transportation models, modification of physical and chemical properties can prove to be effective

□ Align transportation strategy with competitive strategy

- Managers should ensure that a firm's transportation strategy supports its competitive strategy.
- They should design functional incentives that help achieve this goal.
- Historically, the transportation function within firms has been evaluated based on the extent to which it can lower transportation costs.
- Such a focus leads to decisions that lower transportation costs but hurt the level of responsiveness provided to customers and may raise the firm's total cost.

Making Transportation Decisions in Practice

□ Consider both in-house and outsourced transportation

- Managers should consider an appropriate combination of company-owned and outsourced transportation to meet their needs.
- This decision should be based on a firm's ability to handle transportation profitably as well as the strategic importance of transportation to the success of the firm.
- In general, outsourcing is a better option when shipment sizes are small, whereas owning the transportation fleet is better when shipment sizes are large and responsiveness is important

□ Use technology to improve transportation performance

- Managers must use information technology to decrease costs and improve responsiveness in their transportation networks.
- Software helps managers do transportation planning and modal selection and build delivery routes and schedules.
- Real-time tracking allows carriers to communicate with each vehicle and identify its precise location and contents.
- These technologies help carriers' lower costs and become more responsive to changes.

□ Design flexibility into the transportation network

When designing transportation networks, managers should take into account uncertainty in demand as well as availability of transportation.

Ignoring uncertainty encourages a greater use of inexpensive and inflexible transportation modes that perform well when everything goes as planned.

- **Artificial Intelligence (AI)** is transforming the transportation industry by enhancing efficiency, safety, and decision-making. Key applications include:
- **Autonomous Vehicles:** AI enables self-driving cars, trucks, and drones to navigate, detect obstacles, and make real-time decisions.
- **Traffic Management:** AI analyzes traffic data to optimize signals, reduce congestion, and predict traffic patterns.
- **Predictive Maintenance:** AI systems monitor vehicle health and predict failures before they occur, reducing downtime and costs.
- **Fleet Management:** AI helps logistics companies optimize routes, schedules, and fuel usage for maximum efficiency.
- **Public Transportation:** AI improves scheduling, demand forecasting, and service reliability for buses and trains.

AI Technologies Used in Transportation

AI Technology

Machine Learning

Deep Learning

Computer Vision

Natural Language Processing

Reinforcement Learning

Robotics

Internet of Things (IoT)

Digital Twins

Transportation Application

Demand prediction, maintenance

Autonomous driving

Traffic monitoring, object detection

Customer service chatbots

Traffic signal optimization

Autonomous vehicles and drones

Real-time vehicle monitoring

Simulation of transportation systems

- Level 5 fully autonomous vehicles
- AI-powered smart cities
- Connected and autonomous transportation systems
- Vehicle-to-Everything (V2X) communication
- AI-enabled traffic digital twins
- Autonomous trucks for long-haul logistics
- Drone-based delivery networks
- Green transportation powered by AI
- Generative AI for transportation planning
- AI-integrated multimodal transportation systems

Real-World Company Examples

Company

Tesla

Waymo

Uber

Amazon

DHL

FedEx

UPS

Maersk

Siemens Mobility

Emirates Airlines

AI Application

Autonomous driving and ADAS

Fully autonomous taxis

Dynamic pricing and route optimization

AI-driven logistics and delivery optimization

Predictive logistics and warehouse automation

Route optimization and fleet management

ORION AI route optimization system

Smart shipping and predictive analytics

AI-powered rail traffic management

Predictive maintenance and flight operations

Summary of Learning Objectives

- 
1. Understand the role of transportation in a supply chain
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 4. Identify the relative strengths and weaknesses of various transportation network design options
 5. Identify trade-offs that shippers need to consider when designing a transportation network
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Thank You