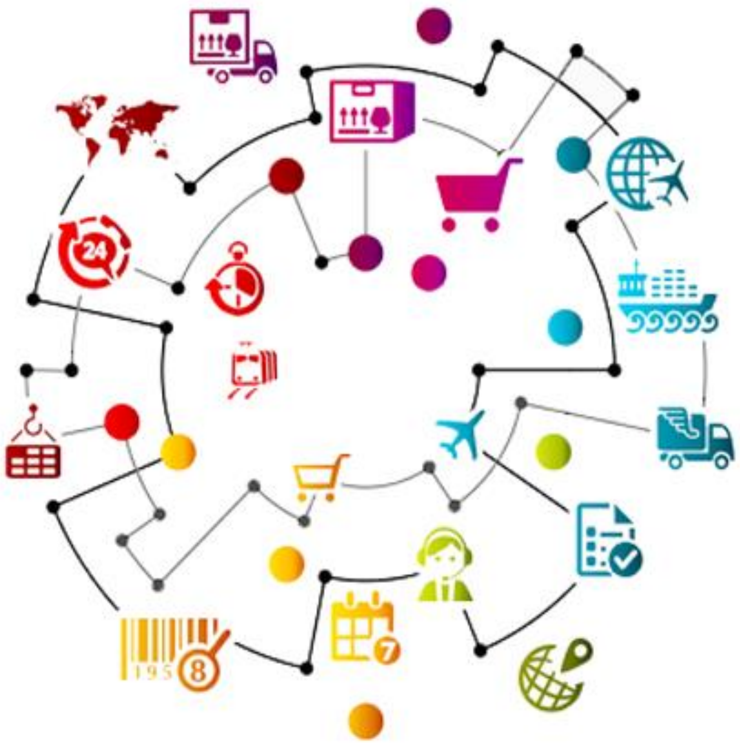

Logistics Engineering & Management

LOGISTICS NETWORK MODELLING & PLANNING

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Introduction to Logistics

Definition

"Logistics is the management of all activities which facilitate movement and the co-ordination of supply and demand in the creation of time and place utility"

(P. Nijkamp, Globalization, 2003)

"Logistics management is the planning, implementation and control of the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customer requirements"

(CSCMP 2006)

Definition 🤔⁉️

"Logistics is the positioning of resource at the right time, in the right place, at the right cost, at the right quality, while optimizing a given performance measure and satisfying a given set of constraints."

(Chartered Institute of Logistics and Transport, 2005)

"In civil organizations, logistics' issues are encountered in firms producing and distributing physical goods."

(L.A. Barroso *et al*., 2008)

Definition

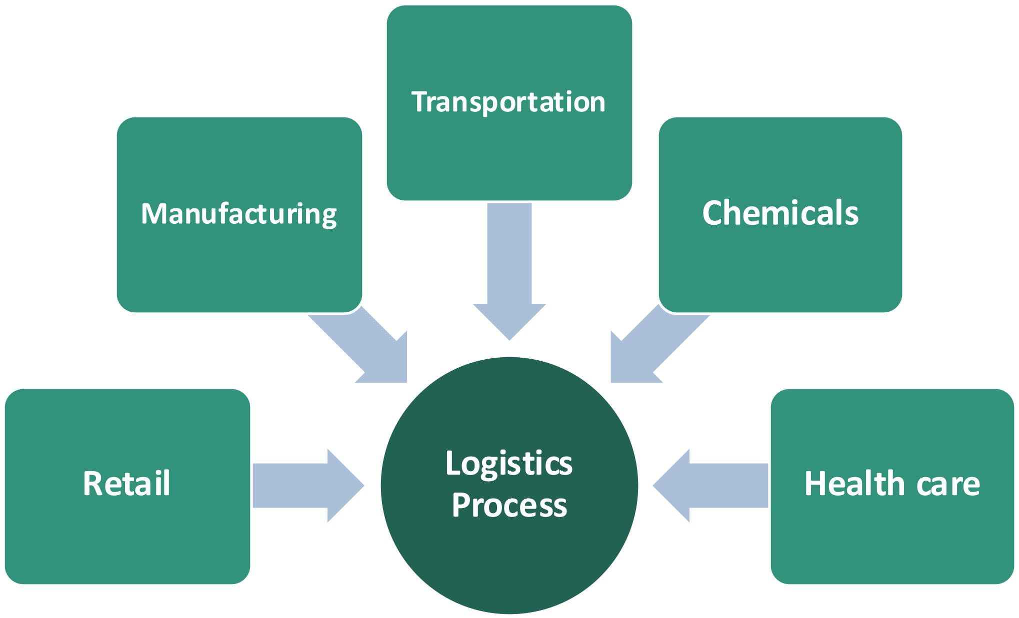
"Logistics is that part of the supply chain process that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements." (Council of Logistics Management 2003)

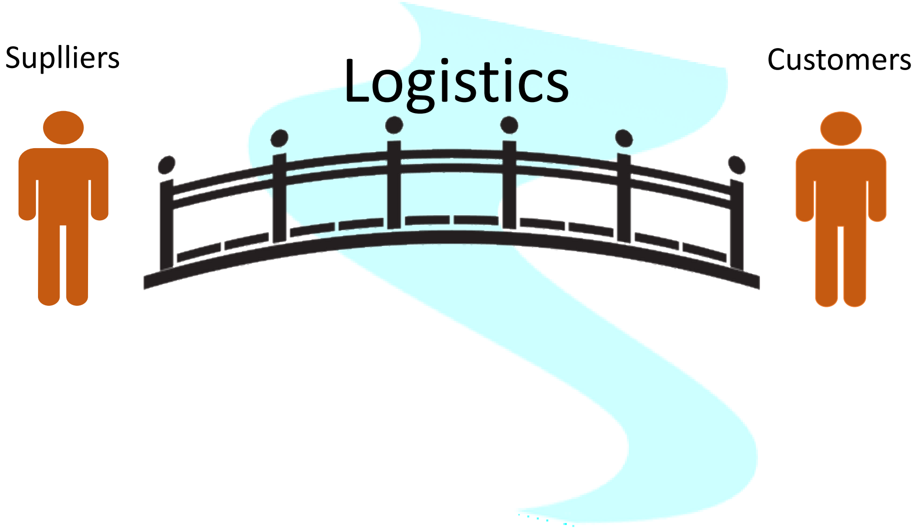
"Logistics is the entire process of planning, implementing, and controlling the efficient flow and storage of materials and products, services, information, energy, people, and other resources that move into, through, and out of a firm from the point of origin to the point of consumption and with the purpose of meeting customer requirements." (IEA, 2003)

Definition

Consumers and companies need products, material and other physical objects at a time when and a place where they are generally not produced. This leads to the task of operative logistics or the four rights of logistics (4R)

(Timm Gudehus, Herbert Kotzab, 2011)

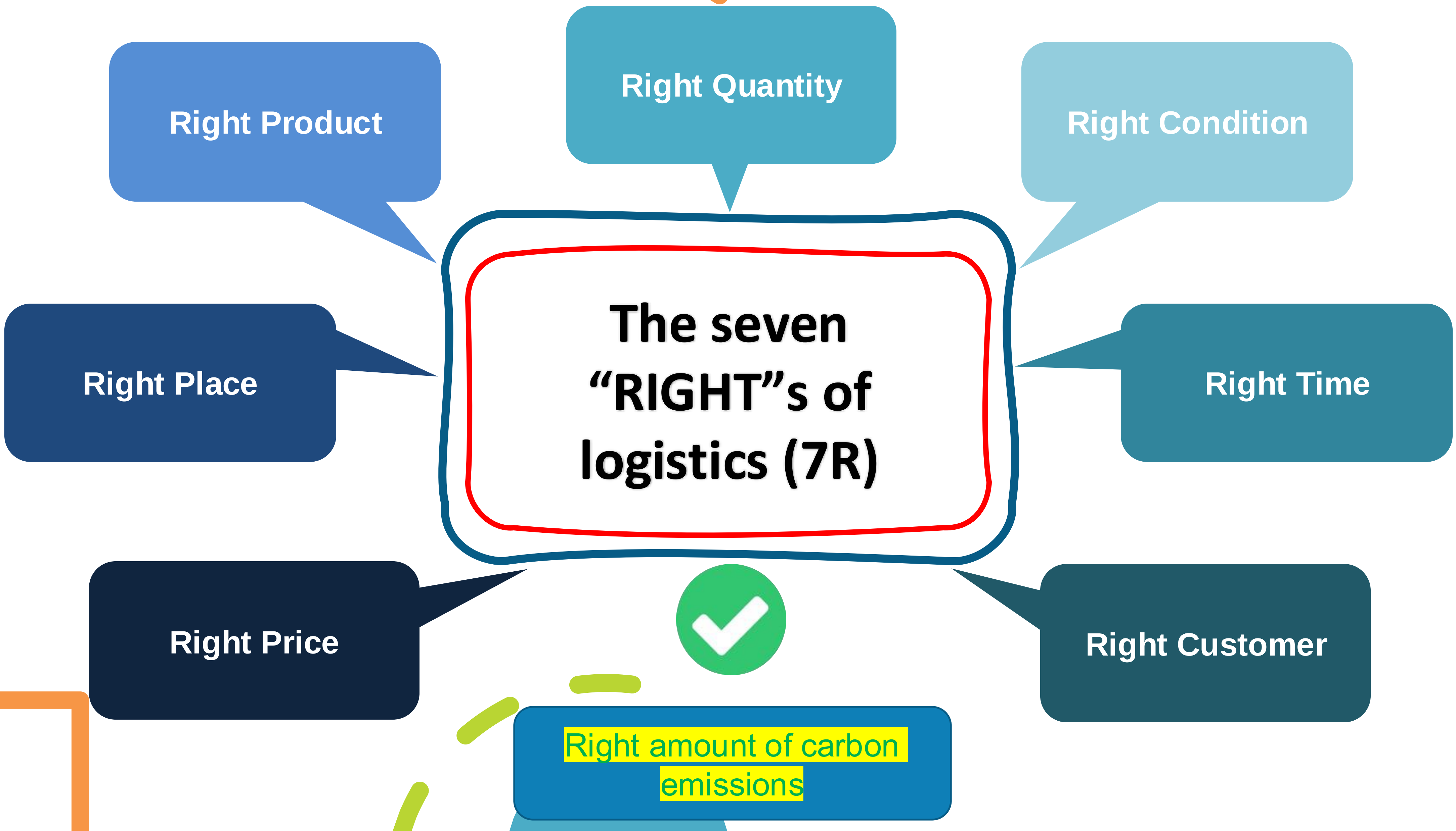




Definition

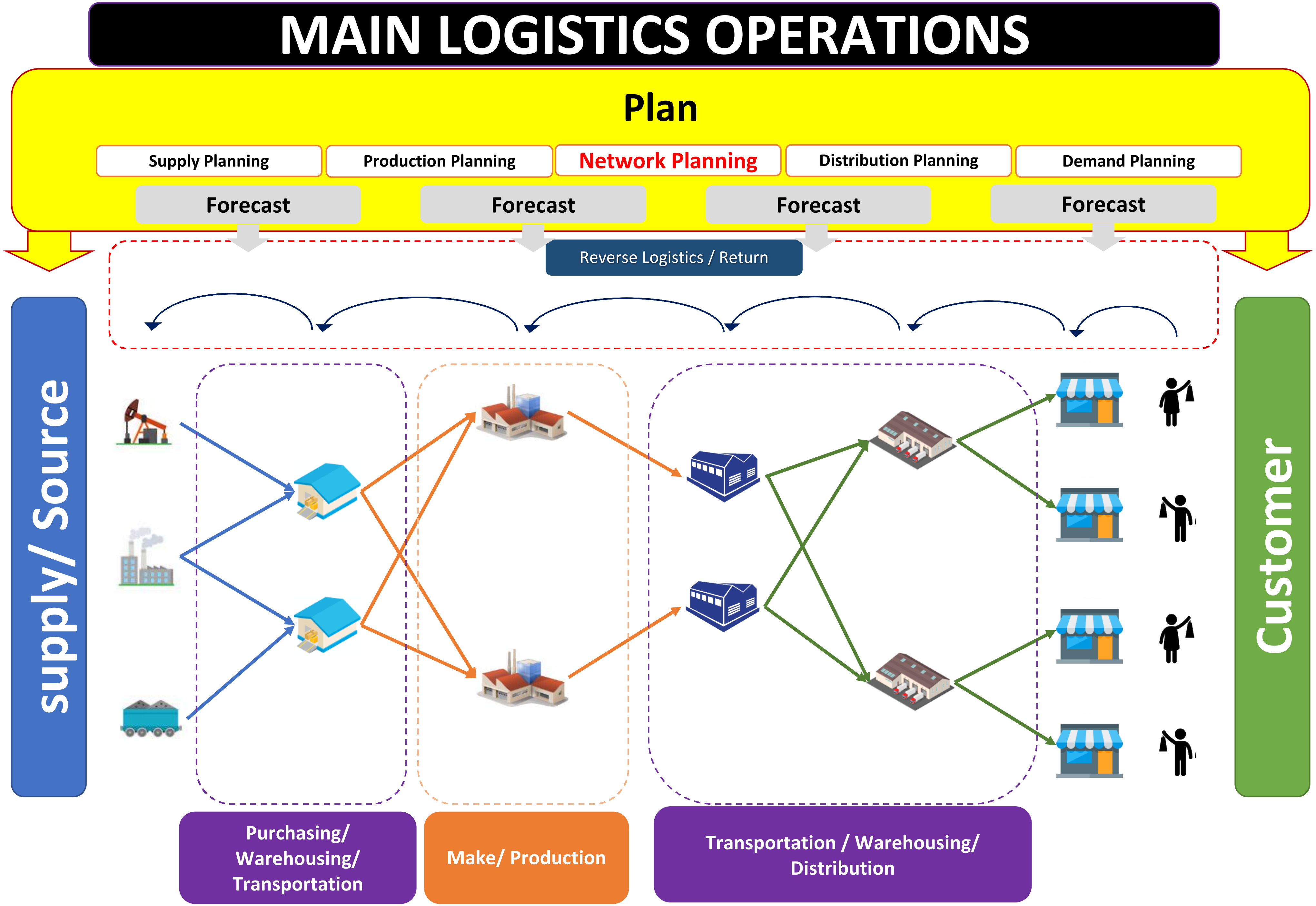
Logistics is the process of planning, implementing and storage of raw materials, in-process inventory, finished goods and related information from point of origin to point of consumption for the purpose of conforming to customer requirements.

(The Council of Logistics Management)


The seven "RIGHT"s of logistics (7R)
Right Product
Right Quantity
Right Condition
Right Place
Right Time
Right Price
Right Customer
Right amount of carbon emissions

Example

Wrong Place Wrong Time	Christmas trees in Iraq after Christmas
Wrong Place Right Time	Christmas trees in Iraq Nov. 25th to Dec. 24th
Right Place Wrong Time	Christmas trees in USA but after Christmas
Right Place Right Time	Christmas trees in USA during Nov. 25th to Dec. 24th


MAIN LOGISTICS OPERATIONS
Plan
Supply Planning
Production Planning
Network Planning
Distribution Planning
Demand Planning
Forecast
Forecast
Forecast
Forecast
Reverse Logistics / Return
supply/ Source
Customer
Purchasing/ Warehousing/ Transportation
Make/ Production
Transportation / Warehousing/ Distribution

The Importance of Logistics

In 2003 US logistical activity costs were 8.5% of the country's GDP.

The US GDP in 2003 was approximately $12,400 billion.

The logistical activity cost was approximately $1054 billion.

(Seventeenth Annual State of Logistics Report of USA 2006).

The total logistics cost incurred by USA organizations in 1997 was 862 billion dollars,

Approximately 11% of the USA Gross Domestic Product (GDP).

Higher than the combined annual USA government expenditure in social security, health services and defense.

The Importance of Logistics

Sector	Transportation	Warehousing	Inventory	Administration	Total
Food / Beverage	3.7	2.2	2.8	1.7	**10.4 %**
Electronics	2.0	2.0	3.8	2.5	**10.3 %**
Chemical	3.8	2.3	2.6	1.5	**10.2 %**
Automotive	2.7	2.3	2.7	1.2	**8.9 %**
Pharmaceutical	2.2	2.0	2.5	2.1	**8.8 %**
Newspapers	4.7	3.0	3.6	2.1	**13.4 %**

Logistics costs (as a precentage of GDP) in EU countries

Logistics decisions

Strategic Planning level

- Performance objectives
- Definition of Customer service and associated metrics
- Overall economic objectives

Network (Tactical) level

- Physical Facility (PF) Network
- Communication and Information (C&I) Network

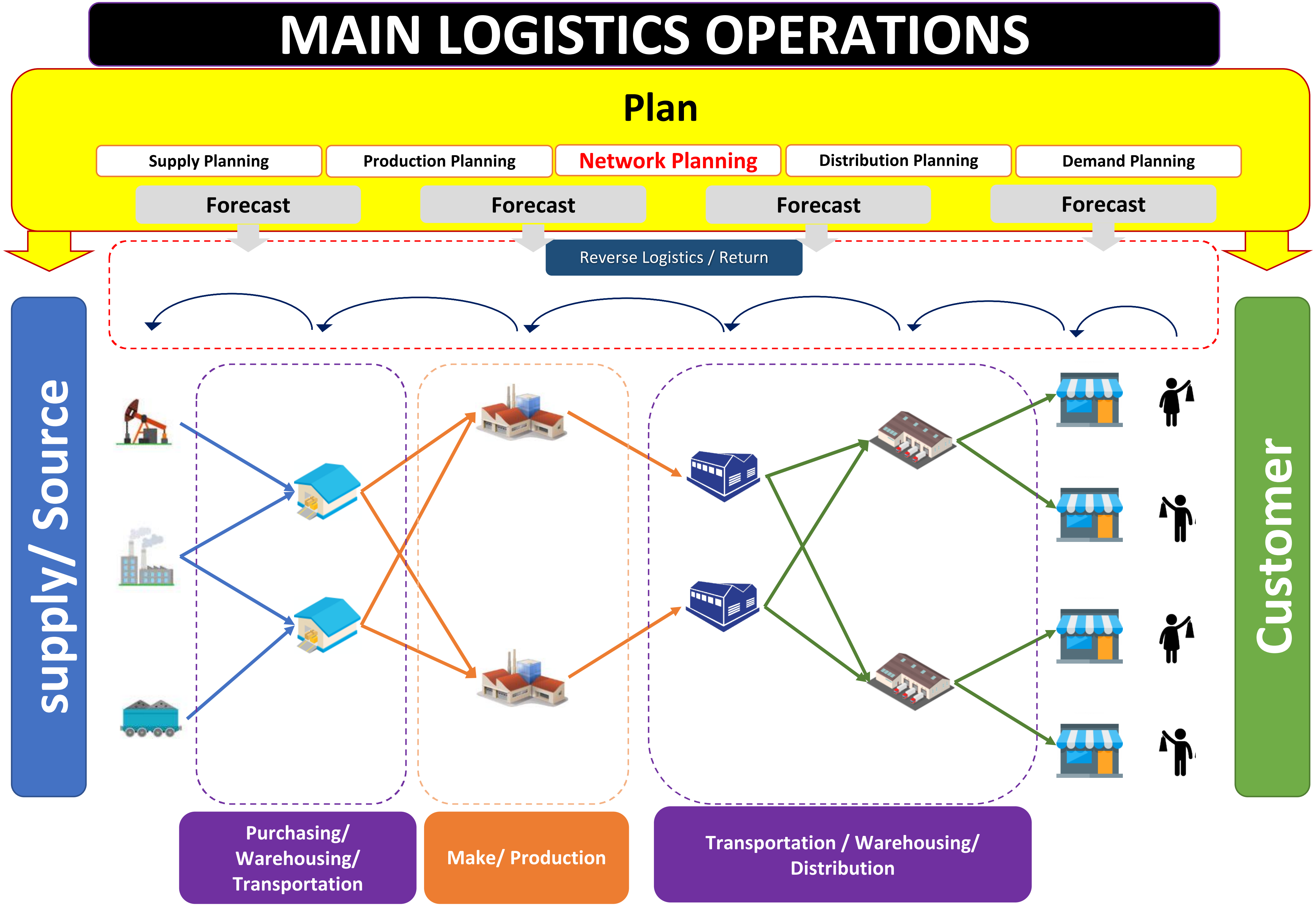
Operations level

- Demand Forecasting
- Inventory Management
- Production
- Procurement and Supply Management
- Transportation
- Product Packaging
- Material Handling
- Warehousing
- Order Processing

Logistics Tasks

Develop and **organize optimal processes**, **structures**, **systems** and **networks**

Execute the **orders** and to **fulfill** the **requirements** of consumers and companies at **lowest costs** with **adequate quality**.



MAIN LOGISTICS OPERATIONS
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Forecast
Forecast
Reverse Logistics / Return
supply/ Source
Customer
Purchasing/ Warehousing/ Transportation
Make/ Production
Transportation / Warehousing/ Distribution

Values added to a product at its life cycle: ?

01
Production and manufacturing

Form value
converting the raw material or components into components or finished parts

02
transportation

Place value
moving the product where it is needed

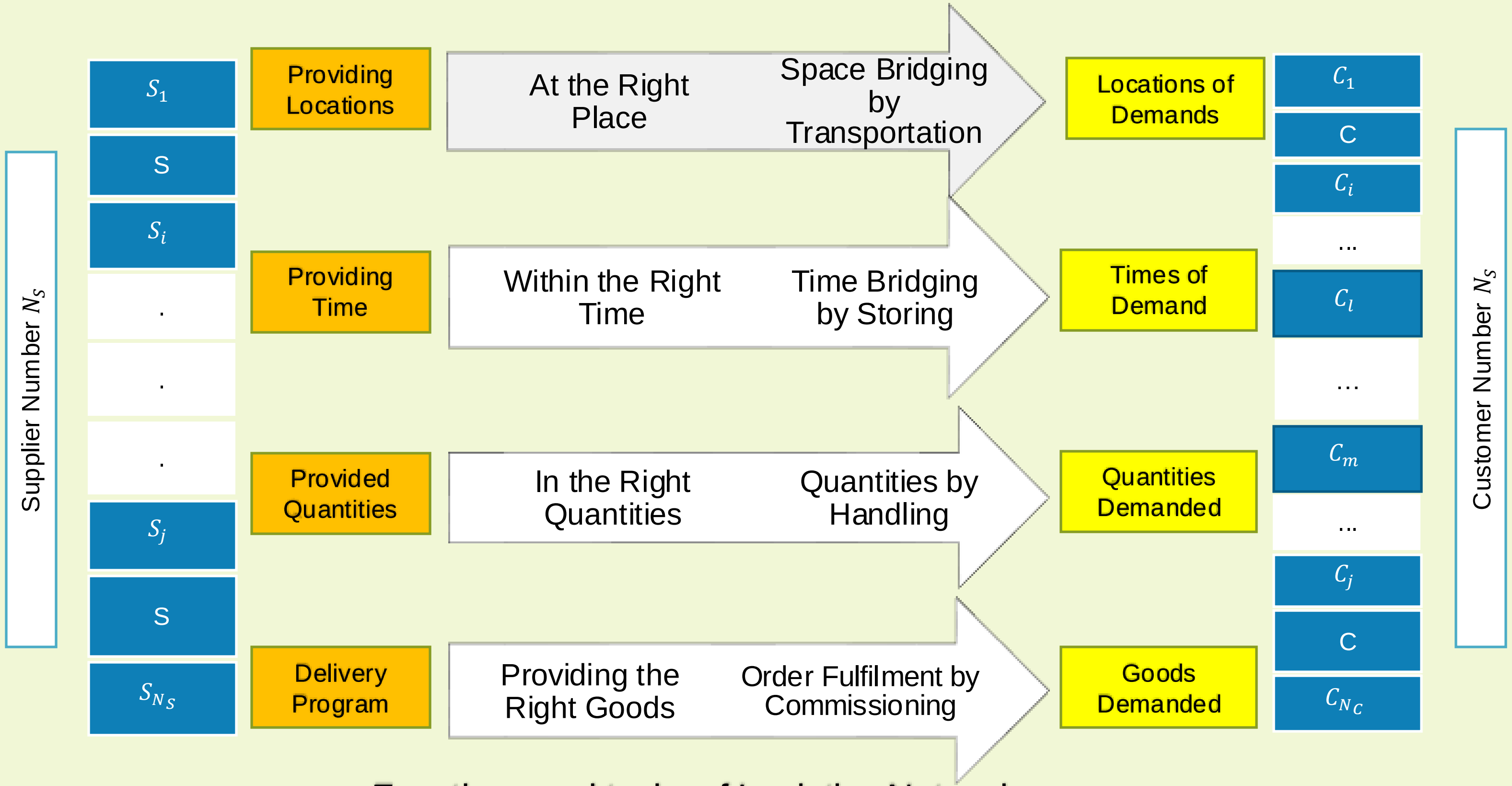
03
storage and inventory control

Time value
ensuring the availability of the product when needed

04
marketing and sales

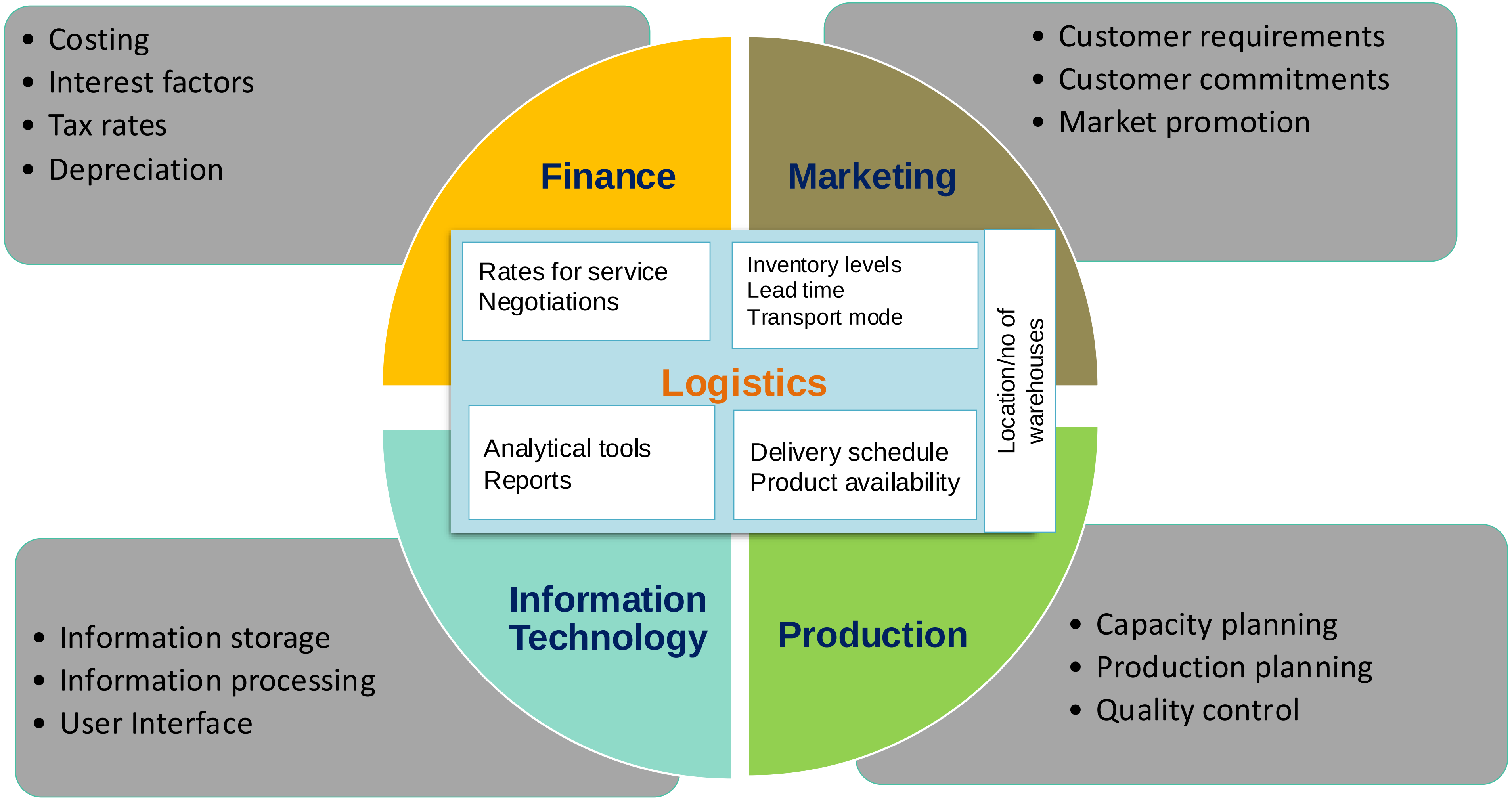
Possession value
Meeting the customer’s expectations

Logistics Tasks



Functions and tasks of Logistics Network

Logistics Interfaces

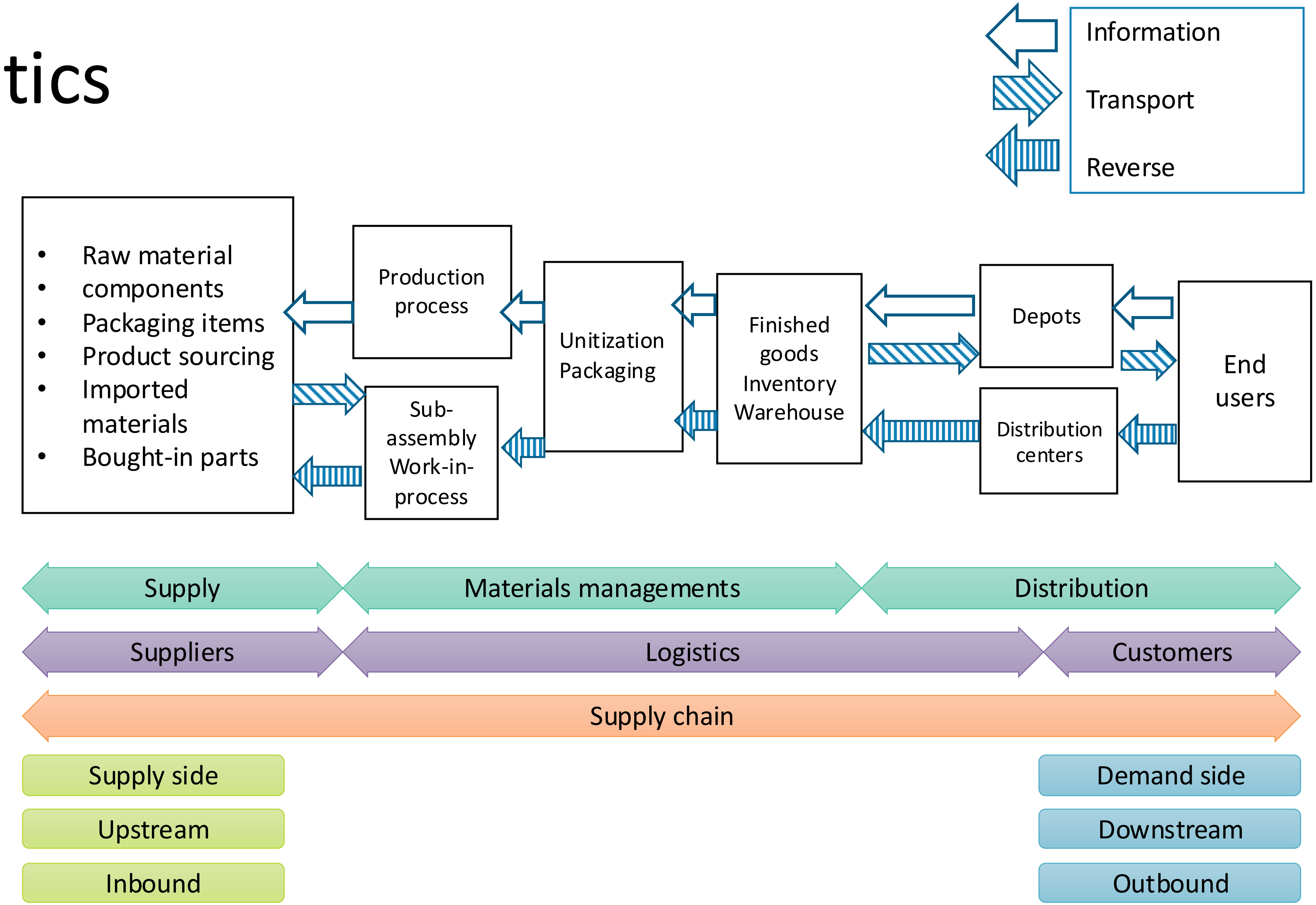


Interfaces between logistics and other functions

Flows in Logistics

- **Physical flow**
- **Information flow**

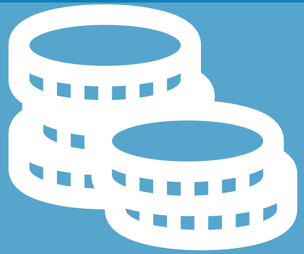
Objects of Logistics



Logistics flows and some of the different logistics terminologies

The Objectives in Designing a Logistics Network

Capital Reduction



Cost Reduction

Service-level improvement

Other

Environmental Obj., Social Obj., etc.

Capital reduction

- ✓ choosing public warehouses instead of privately owned warehouses
- ✓ using common carriers instead of privately owned vehicles
- ✓ …

Capital reduction usually comes at the expense of higher operating costs.

Cost reduction

- ✓ Privately owned warehouses and vehicles
- ✓ Optimizing the logistics Processes
- ✓ …

Service level improvement

- Improving the logistics service level may increase revenues, especially in markets with homogeneous low-price products

Real Business Examples

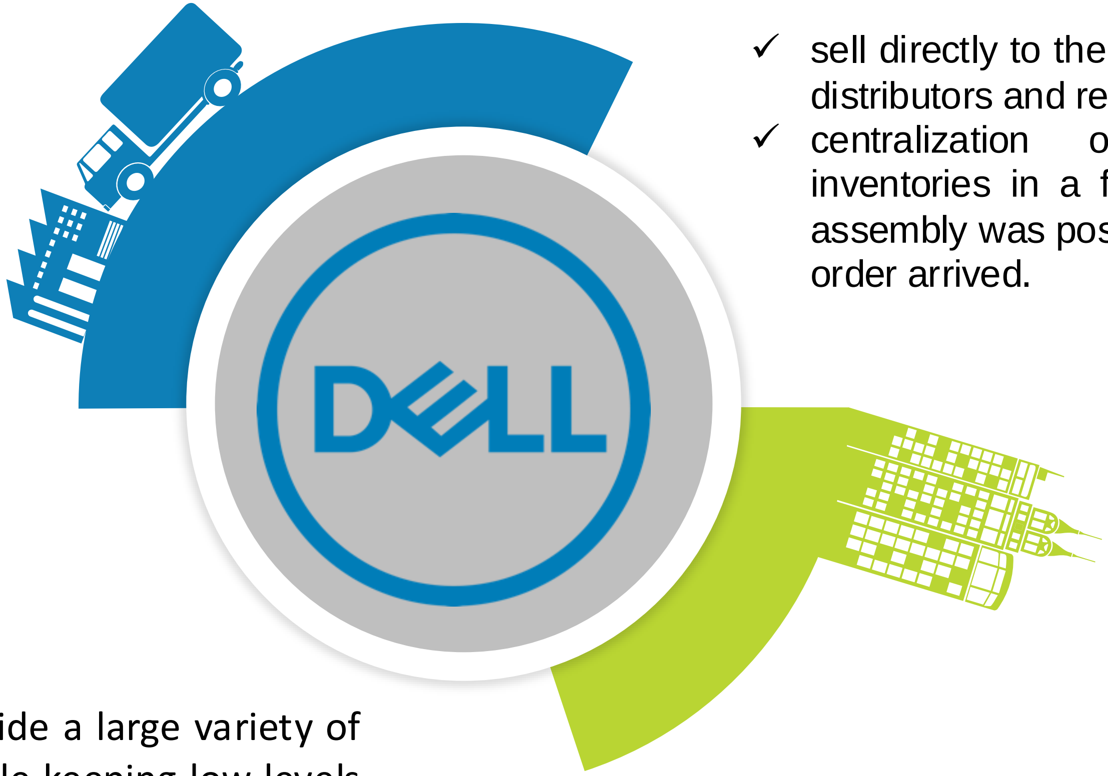
from sales of 1 billion yen in 1974 to almost 1.9 trillion yen in 2013, with profits in 2013 totaling 222 billion yen.

✓ very responsive replenishment system with an outstanding information system

✓ change the merchandising mix at each store by time of day to precisely match customer demand

By 2006, Dell had a net income of more than $3.5 billion on revenues of just over $56 billion.

- ✓ Dell reacted by adjusting its logistics regard to both direct selling and building to order.



- ✓ sell directly to the end customer, bypassing distributors and retailers.
- ✓ centralization of manufacturing and inventories in a few locations where final assembly was postponed until the customer order arrived.

- ✓ Dell was able to provide a large variety of PC configurations while keeping low levels of component inventories

In 1980 - $1 billion annual sales
In 2013 - $17 billion net income on revenues of about $469 billion
More than 20 percent annual compounded growth rate

- ✓ sharing information and collaborating with suppliers

- ✓ using logistics design, planning, and operation
- ✓ Invest on transportation and information infrastructure
- ✓ facilitate the effective flow of goods and information.

- ✓ Walmart designed its logistics with clusters of stores around distribution centers

Company Background

operates more than 11,700 stores under 59 company names, with 2.3 million employees in 28 countries around the world while managing an average of $32 billion in inventory..

In the early 1970s, Walmart became one of the first retailing companies in the world to centralize its distribution system, pioneering the retail hub-and-spoke system.

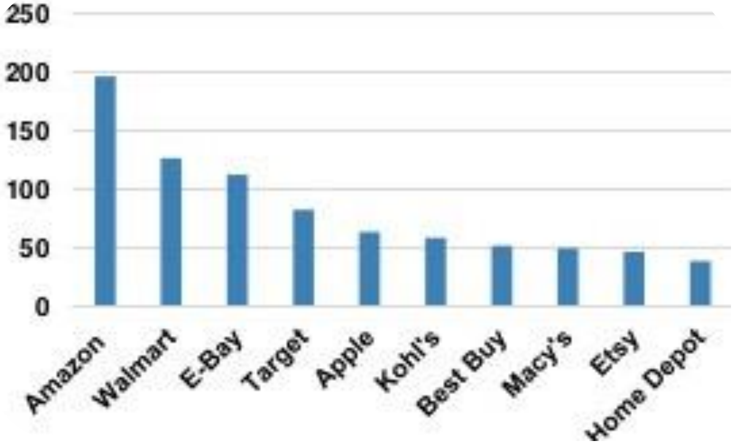
Phenomenal growth of Walmart is attributed to its continued focus on customer needs and reducing cost through efficient supply chain management practices.

Walmart began with the goal to provide customers with the goods they wanted, whenever and wherever they wanted them. .

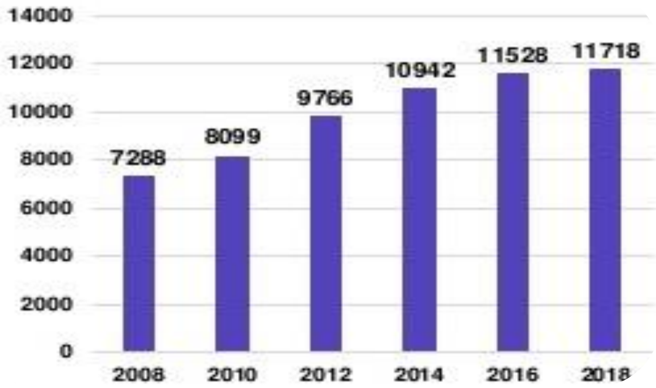
Company Background

Largest Employers In the World

Popular retail websites in USA



Number of Walmart Stores



Retail Revenue (USD Billion) - 2016

Walmart Company

Fewer links

- removing a few of the chain's links, right from the very beginning.
-Walmart began working directly with manufacturers to cut costs and more efficiently manage the supply chain.

Using EDI for procurement

-EDI saved time and made procurement efficient.
- Using the bar code scanners

Using IT in SCM

1977: set up a Computer Terminal Network (CTN)
1978: set up its first fully automated distribution center.
Using voice based technologies

GPS System

-Any truck can be located
-Drivers could activate system by voice and interact with staff

Walmart Procurement

-emphasized the need to reduce purchasing costs and offer the best price to the customer.
-directly procurement from manufacturers

Logistics Management

-fast and responsive transportation system
-fast and responsive transportation system
Cross-docking

Walmart Company

EDLP Strategies

-The concept of Every Day Low Pricing
-Wide variety of high quality branded as well as unbranded products at lowest possible price.

Developing partnership with suppliers

-Establishes strategic partnerships with most of their vendors, offering them long-term and high volume purchases in exchange for the lowest possible prices.
-Invited its major suppliers to co-developed profitable supply chain partnership
-Walmart and P&G also incorporated several other inter company innovations

Selection of Vendors

-Embarked on strategic sourcing to find products at the best price from suppliers who are in a position to ensure they can meet demand
-Walmart streamlined supply chain management by constructing communication and relationship networks with suppliers

Distribution of Traffic and Fleet

-Able to move goods to-and-from distribution centers because they maintain a private fleet of trucks and a skilled staff of truck drivers.
-Drivers follow the most efficient routes to their destinations

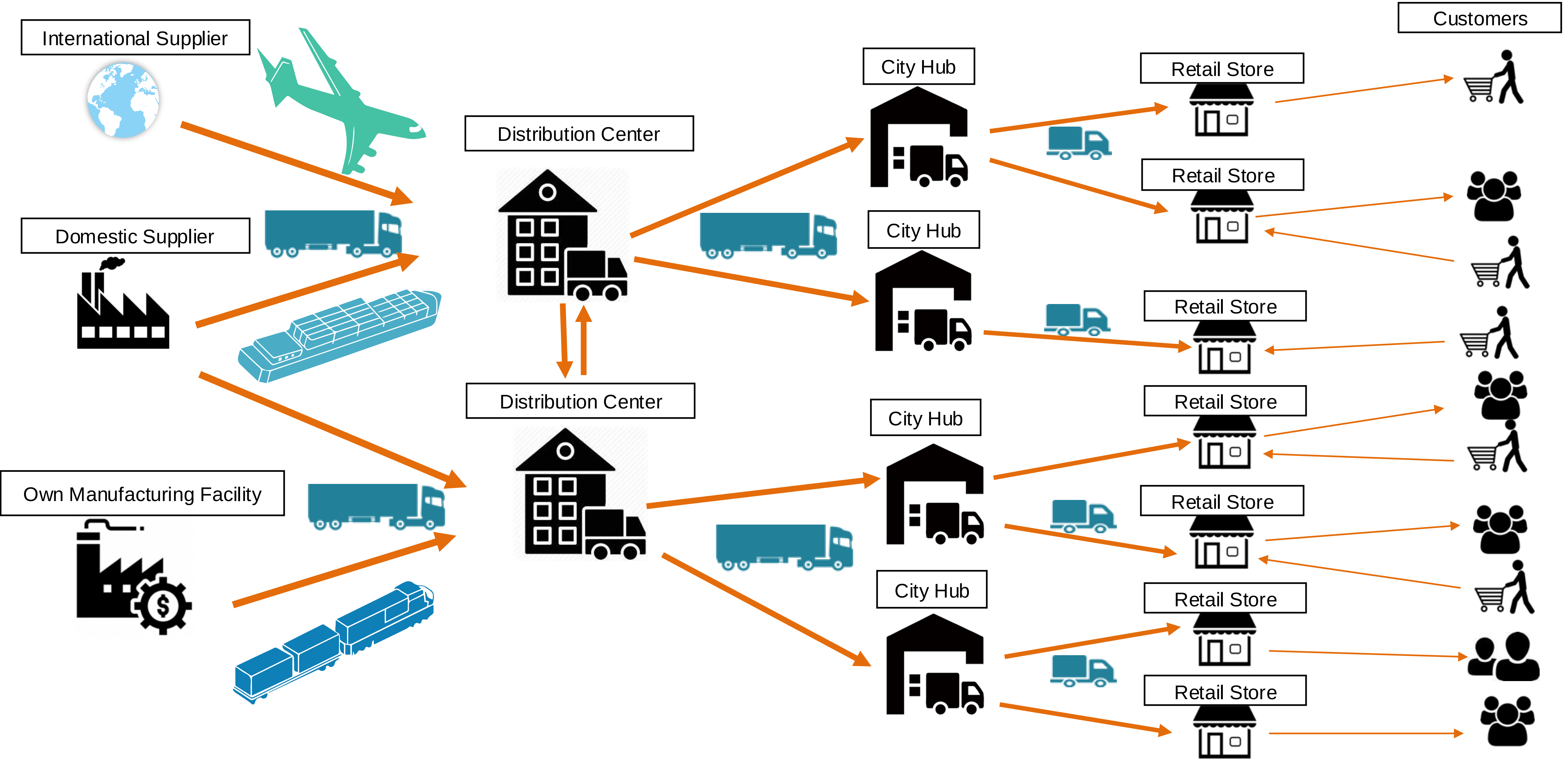
Cross-docking

- A logistics practice of Walmart's strategy to replenish inventory efficiently
-Keeps inventory and transportation costs down, reduces transportation time, and eliminates inefficiencies
-Reducing Walmart's costs significantly, allowing the company to pass those savings on to their customers with highly competitive pricing

Investing in advanced inventory technology

-In 2015, spent $10.5 billion on information technology and invested in improving their eCommerce capability
-The largest information technology infrastructure of any private company in the world
-Accurately forecast demand, track and predict inventory levels, create highly efficient transportation routes, manage customer relationships, and service response logistics

Walmart Logistics Network



Walmart gets benefited through Logistics…

Company Background

its brand is it's primary asset but the way it's logistics and supply chain network works in collaboration, and its constant adaptation to local contexts is its another important feature

- 146,200 worldwide employees and 3,500 different products
- 8 billion coke bottles is sold each day and it has 275 global Coke bottling companies

In large scale operations such as Europe, the company can get drinks from its factories to supermarket shelves within 48 hours.

In local operations such as Spain, the company delivers within 24 hours

Taking real-time data and immediately feed it back into the product

- very continuous feedback loop. They learn something; they put it back into the product, and they put it back into the market
- accurate and precise online data about their sales status

.

Tap into local entrepreneurial talent.

- In 1990, the company started training local entrepreneurs and provided them with small loans
-They set them up as micro-distribution centers, and those local entrepreneurs then hire sales people, who go out with bicycles and pushcarts and wheelbarrows to sell the product.
-There are now some 3,000 of these centers employing about 15,000 people in Africa

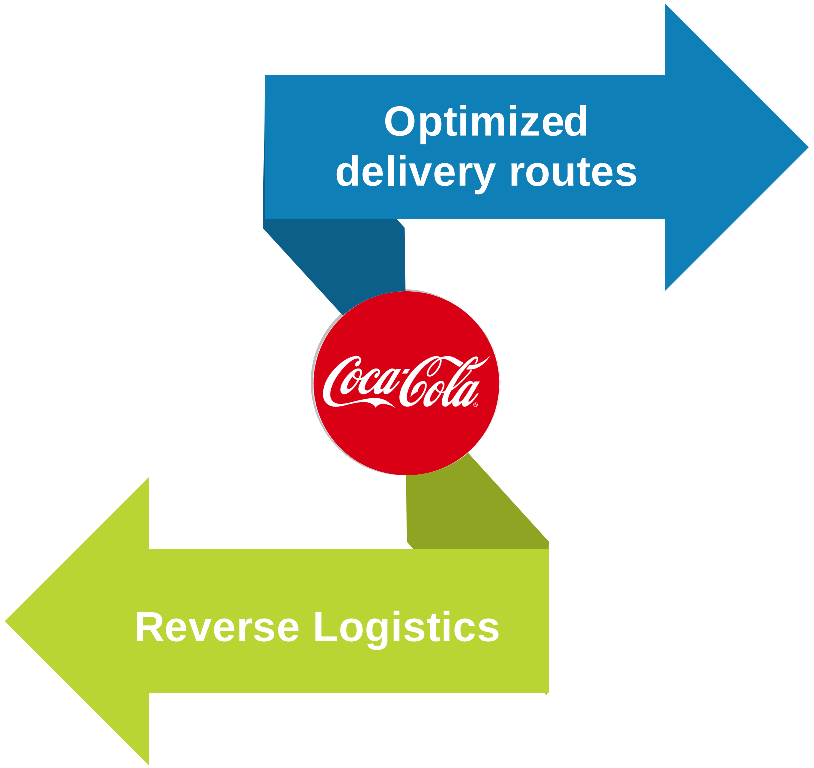
Networked capacity to adapt

- In several operations of Western Europe, they've developed systems to work in close collaboration with customers
- Production systems are networked to allow them to raise or lower capacity, to meet demand peaks by flexing up production at several sites.
  -For exceptional levels of demand(e.g. during Christmas or major sporting events like the Olympics)

.

Customized trucks

- They built mixed pallets to fit various products in the right quantities to fulfill particular stores' orders, reducing times and effort from a traditional approach.
- According to the site Logistics Viewpoints this was done by using the intelligence data from Advanced Shipping Notices (ASNs)



-In Mexico, the logistics system has 13 franchised bottling companies, 60 production plants and 428 distribution centers (DCs).

- An umbrella organization in Mexico City controls the distribution network, handled locally by the franchises.

-The central office designs point-of-sale service management tactics, with computing systems which "within a few hours, review all routes and sales territories,"

-Truck and workload scheduling for point-of-sale distributors used to take months but now are fully sensitive to real-time market demands.

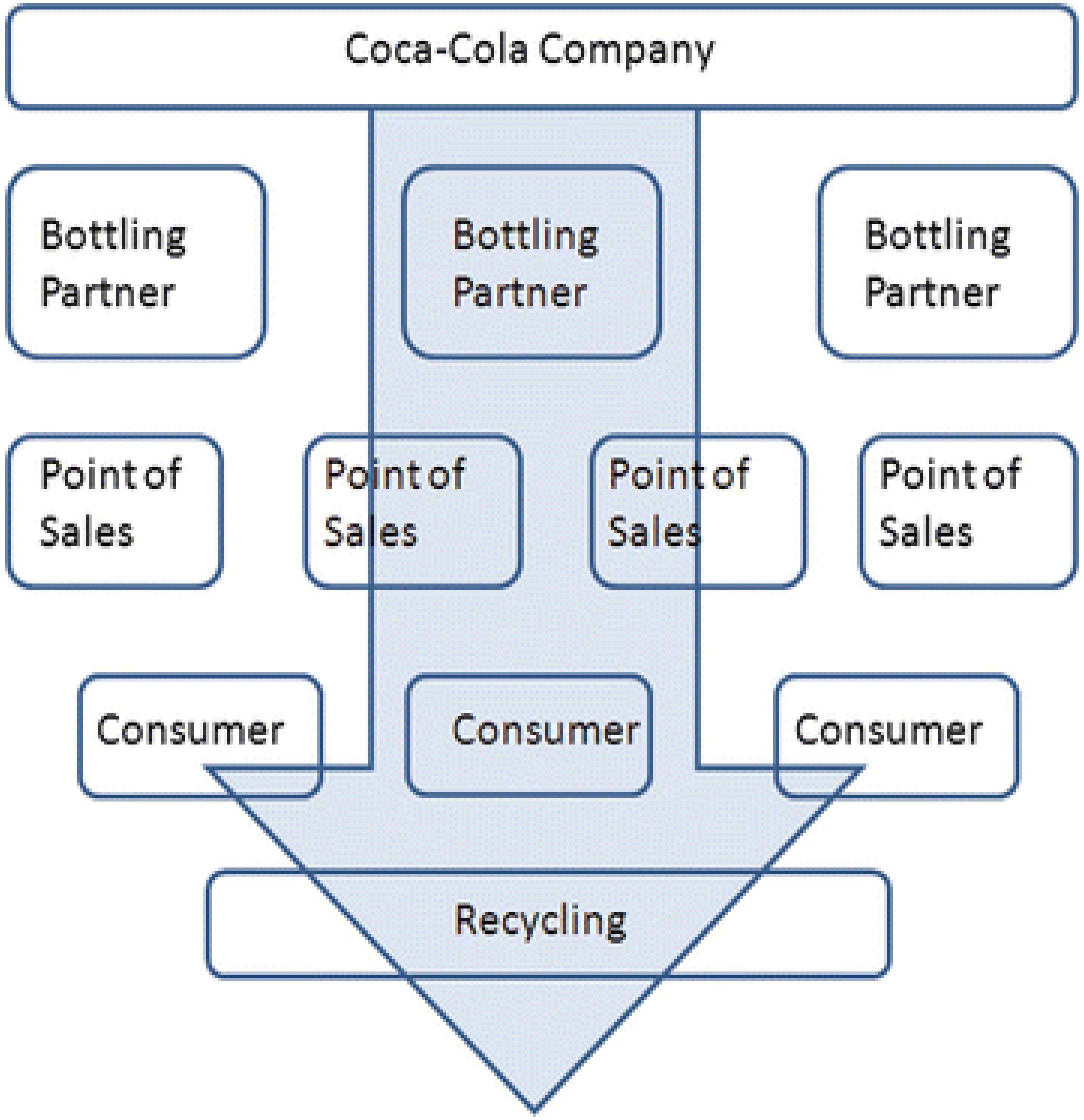
-The company delivers local bottlers planning processes developed for the entire supply chain. These are not compulsory, but bottlers design their own distribution schemes.

-Computer software also works in distribution plans to forecast demand and route optimization.

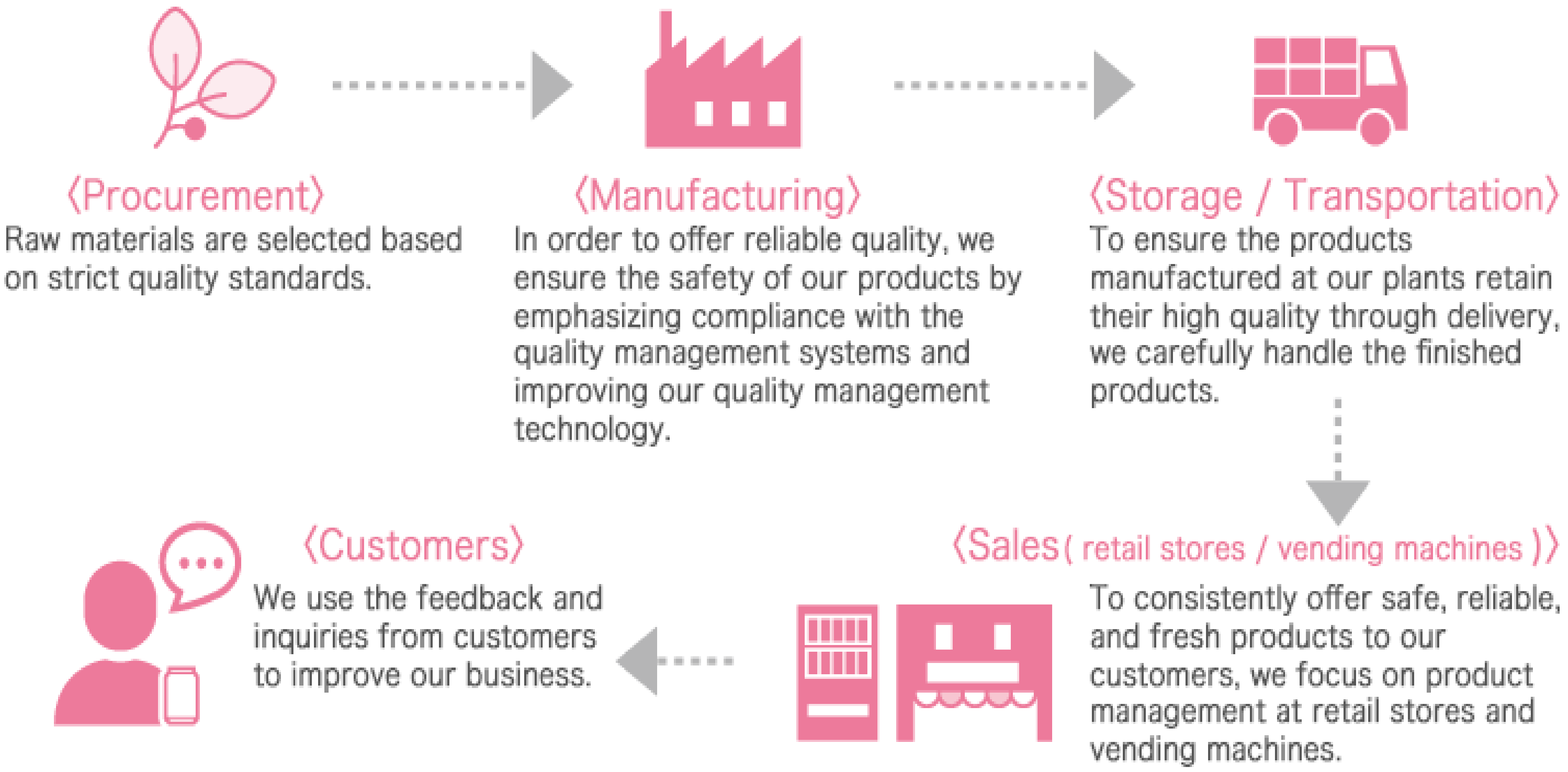
-At a global level, the different distribution centers of this brand work in close collaboration with retail companies and local dealers in order to have recyclable bottles returned, sanitized and repurposed.

-This adds to the brand value and maximizes their local fleet management capacity in the return of bottles.

Coca Cola Logistics Network



Coca Cola Logistics Network



Company Background

- It carries about 11,000 distinct items per year in thousands of stores worldwide compared to competitors that carry 2,000 to 4,000 items per year in their stores.

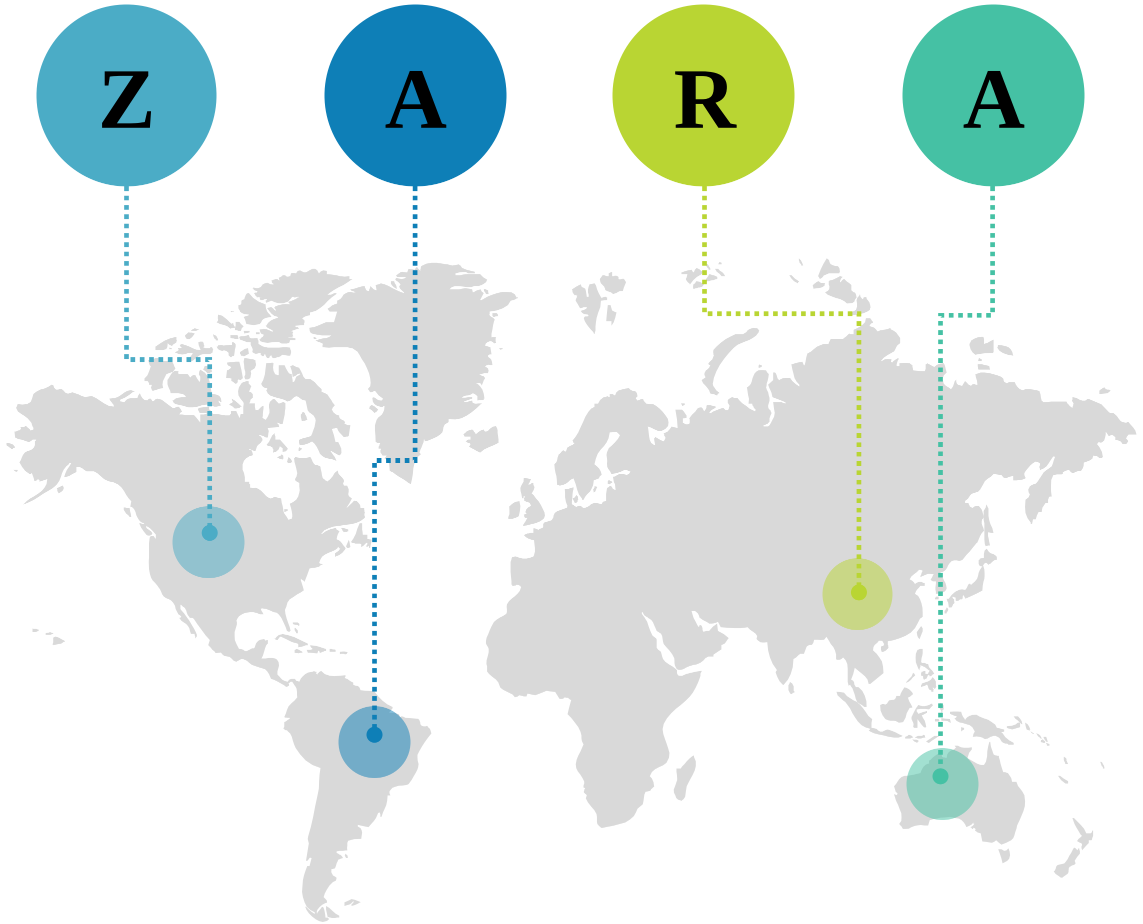
-The heart of the company and its supply chain is a huge, highly automated distribution center (DC) called "The Cube".

ZARA

- Zara's highly responsive Logistics Network is central to its business success.

-In 2019 Zara was ranked as the 46th most valuable brand in the world by Forbes.

Zara Business Model

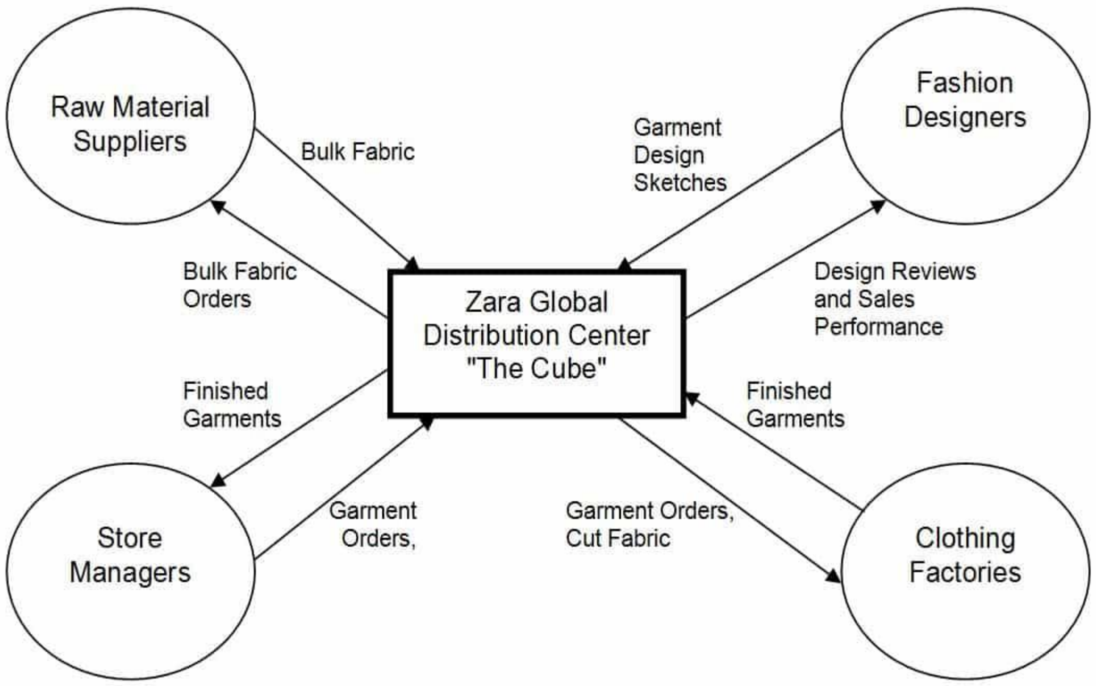


A Stores place orders twice a week and this drives factory scheduling. Such short term focused order cycles make forecasts very accurate, much more accurate than competitors who may order every two weeks or every month.

B Annually there is 10 percent of inventory unsold compared to industry averages of 17 – 20 percent..

C Annually there is 10 percent of inventory unsold compared to industry averages of 17 – 20 percent.

D Annual sales for 2018 were estimated by Forbes to be $21.3 billion.



Manufacturing and Logistics Operations

- Zara buys large quantities of only a few types of fabric.
- This way fabric manufacturers can make quick deliveries of bulk quantities of fabric directly to the Zara DC – the Cube.
- The company purchases raw fabric from suppliers in Italy, Spain, Portugal and Greece. And those suppliers deliver within 5 days of orders being placed.
- Inbound logistics from suppliers are mostly by truck.
- All raw materials pass through the Cube on their way to the clothing factories, and all finished goods also pass through on their way out to the stores. The diagram below illustrates Zara’s supply chain model
- They do only 50 – 60 percent of their manufacturing in advance versus the 8 0 – 90 percent done by competitors.

Manufacturing and Logistics Operations

The Zara factories are connected to the Cube by underground tunnels with high speed monorails (about 200 kilometers or 124 miles of rails) to move cut fabric to these factories for dyeing and assembly into clothing items.

The monorail system then returns finished products to the Cube for shipment to stores. .

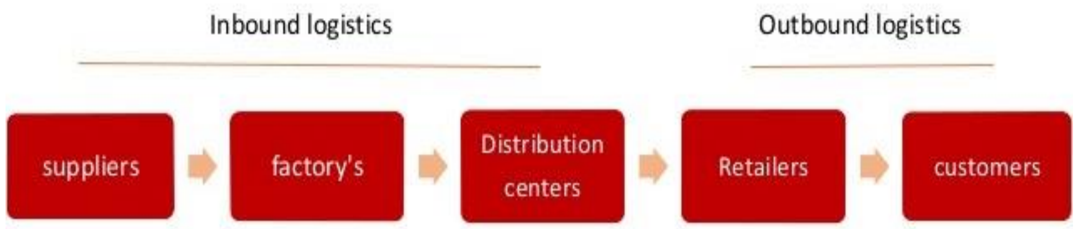
Zara competes on flexibility and agility instead of low cost and cheap labor.

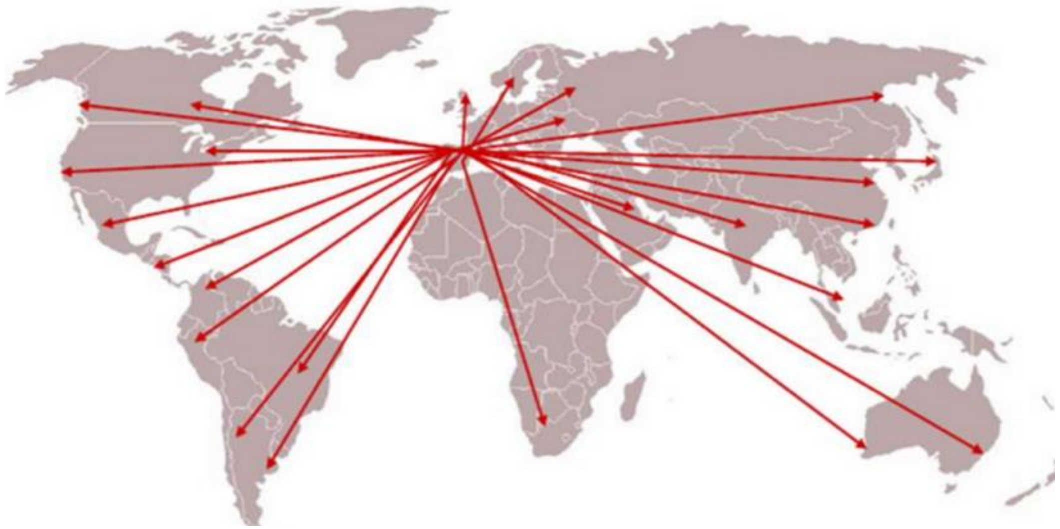
They employ about 3,000 workers in manufacturing operations in Spain at an average cost of 8.00 euros per hour compared to average labor cost in Asia of about 0.40 euros per hour.

Zara factories in Spain use flexible manufacturing systems for quick change over operations.

50% of all items are manufactured in Spain, 26% in the rest of Europe

24% in Asia and Africa



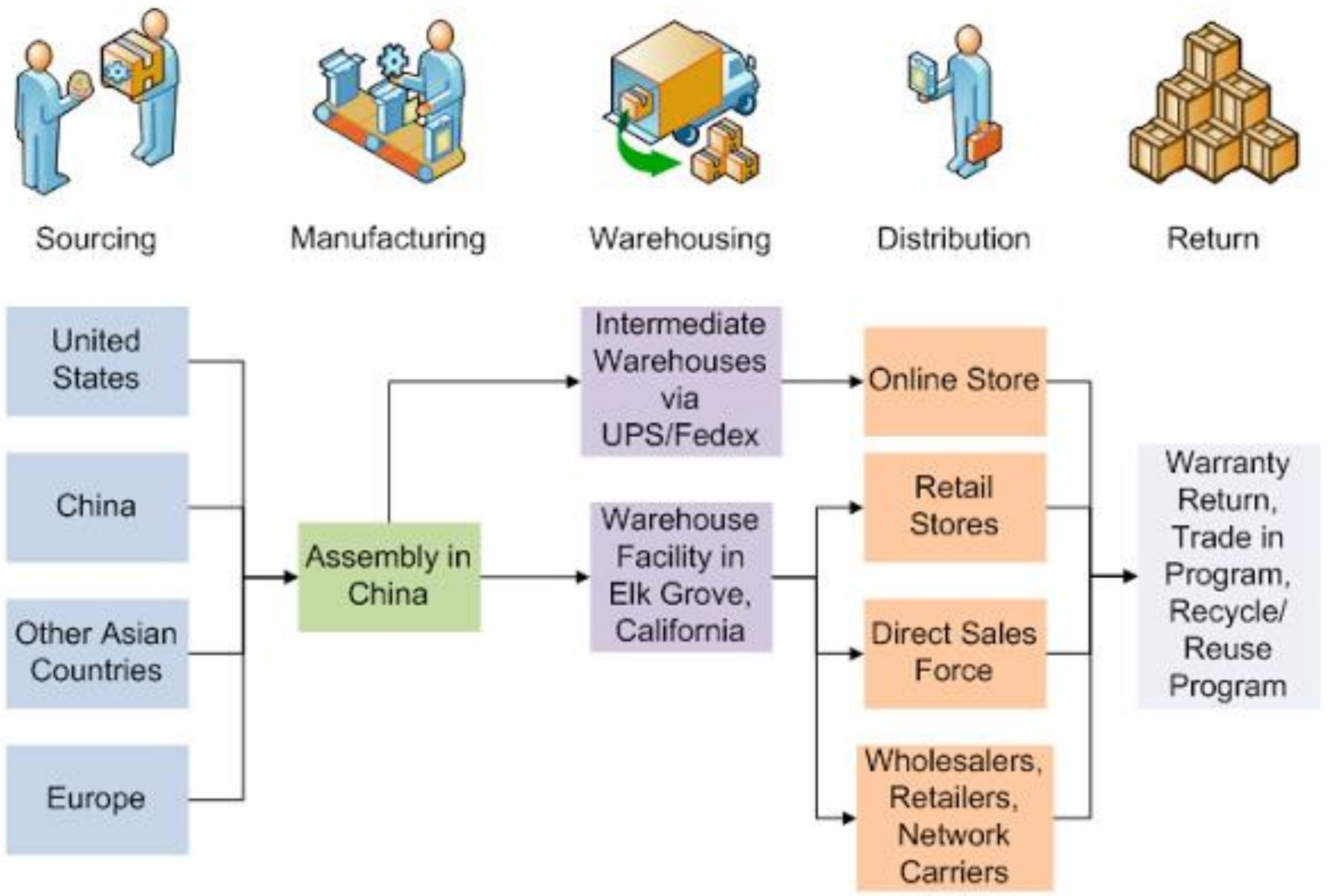


All clothes are shipped back to there distribution center in Spain. And it distributed to all there stores overall the world

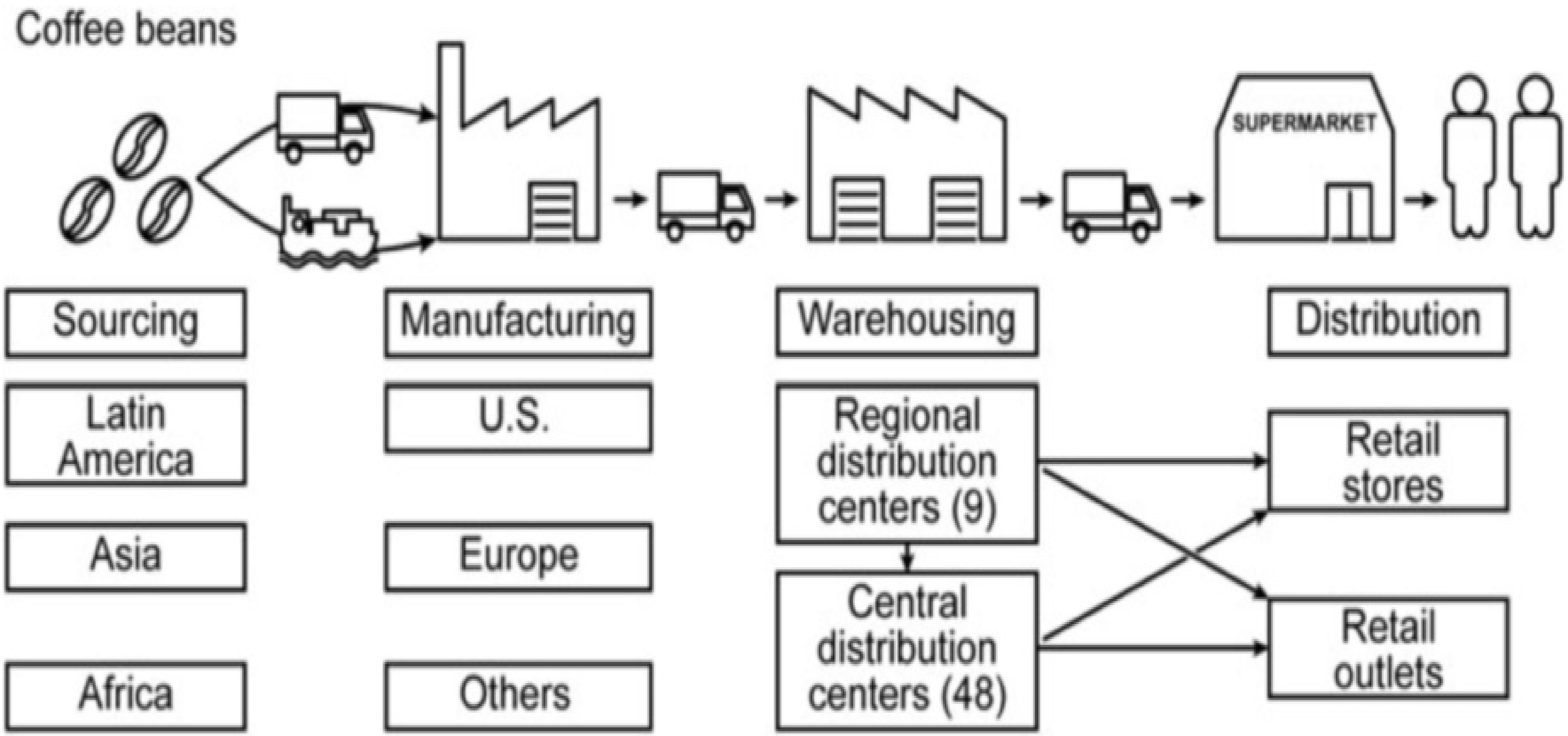
Manufacturing and Logistics Operations

- Manufacturing is centered in northwestern Spain where company headquarters and the Cube are located. But for their main distribution and logistics hub they chose a more centrally located facility.
- Raw material is sent by suppliers to Zara’s manufacturing center. Then finished garments leave the Cube and are transported to the Zara logistics hub in Zaragoza. And from there they are delivered to stores around the world by truck and by plane.
- Zara can deliver garments to stores worldwide in just a few days: China – 48 hrs; Europe – 24 hrs; Japan – 72 hrs; United States – 48 hrs.
- It uses trucks to deliver to stores in Europe and uses air freight to ship clothes to other markets.
- Its agile and responsive supply chain enables Zara to work on a short sales and operations planning (S&OP) cycle.
- Zara has spent more than 30 years building its unique real-time supply chain and training its people.

Other Examples



Other Examples



Storage, Warehousing, and Inventory Management

Why we Keep inventory?

- unexpected changes demand and lead time.
- economies of scale.
- Balance supply and demand.
- contingencies.
- manufacturing bottlenecks.
- price changes.

The Role of Distribution Centers and Warehouses in Logistics

1. Storage of goods
2. part of production process
3. Returned goods center
4. Consolidation
5. Breakbulk
6. Postponement
7. Cross docking
8. Transshipment
9. Product-fulfilment Center

Warehouse Design

Storage Policies

- Randomized
- Dedicated
- class based

Size of Warehouse

- Customer-service level
- Size of market(s) served
- Number of products marketed
- Size of the product(s)
- Material-handling system used
- Production lead time
- Economics of scale
- Stock layout
- Aisle requirements
- Throughput rate (i.e., inventory turnover)
- Office area in warehouse
- Types of racks and shelves used
- Level and pattern of demand
- Storage policy

Types of Warehouses

1. By stage in the logistics system
2. By geographic area
3. By product type
4. By function
5. By area
6. By systems
7. By ownership

Warehouse Components

- Equipment
- People
- Space

Warehouse Tasks and Activities

- ✓ Receiving
- ✓ Inspection and quality control
- ✓ Preparation for transportation to the storage area
- ✓ Aggregation of SKUs
- ✓ Transportation of goods to the shipping area
- ✓ Inventory tracking
- ✓ Cross docking
- ✓ Packaging
- ✓ Light assembly, blending, filling, and outfitting
- ✓ Labelling and shrink wrapping
- ✓ Breakbulk and consolidation
- ✓ Postponement
- ✓ Transportation
- ✓ Import and export services
- ✓ Tracing, customer service, and billing
- ✓ Carrier monitoring
- ✓ Site location
- ✓ Real estate management
- ✓ Network analysis
- ✓ Systems development
- ✓ Order Picking

Inventory Management

raw materials

finished goods

work in process

basic element of customer service → inventory availability

Types of Inventory

- Cycle stock
- Safety stock
- Transit inventory or pipeline inventory
- Speculative stock
- Seasonal stock
- Dead stock

Costs of Inventory

- Order forms
- Postage
- Telecommunication
- Authorization
- Purchasing management
- Office space
- Office supplies
- Purchase-order entry systems
- Tracking and expediting

A Inventory Holding Costs

B Procurement Costs

C The costs of orders from vendors

D Shortage Costs

Transportation

Transportation

Transportation systems move goods between origins and destinations

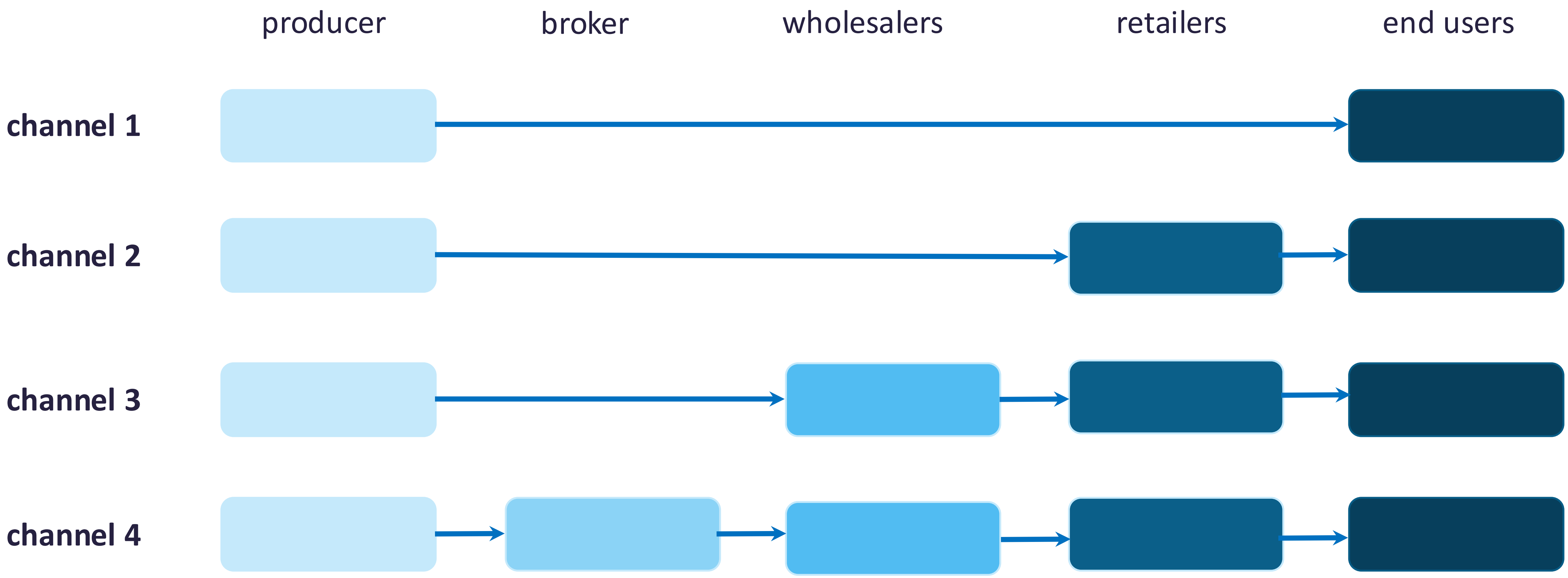
A transportation system designs, arranges, sets up, and schedules freight-transportation orders during a given and limited time period with technical restrictions at the lowest possible cost

Importance of Transportation

Transportation costs: between one-third and two-thirds of total logistics costs

Transportation Costs a product's price

Distribution Channels



Logistics Networks Design

The basic components of a logistics network

01 vendors

02 Products

03 Plants

04 warehouses / distribution centers

05 transportation services

06 customers

Limitations of Logistics

01 Spatial restrictions

02 Temporal restrictions

03 Technical constraints

04 Structural constraints

05 Organizational conditions

06 Economical restrictions

07 Safety requirements

08 Competitive conditions

09 Legal restrictions

Logistics Network Performance Measures

01 Qualitative

- Customer satisfaction
- flexibility
- effective risk management

02 Quantitative

- cost minimization
- sales maximization
- profit maximization
- fill rate maximization
- customer response time Minimization
- lead time minimization

☑ **Improvements to logistics networks → 5% to 15% savings in logistics costs.**

LOGISTICS NETWORK MODEL

- Customer service levels
- Location decisions
- Inventory planning
- Transportation management

Outputs of Logistics Network Model

- Number of warehouses, their location, ownership (private or public) and their size
- Allocation of customer demand to supply points (warehouses or plants), allocation to single or multiple supply points
- Amount of inventory to be maintained at various locations
- Type of transportation services to use
- Level of customer service to be provided (that can be provided).

Classification of logistics-oriented Location Problems

1

Time horizon
- single period
- multiperiod

2

Facility typology
- single-type
- multi-type

3

Hierarchy
- single-Level
- multi-Level

4

Material flow
- single commodity
- multicommodity

5

Interaction among facilities
- with interactions
- without interactions

6

Dominant material flow
- single echelon
- multi-echelon

7

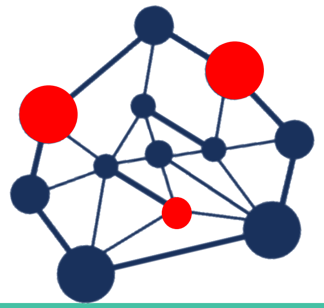
Demand divisibility
- divisible
- indivisible

8

Influence of transportation on location decisions
- location problems
- location-routing problems

9

Retail location
- with competition
- without competition



Facilities Planning

Facilities location

The layout and location of facilities play a vital role in minimizing the total cost of logistics.

Facilities layout

Facility location decisions have a long-term impact on a logistics system’s performance

The Role of Network Design in the Logistics

TOYOTA

A Facility role

What role should each facility play? What processes are performed at each facility?

B Facility location

Where should facilities be located?

C Capacity allocation

How much capacity should be allocated to each facility?

D Market and supply allocation

What markets should each facility serve? Which supply sources should feed each facility?

NETFLIX amazon

Revisit Logistics Network design decisions

After market changes, mergers, or factor cost changes

FACTORS INFLUENCING NETWORK DESIGN DECISIONS

Apple negotiate with Indian government to open iPhone manufacturing plant in India. (Win-Win for both)

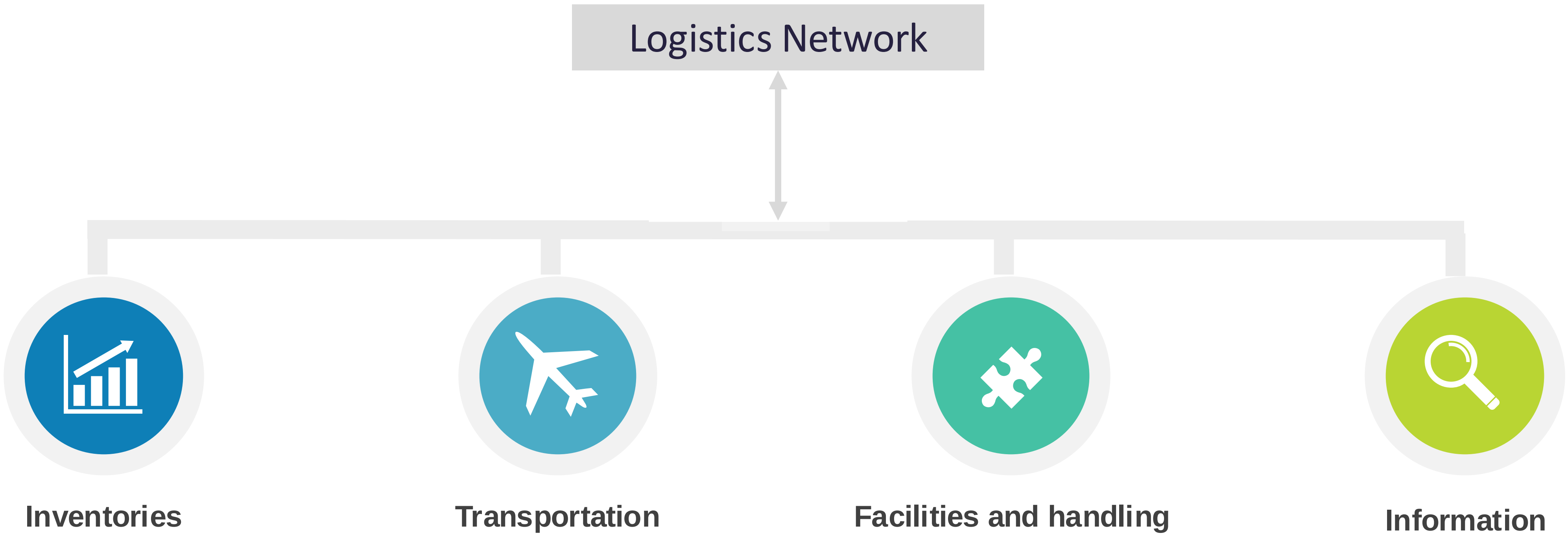
Strategic Factors	Technological Factors	Macroeconomic Factors	Customer Response Time and Local Presence
Political Factors	Infrastructure Factors	Competitive Factors	Logistics and Facility Costs

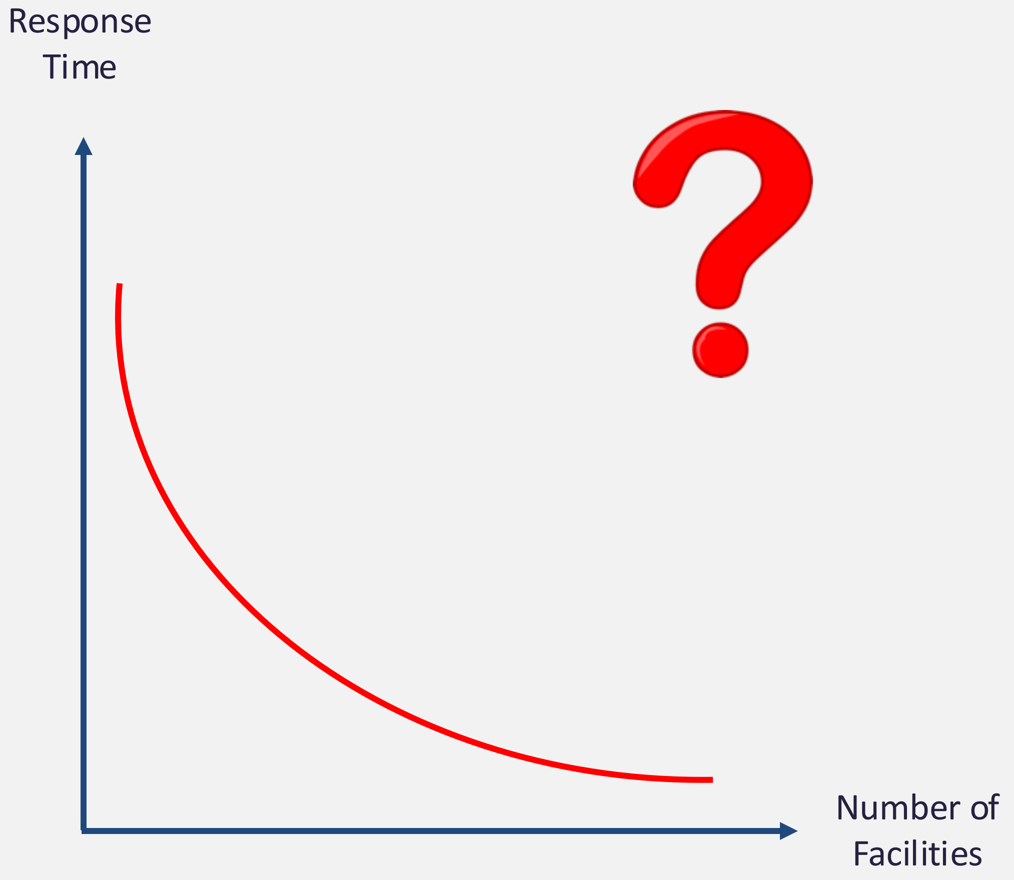
- Transportation costs
- Availability of good roads and railway
- Closeness to airports

- Positive externalities between firms
- Locating to split the market

Amazon has fewer DCs compared with Barnes and Noble has hundreds of stores with lower transportation cost

Trade-Offs in Logistics Network Design





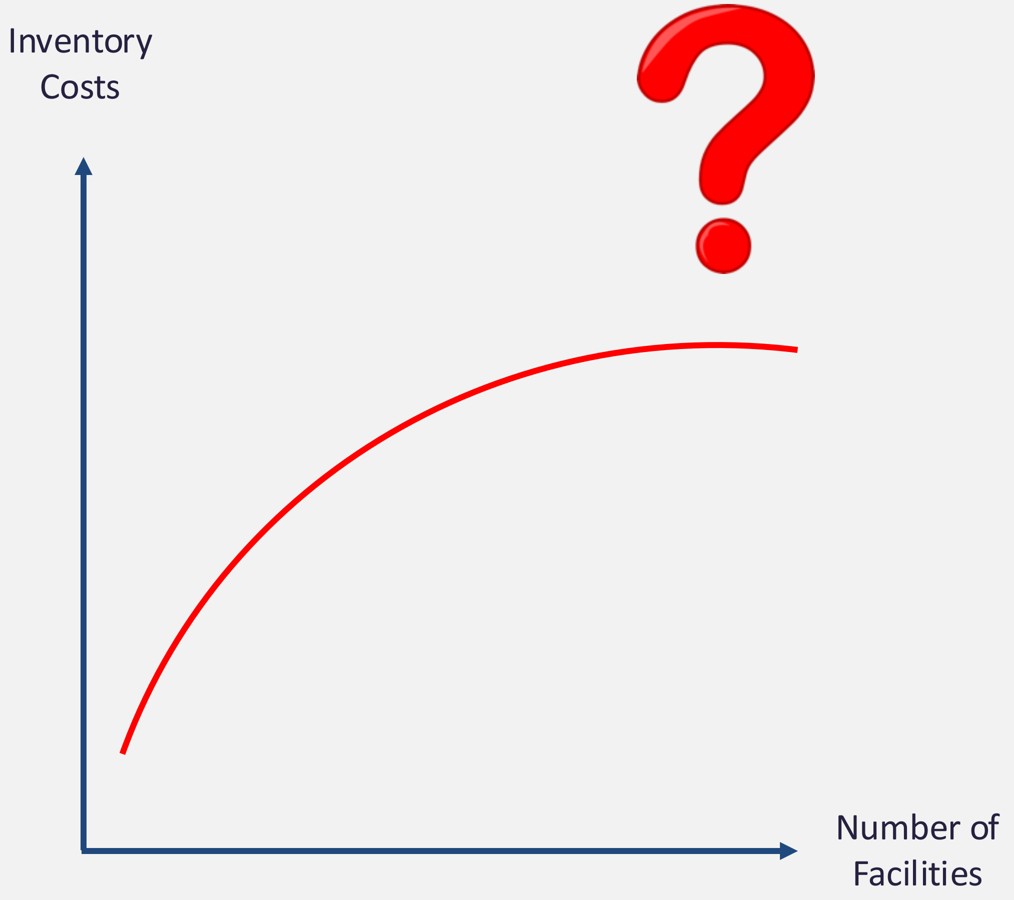
Relationship Between Desired Response Time and Number of Facilities

Long response time → Few locations → Increasing the capacity

amazon

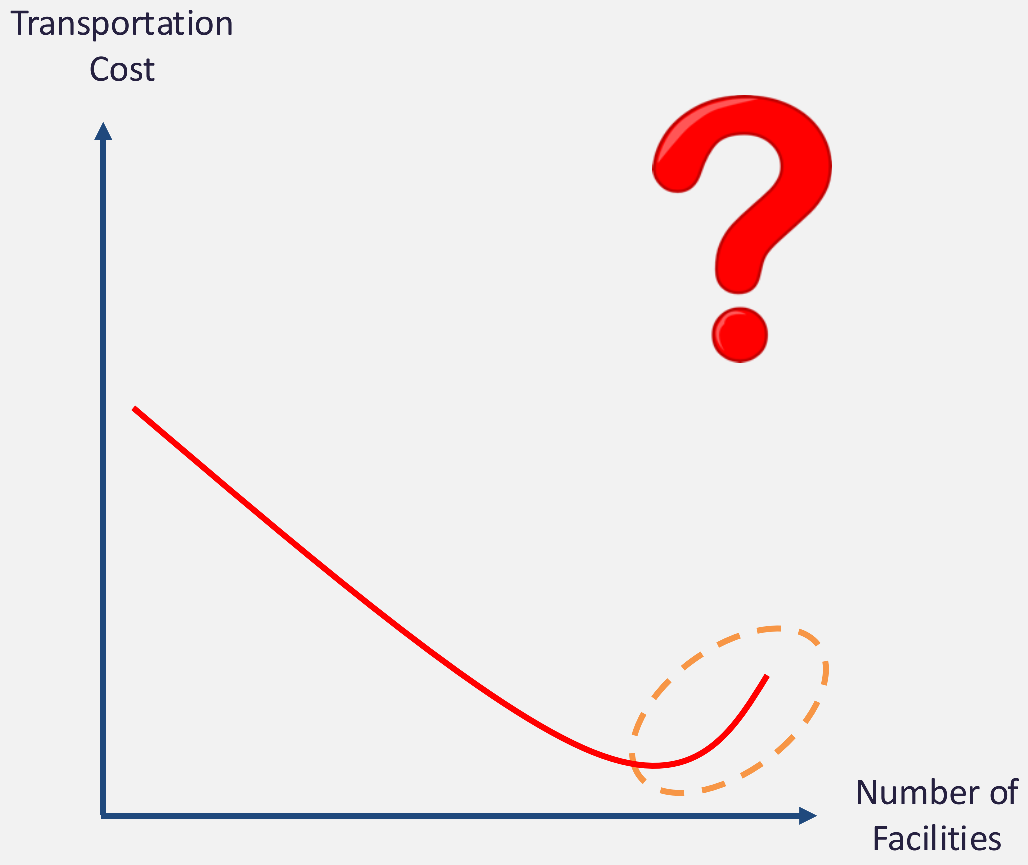
Short response time → Many facilities → Low capacity

BARNES&NOBLE



Relationship Between Number of Facilities and Inventory Costs

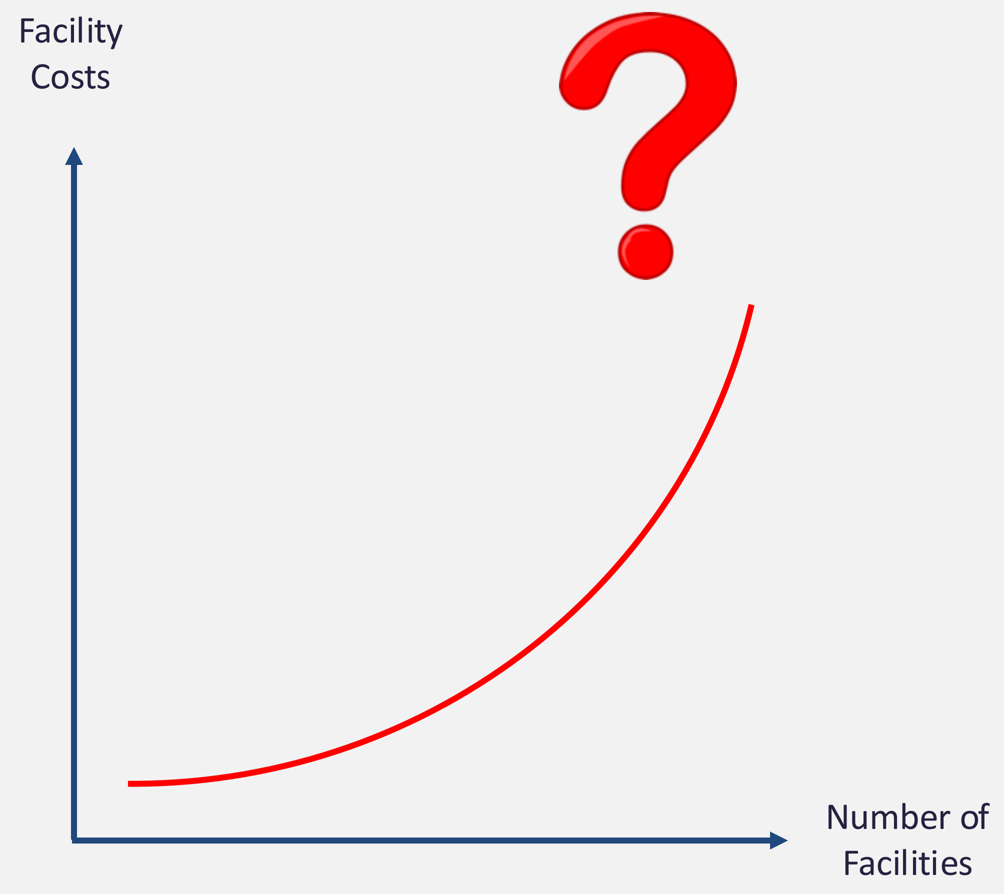
Increase the number of facilities → Increase the inventory → Increase the cost



Relationship Between Number of Facilities and Transportation Cost

- ✓ **Inbound transportation**
- ✓ **Outbound transportation**

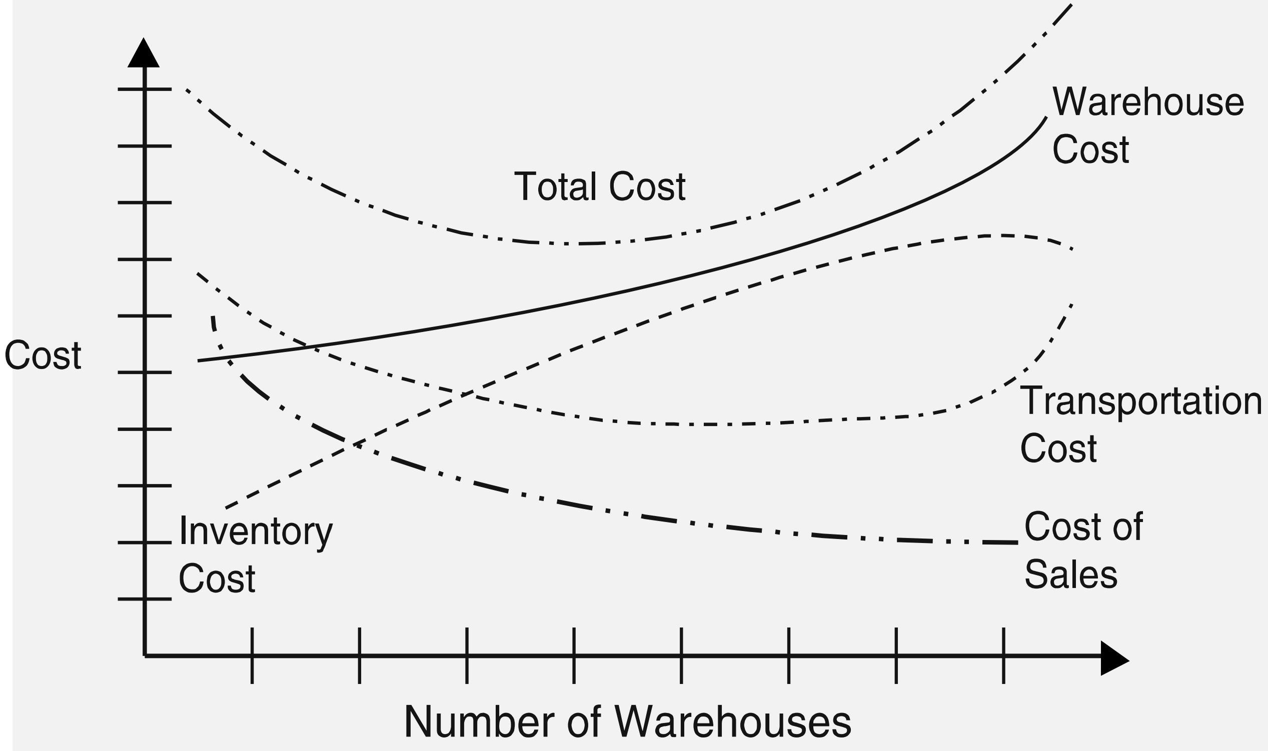
Increasing the number of warehouse locations → Decrease the average outbound distance to the customer → Decrease total transportation cost



Relationship Between Number of Facilities and Facility Costs

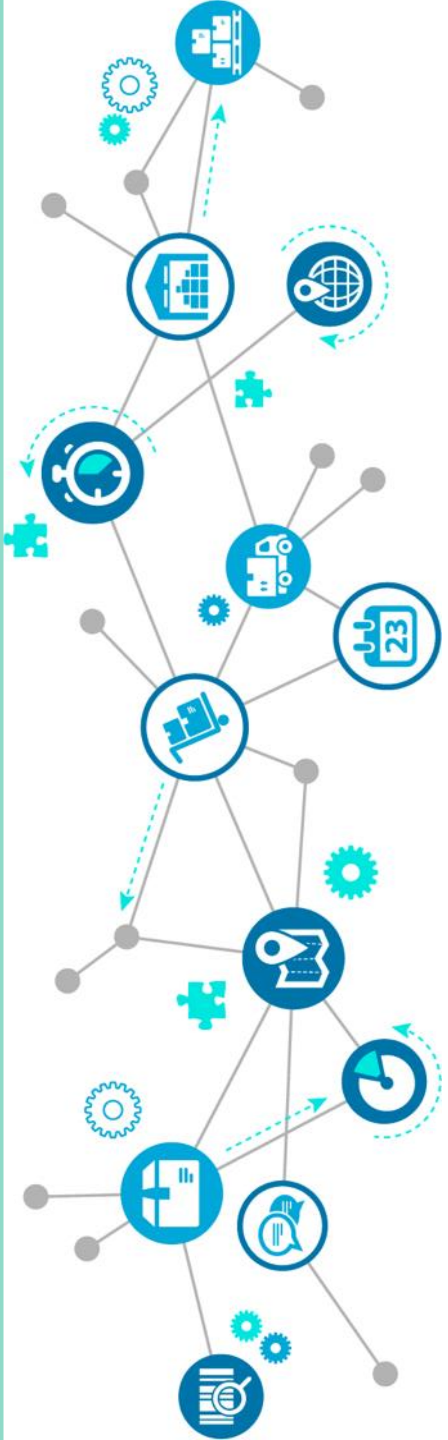
Reduce the number of facilities → Decrease facility cost

Variation in Logistics Cost and Response Time with Number of Facilities



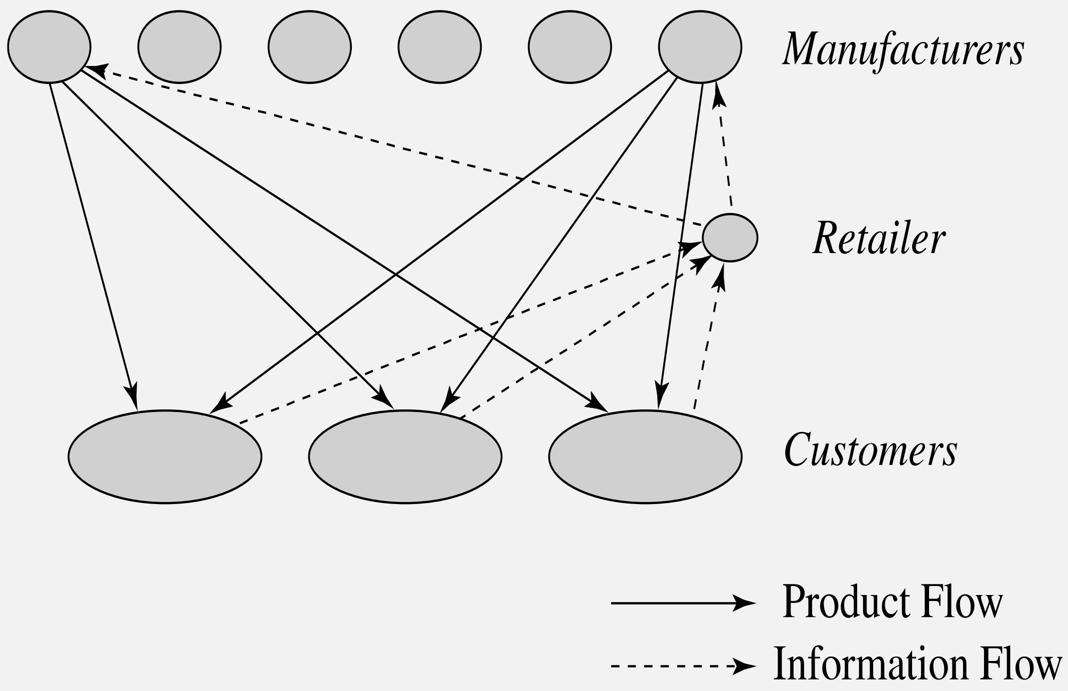
Total logistics costs = inventory + transportation + facility costs

- ✓ As the number of facilities increases, total logistics costs first decrease and then increase.
- ✓ Each firm should have at least the number of facilities that minimizes total logistics costs.
- ✓ If a firm wants to reduce the response time to its customers further (increase in revenues), it may have to increase the number of facilities beyond the point that minimizes logistics costs.



Different Types of Logistics Networks

1. Manufacturer storage with direct shipping
2. Manufacturer storage with direct shipping and in-transit merge
3. Distributor storage with carrier delivery
4. Distributor storage with last-mile delivery
5. Manufacturer/distributor storage with customer pickup
6. Retail storage with customer pickup



Manufacturer storage with Direct shipping

eBags

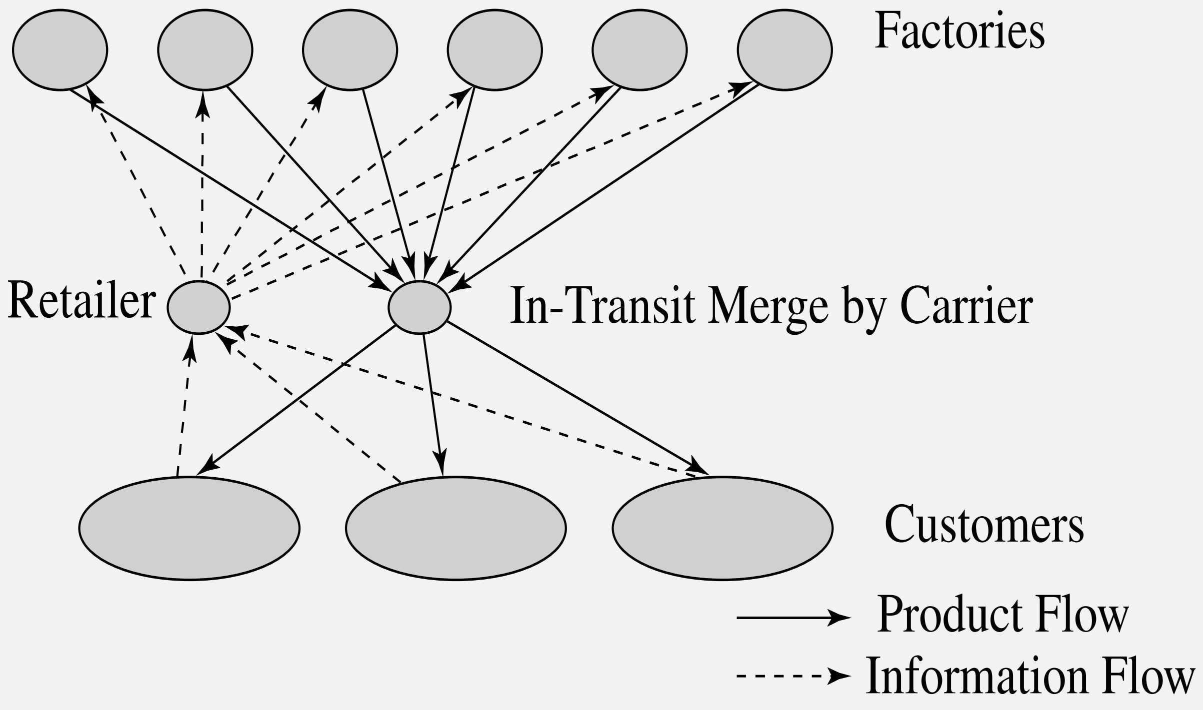
NORDSTROM

GRAINGER

slow-moving items

Performance Characteristics of Manufacturer Storage with Direct Shipping Network

Cost Factor	Performance
Inventory	Lower costs because of aggregation. Benefits of aggregation are highest for low-demand, high-value items. Benefits are large if product customization can be postponed at the manufacturer.
Transportation	Higher transportation costs because of increased distance and disaggregate shipping.
Facilities and handling	Lower facility costs because of aggregation. Some saving on handling costs if manufacturer can manage small shipments or ship from production line.
Information	Significant investment in information infrastructure to integrate manufacturer and retailer.
Service Factor	**Performance**
Response time	Long response time of one to two weeks because of increased distance and two stages for order processing. Response time may vary by product, thus complicating receiving.
Product variety	Easy to provide a high level of variety.
Product availability	Easy to provide a high level of product availability because of aggregation at manufacturer.
Customer experience	Good in terms of home delivery but can suffer if order from several manufacturers is sent as partial shipments.
Time to market	Fast, with the product available as soon as the first unit is produced.
Order visibility	More difficult but also more important from a customer service perspective.
Returnability	Expensive and difficult to implement.



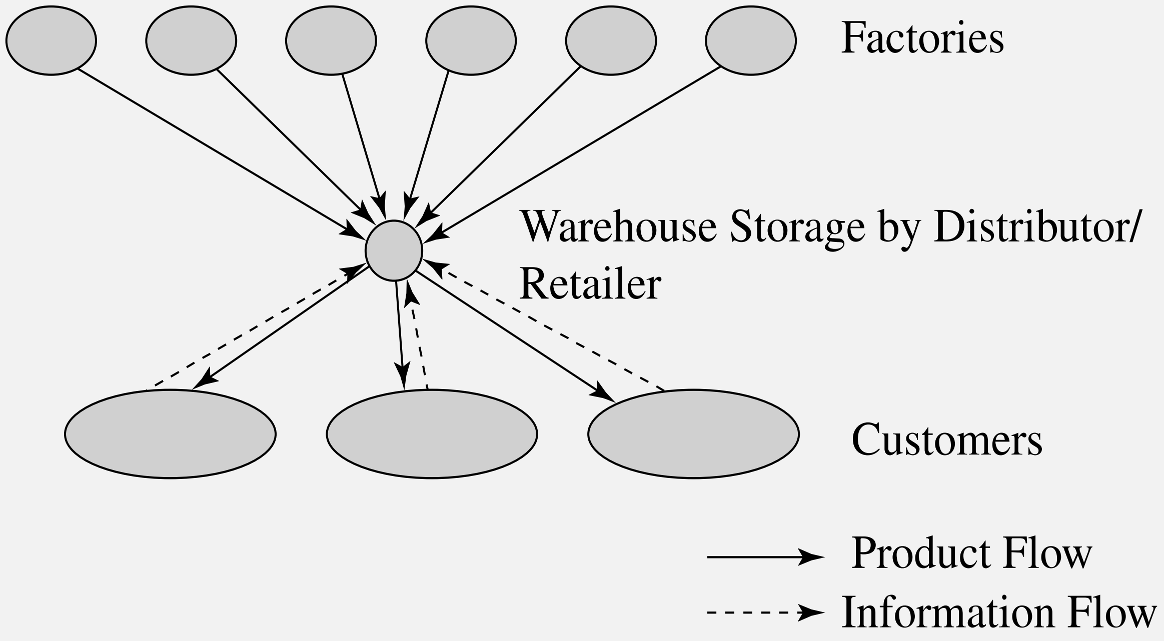
Manufacturer storage with Direct shipping and in-Transit Merge

in-transit merge combines pieces of the order

coming from different locations

Performance Characteristics of In-Transit Merge

Cost Factor	Performance
Inventory	Similar to drop-shipping.
Transportation	Somewhat lower transportation costs than drop-shipping.
Facilities and handling	Handling costs higher than drop-shipping at carrier; receiving costs lower at customer.
Information	Investment is somewhat higher than for drop-shipping.
Service Factor	**Performance**
Response time	Similar to drop-shipping; may be marginally higher.
Product variety	Similar to drop-shipping.
Product availability	Similar to drop-shipping.
Customer experience	Better than drop-shipping because only a single delivery is received.
Time to market	Similar to drop-shipping
Order visibility	Similar to drop-shipping.
Returnability	Similar to drop-shipping.



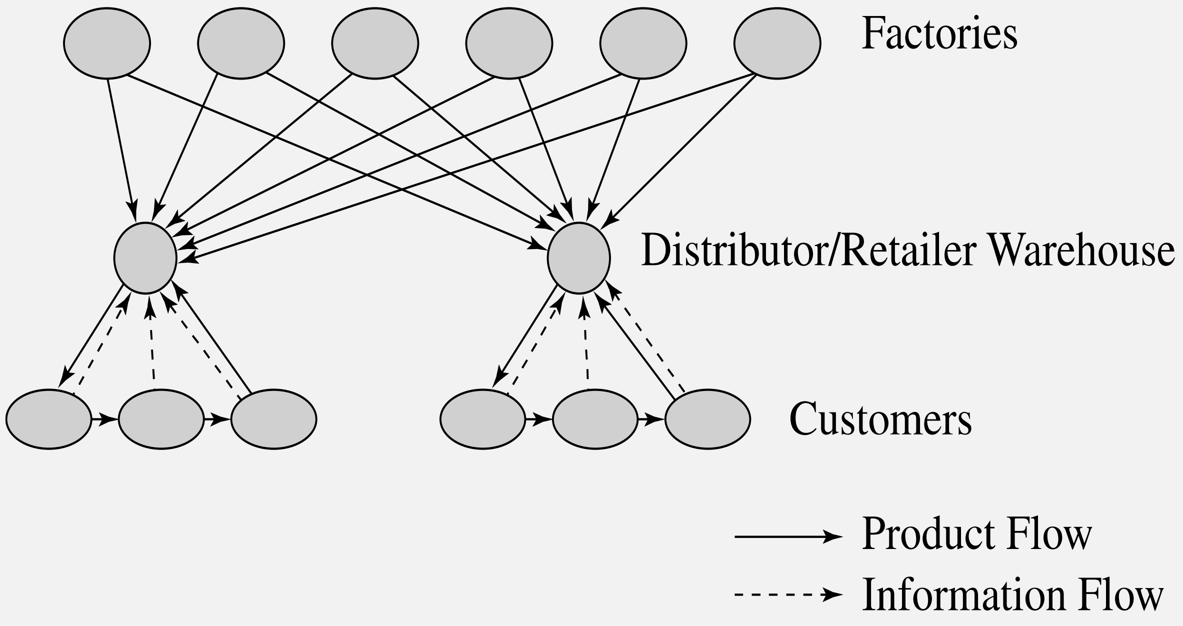
Distributor Storage with Carrier Delivery

- ✓ Inventory is held by distributors/ retailers in intermediate warehouses, and package carriers are used to transport products from the intermediate location to the final customer.

This approach combined with drop-shipping from a manufacturer (or distributor).

Performance Characteristics of Distributor Storage with Carrier Delivery

Cost Factor	Performance
Inventory	Higher than manufacturer storage. Difference is not large for faster-moving items but can be large for very-slow-moving items.
Transportation	Lower than manufacturer storage. Reduction is highest for faster-moving items.
Facilities and handling	Somewhat higher than manufacturer storage. The difference can be large for very-slow-moving items.
Information	Simpler infrastructure compared with manufacturer storage.
Service Factor	**Performance**
Response time	Faster than manufacturer storage.
Product variety	Lower than manufacturer storage.
Product availability	Higher cost to provide the same level of availability as manufacturer storage.
Customer experience	Better than manufacturer storage with drop-shipping.
Time to market	Higher than manufacturer storage.
Order visibility	Easier than manufacturer storage.
Returnability	Easier than manufacturer storage.



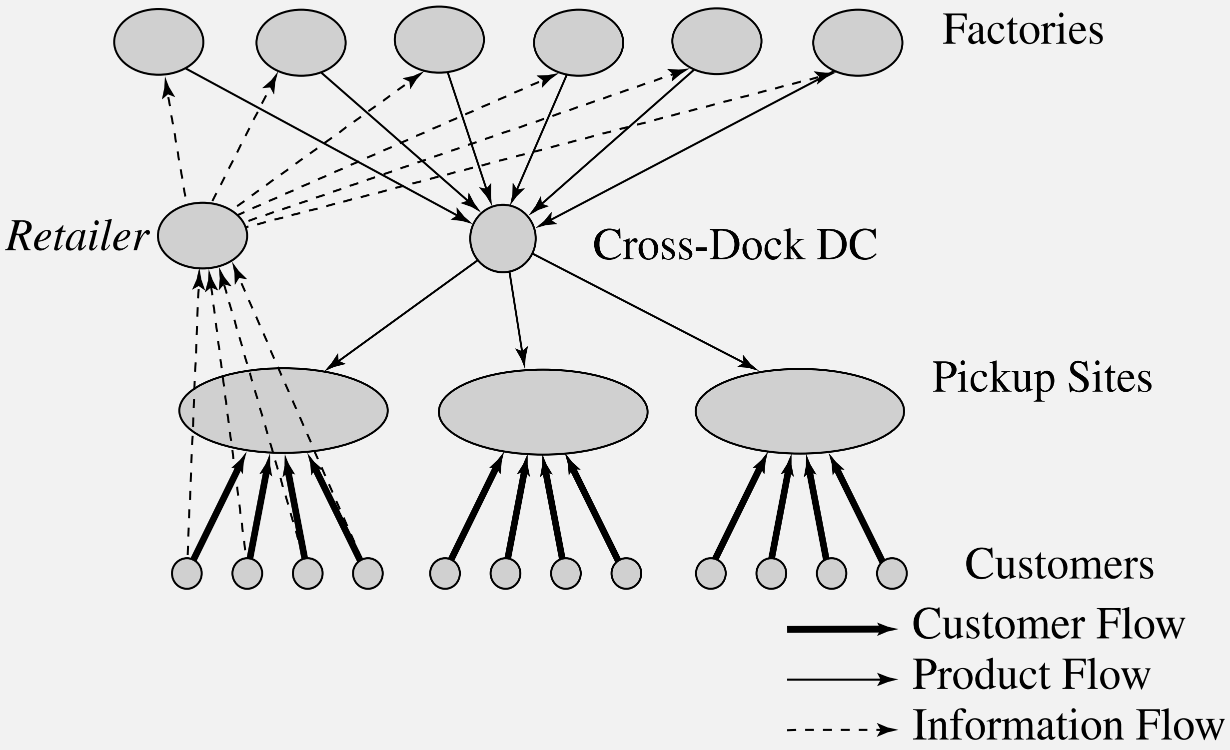
Distributor storage with last-Mile Delivery

- ✓ Last-mile delivery refers to the distributor/retailer delivering the product to the customer's home instead of using a package carrier.

- ✓ Original equipment manufacturers (OEMs) tend to carry most spare parts at a local distribution center.

Performance Characteristics of Distributor Storage with Last-Mile Delivery

Cost Factor	Performance
Inventory	Higher than distributor storage with package carrier delivery.
Transportation	Very high cost, given minimal scale economies. Higher than any other distribution option.
Facilities and handling	Facility costs higher than manufacturer storage or distributor storage with package carrier delivery, but lower than a chain of retail stores.
Information	Similar to distributor storage with package carrier delivery.
Service Factor	**Performance**
Response time	Very quick. Same-day to next-day delivery.
Product variety	Somewhat less than distributor storage with package carrier delivery but larger than retail stores.
Product availability	More expensive to provide availability than any other option except retail stores.
Customer experience	Very good, particularly for bulky items.
Time to market	Slightly higher than distributor storage with package carrier delivery.
Order visibility	Less of an issue and easier to implement than manufacturer storage or distributor storage with package carrier delivery.
Returnability	Easier to implement than other previous options. Harder and more expensive than a retail network.



Manufacturer or Distributor storage with Customer pickup

✓ Inventory is stored at the manufacturer or distributor warehouse, but customers place their orders online or on the phone and then travel to designated pickup points to collect their merchandise. Orders are shipped from the storage site to the pickup points as needed.

- 7dream.com and Otoriyose-bin, operated by Seven-Eleven Japan uses this type.
- Tesco has implemented such a service in the United Kingdom.
- Amazon is also experimenting with Amazon lockers.
- A business-to- business (B2B) example is W.W. Grainger, whose customers can pick up their orders at one of the W.W. Grainger retail outlets.

Performance Characteristics of Network with Consumer Pickup Sites

Cost Factor	Performance
Inventory	Can match any other option, depending on the location of inventory.
Transportation	Lower than the use of package carriers, especially if using an existing delivery network.
Facilities and handling	Facility costs can be high if new facilities have to be built. Costs are lower if existing facilities are used. The increase in handling cost at the pickup site can be significant.
Information	Significant investment in infrastructure is required.
Service Factor	**Performance**
Response time	Similar to package carrier delivery with manufacturer or distributor storage. Same-day delivery is possible for items stored locally at pickup site.
Product variety	Similar to other manufacturer or distributor storage options.
Product availability	Similar to other manufacturer or distributor storage options.
Customer experience	Lower than other options because of the lack of home delivery. Experience is sensitive to capability of pickup location.
Time to market	Similar to manufacturer storage options.
Order visibility	Difficult but essential.
Returnability	Somewhat easier, given that pickup location can handle returns.

Retail storage with Customer pickup

- ✓ Inventory is stored locally at retail stores.
- ✓ Order online or by phone and pick it up at the retail store.
- ✓ Walmart and Tesco.
- ✓ W.W. Grainger
- ✓ Good response times

Performance Characteristics of Retail Storage at Consumer Pickup Sites

Cost Factor	Performance
Inventory	Higher than all other options.
Transportation	Lower than all other options.
Facilities and handling	Higher than other options. The increase in handling cost at the pickup site can be significant for online and phone orders.
Information	Some investment in infrastructure required for online and phone orders.
Service Factor	**Performance**
Response time	Same-day (immediate) pickup possible for items stored locally at pickup site.
Product variety	Lower than all other options.
Product availability	More expensive to provide than all other options.
Customer experience	Related to whether shopping is viewed as a positive or negative experience by customer.
Time to market	Highest among distribution options.
Order visibility	Trivial for in-store orders. Difficult, but essential, for online and phone orders.
Returnability	Easier than other options because retail store can provide a substitute.

Selecting a Logistics Network

- ✓ The combination of delivery networks used depends on product characteristics and the strategic position that the firm is targeting.

- ✓ hybrid network

combines all the mentioned options in its distribution network.

stocks fast-moving items at most of its warehouses

slower-moving items are stocked at fewer ware-houses

very-slow-moving items may be drop-shipped from suppliers.

Comparative Performance of Delivery Network Designs

	Retail Storage with Customer Pickup	Manufacturer Storage with Direct Shipping	Manufacturer Storage with In-Transit Merge	Distributor Storage with Package Carrier Delivery	Distributor Storage with Last-Mile Delivery	Manufacturer Storage with Pickup
Response time	1	4	4	3	2	4
Product variety	4	1	1	2	3	1
Product availability	4	1	1	2	3	1
Customer experience	Varies from 1 to 5	4	3	2	1	5
Time to market	4	1	1	2	3	1
Order visibility	1	5	4	3	2	6
Returnability	1	5	5	4	3	2
Inventory	4	1	1	2	3	1
Transportation	1	4	3	2	5	1
Facility and handling	6	1	2	3	4	5
Information	1	4	4	3	2	5

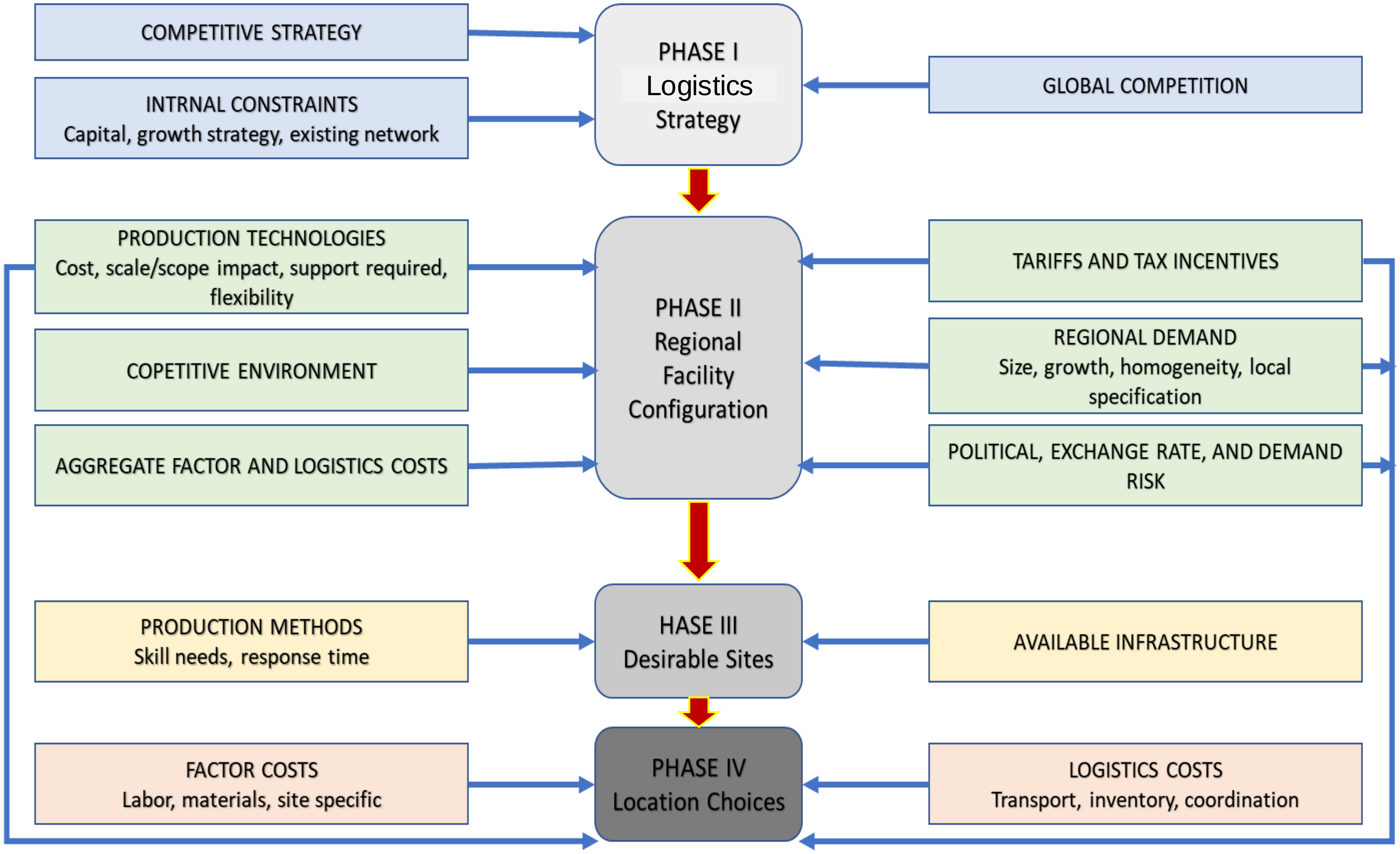
Key: 1 corresponds to the strongest performance and 6 the weakest performance.

Performance of Delivery Networks for Different Product/Customer Characteristics

	Retail Storage with Customer Pickup	Manufacturer Storage with Direct Shipping	Manufacturer Storage with In-Transit Merge	Distributor Storage with Package Carrier Delivery	Distributor Storage with Last-Mile Delivery	Manufacturer Storage with Pickup
High-demand product	+2	-2	-1	0	+1	-1
Medium-demand product	+1	-1	0	+1	0	0
Low-demand product	-1	+1	0	+1	-1	+1
Very-low demand product	-2	+2	+1	0	-2	+1
Many product sources	+1	-1	-1	+2	+1	0
High product value	-1	+2	+1	+1	0	+2
Quick desired response	+2	-2	-2	-1	+1	-2
High product variety	-1	+2	0	+1	0	+2
Low customer effort	-2	+1	+2	+2	+2	-1

Key: +2 = very suitable; +1 = somewhat suitable; 0 = neutral; -1 = somewhat unsuitable; -2 = very unsuitable.

Framework for Network Design Decisions



Models for Facility Location and Capacity Allocation

- maximize the overall profitability ---- >> appropriate responsiveness
- many trade-offs during Network Design
- Network design models used:

  - to decide on location and capacities

  - to assign current demand to facilities and identify Transportation Lanes

Information for network design decisions

- Location of supply sources and markets
- Location of potential facility sites
- Demand forecast by market
- Facility, labor, and material costs by site
- Transportation costs between each pair of sites
- Inventory costs by site
- Sale price of product in different regions
- Taxes and tariffs
- Desired response time and other service factors

Network Optimization Models

Capacitated Facility Location Model

Model Inputs (Parameters)

n = number of potential plant locations/capacity (each level of capacity will count as a separate location)

m = number of markets or demand points

D_j = annual demand from market j

K_i = potential capacity of plant i

F_i = annualized fixed cost of keeping plant i open

C_{ij}= cost of producing and shipping one unit from plant i to market j (cost includes production, inventory, transportation, and tariffs)

Model Outputs (Decision Variables)

y_i= 1 if plant i is open, 0 otherwise

x_{ij} = quantity shipped from plant i to market j

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Objective Function and its Constraints

Fixed Costs

Variable Cost

$$Min \sum_{i=1}^{n} f_i y_i + \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} x_{ij}$$

Demand Satisfied

$$\sum_{i=1}^{n} x_{ij} = D_j \quad for \quad j = 1, \dots, m$$

Supply can not be more than capacity

$$\sum_{j=1}^{m} x_{ij} \le K_i y_i \quad for \quad i = 1, \dots, n$$

$$y_i \in \{0,1\} \quad for\ i = 1, \dots, n, x_{ij} \ge 0$$

Mixed Integer Programming

Network Optimization Models

Gravity Location Models

Model Inputs (Parameters):

x_n, y_n : Coordinate location of either a market or supply source *n*

F_n: cost of shipping one unit (a unit could be a piece, pallet, truckload or ton) for one mile between the facility and either market or supply source *n*

D_n: quantity to be shipped between facility and market or supply source *n*

If (*x*, *y*) is the location selected for the facility, the distance d_n between the facility at location (*x*, *y*) and the supply source or market *n* is given by

$$d_n = \sqrt{(x - x_n)^2 + (y - y_n)^2}$$

Total transportation cost (*TC*): $$TC = \sum_{n=1}^{k} d_n D_n F_n$$

Click for Excel File

Network Optimization Models

Allocating Demand to Production Facilities

Model Inputs (Parameters)
n = number of factory locations
m = number of markets or demand points
D_j = *annual demand from market j*
K_i = *capacity of factory i*
C_{ij} = *cost of producing and shipping one unit from factory i to market j (cost includes production, inventory, and transportation)*
Goal: allocate the demand from different markets to the various plants to minimize the total cost of facilities, transportation, and inventory.

Model Outputs (Decision Variables)
X_{ij}= quantity shipped from plant *i* to market *j*

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Objective Function and its Constraints

$$\text{Min} \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} x_{ij}$$

all demand is satisfied

$$\sum_{i=1}^{n} x_{ij} = D_j \quad \text{for} \quad j = 1, \ldots, m$$

Production <= Capacity

$$\sum_{j=1}^{m} x_{ij} \le K_i \quad \text{for} \quad i = 1, \ldots, n$$

Network Optimization Models

The Capacitated Plant Location Model with Single Sourcing

- Market supply by only one Factory
- Modify decision variables

reducing complexity
improving coordination

Model Outputs (Decision Variables)

y_i = 1 if factory is located at site *i*, 0 otherwise

x_{ij} = 1 if market *j* is supplied by factory *i*, 0 otherwise

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Objective Function and its Constraints

$$\text{Min} \sum_{i=1}^{n} f_i y_i + \sum_{i=1}^{n} \sum_{j=1}^{m} D_j c_{ij} x_{ij}$$

$$\sum_{i=1}^{n} x_{ij} = 1 \quad \text{for} \quad j = 1, \ldots, m$$

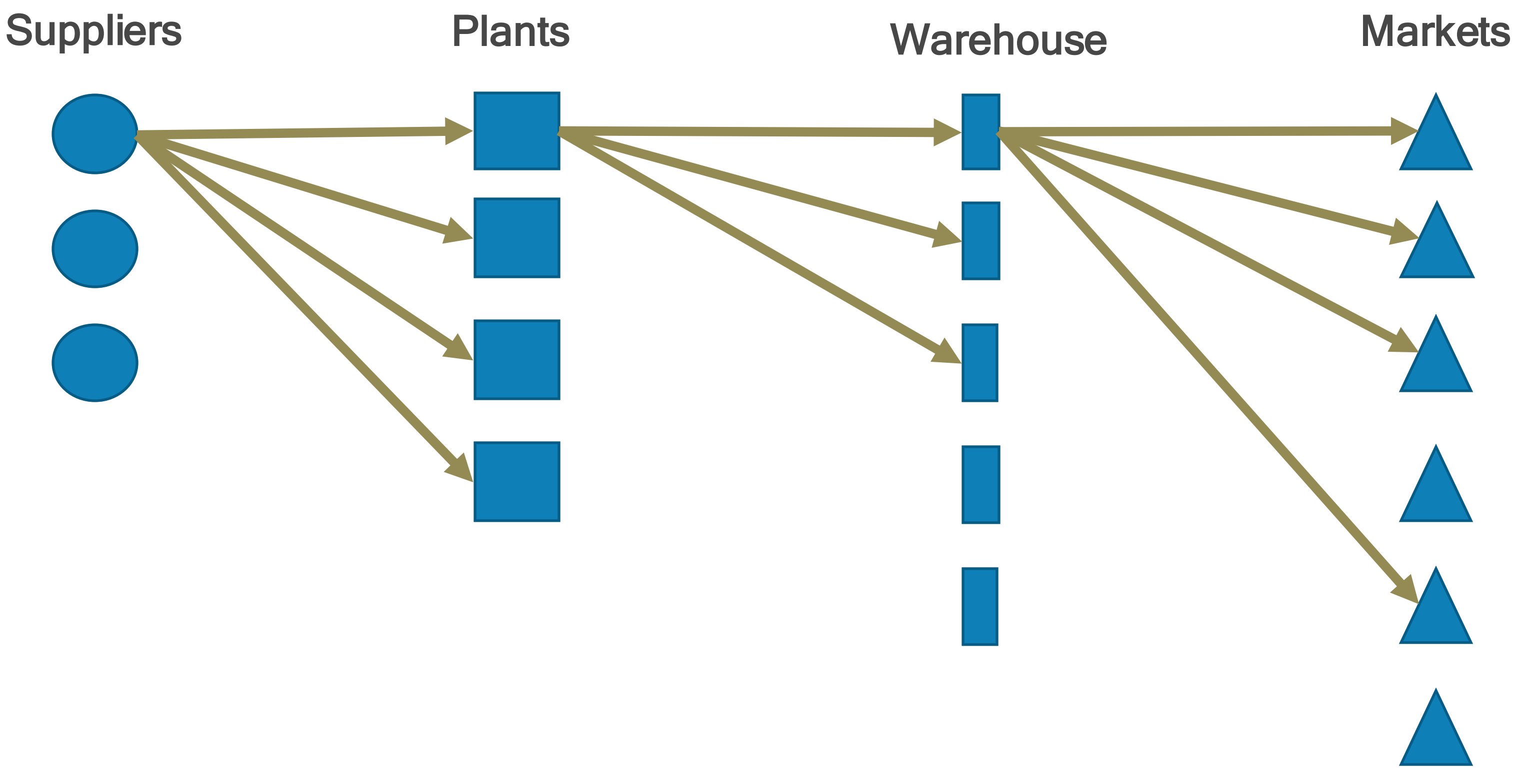
$$\sum_{j=1}^{m} D_j x_{ij} \leq K_i y_i \quad \text{for} \quad i = 1, \ldots, n$$

$$x_{ij}, y_i \in \{0, 1\}$$

Ensures single sourcing

Network Optimization Models

Plants and Warehouses Simultaneously



Network Optimization Models

Plants and Warehouses Simultaneously

Model Outputs (Decision Variables)

m = number of markets or demand points
n = number of potential factory locations
l = number of suppliers
t = number of potential warehouse locations
D_j = annual demand from customer j
K_i = potential capacity of factory at site i
S_h = supply capacity at supplier h
W_e = potential warehouse capacity at site e
F_i = fixed cost of locating a plant at site i
f_e = fixed cost of locating a warehouse at site e
c_{hi} = cost of shipping one unit from supply source h to factory i
c_{ie} = cost of producing and shipping one unit from factory i to warehouse e
c_{ej} = cost of shipping one unit from warehouse e to customer j

The goal is to identify plant and warehouse locations, as well as quantities shipped between various points, that minimize the total fixed and variable costs.

Network Optimization Models

Plants and Warehouses Simultaneously

Model Outputs (Decision Variables)

y_i = 1 if factory is located at site i, 0 otherwise

y_e = 1 if warehouse is located at site e, 0 otherwise

x_{ej} = quantity shipped from warehouse e to market j

x_{ie} = quantity shipped from factory at site i to warehouse e

x_{hi} = quantity shipped from supplier h to factory at site i

$$\text{Min} \underbrace{\sum_{i=1}^{n} F_i y_i}_{\text{Plant Fixed Cost}} + \underbrace{\sum_{e=1}^{t} f_e y_e}_{\text{Warehouse Fixed Cost}} + \underbrace{\sum_{h=1}^{l}\sum_{i=1}^{n} c_{hi} x_{hi}}_{\text{Variable cost: Supplier to Plants}} + \underbrace{\sum_{i=1}^{n}\sum_{e=1}^{t} c_{ie} x_{ie}}_{\text{Variable cost: Plants to warehouse}} + \underbrace{\sum_{e=1}^{t}\sum_{j=1}^{m} c_{ej} x_{ej}}_{\text{Variable cost: warehouse to Customers}}$$

Network Optimization Models

Plants and Warehouses Simultaneously

specifies that the total amount shipped from a supplier cannot exceed the supplier's capacity.

$$\sum_{i=1}^{n} x_{hi} \leq S_h \quad \text{for} \quad h = 1, \dots, l$$

the amount shipped out of a factory cannot exceed the quantity of raw material received

$$\sum_{h=1}^{l} x_{hi} - \sum_{e=1}^{t} x_{ie} \geq 0 \quad \text{for} \quad i = 1, \dots, n$$

the amount produced in the factory cannot exceed its capacity.

$$\sum_{h=1}^{l} x_{hi} - \sum_{e=1}^{t} x_{ie} \geq 0 \quad \text{for} \quad i = 1, \dots, n$$

specifies that the amount shipped out of a warehouse cannot exceed the quantity received from the factories.

$$\sum_{i=1}^{n} x_{ie} - \sum_{j=1}^{m} x_{ej} \geq 0 \quad \text{for} \quad e = 1, \dots, t$$

Network Optimization Models

Plants and Warehouses Simultaneously

the amount shipped through a warehouse cannot exceed its capacity.

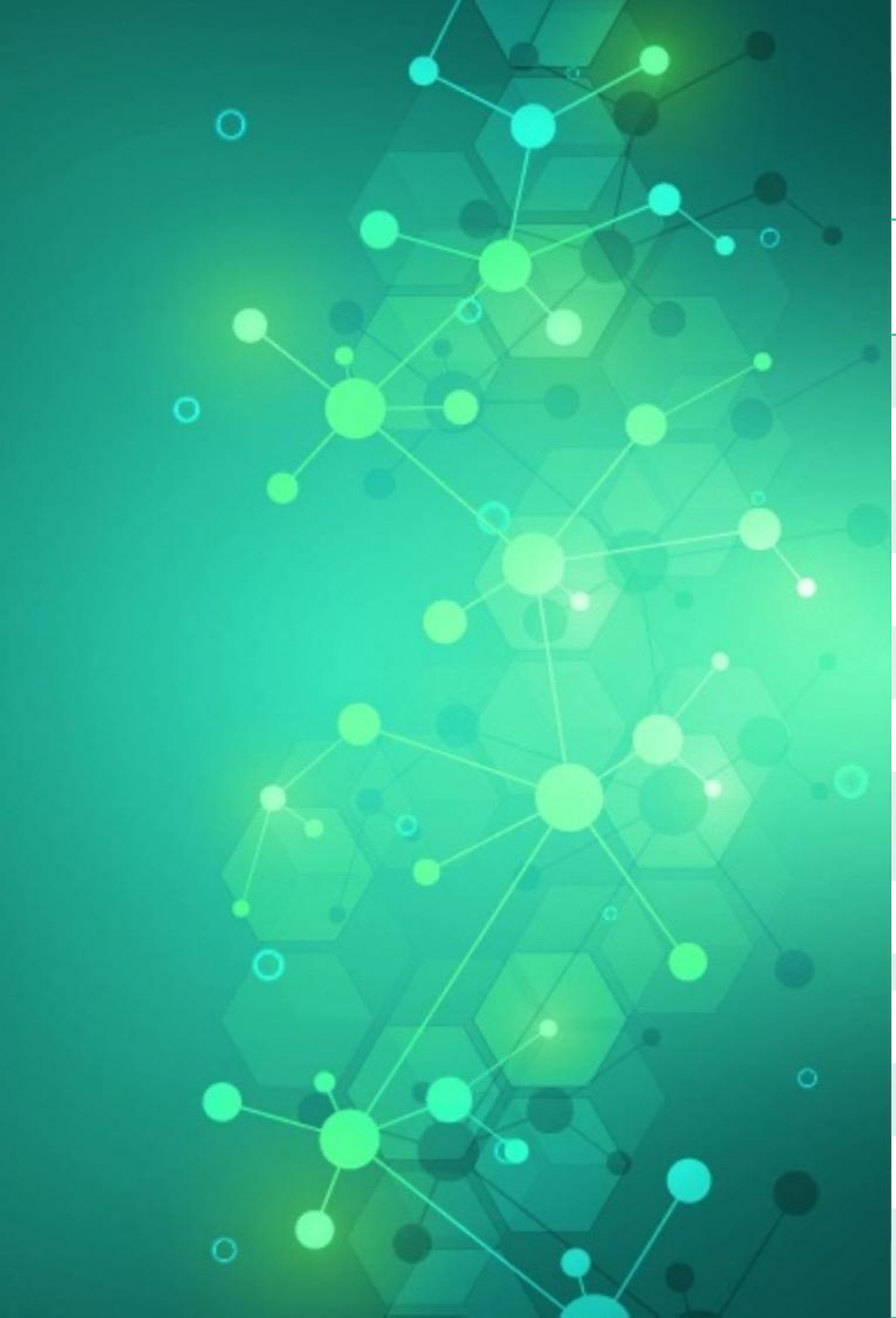
$$\sum_{j=1}^{m} \mathrm{x}_{\mathrm{ej}} \leq W_e y_e \quad for \quad e = 1, \ldots, t$$

specifies that the amount shipped to a customer must cover the demand.

$$\sum_{e=1}^{t} \mathrm{x}_{\mathrm{ej}} = D_j \quad for \quad j = 1, \ldots, m$$

enforces that each factory or warehouse is either open or closed.

$$y_i, y_e \in \{0,1\}, \mathrm{x}_{\mathrm{ie}}, \mathrm{x}_{\mathrm{ej}}, \mathrm{x}_{\mathrm{hi}} \geq 0$$



Solution Techniques

References	Problem	Solution method
Yeh (2005)	Multistage supply chain network problem (MSCN)	Hybrid heuristic algorithm
Yeh (2006)	Multistage supply chain network problem (MSCN)	Memetic algorithm (MA)
Yeh (2006)	Multistage supply chain network problem (MSCN)	Memetic algorithm (MA)
Romeijn et al. (2007)	Two-Echelon supply chain design problem	Column generation
Altiparmak et al. (2006)	Multi-objective SCN design problem	New solution procedure based on genetic algorithms
Altiparmak et al. (2007)	Design of a single-source, multi-product, multi-stage SCN	Solution procedure based on steady-state genetic algorithms (Ssga)
Hinojosa et al. (2008)	Dynamic supply chain design with inventory	Lagrangian approach which relaxes the constraints connecting the distribution levels
Jayaraman and Pirkul (2001)	Single-source, multi-product, multi-stage SCN design problem	Heuristic approach based on Lagrangean relaxation
Jang et al. (2002)	Design of SCN	Lagrangian heuristic
Syarif et al. (2002)	Multi-source, single-product, multi-stage SCN design problem	Spanning tree-based GA approach
Jayaraman and Ross (2003)	Designing of distribution network and management in supply chain environment	Heuristic approach based on simulated annealing
Shen (2007)	Model with unreliable supply	Algorithm based on the bisection search and the outer approximate algorithm
Snyder et al. (2007)	Model with parameter uncertainty	Lagrangian-relaxation based solution algorithm

Solution Techniques

References	Problem	Solution method
Maranzana (1964)	Uncapacitated fixed charge location model	Neighborhood search improvement algorithm
Teitz and Bart (1968)	Fixed charge facility location problem	Exchange or “swap” algorithm
Hensen and Mladenovic (1997)	Fixed charge facility location problem	Variable neighborhood search algorithm
Al-Sultan and Al-Fawzan (1999)	Uncapacitated fixed charge location problem	Tabu search
Galvo (1993) and Daskin (1995)	Uncapacitated fixed charge location problem	Lagrangian relaxation algorithms
Geoffrion (1974)	Fixed charge location	Lagrangian relaxation algorithms
Shen et al. (2003)	Basic model	Column generation approach
Shen and Qi (2004)	Model with routing cost estimation	Lagrangian relaxation based solution algorithm
Ozsen et al. (2003)	Capacitated DCs problems	Lagrangian relaxation solution algorithm
Amiri (2006)	Designing a distribution network in a supply chain system with allow for multiple levels of capacities	Lagrangian based solution procedure
Shen and Daskin (2005)	Model with service consideration	Weighting method
Shen and Daskin (2005)	Model with service consideration	Genetic algorithms
Shen (2006)	Profit maximizing model with demand choice flexibility	Branch-and-price algorithm
Shen (2005)	Model with multiple commodities	Lagrangian relaxation embedded in a branch and bound algorithm

Making Network Design Decisions in Practice

- *Do not underestimate the life span of facilities.*
- *Do not gloss over the cultural implications.*
- *Do not ignore quality-of-life issues.*
- *Focus on tariffs and tax incentives when locating facilities.*

Examples and Exercises

Facility Location Example

SunOil is a manufacturer of petrochemical products with worldwide sales.

The vice president of supply chain is considering several options to meet demand.

One possibility is to set up a facility in each region.

- The advantage of such an approach is that it lowers transportation cost and also helps avoid duties that may be imposed if product is imported from other regions.
- The disadvantage of this approach is that plants are sized to meet local demand and may not fully exploit economies of scale.

An alternative approach is to consolidate plants in just a few regions.

- This improves economies of scale but increases transportation cost and duties.

Facility Location Example

Network optimization models are useful for managers considering regional configuration during Phase II.

The first step is to collect the data in a form that can be used for a quantitative model.

For SunOil, the vice president of supply chain decides to view the worldwide demand in terms of five regions—North America, South America, Europe, Africa, and Asia.

Annual de… for each of t… regions

The variable production, inventory, and transportation cost

Annual fixed c… build a low-ca… plant in each r…

Annual fixed cost to build a high-capacity plant in each re…

Production capacity

	Demand Region …ansportation Cost per 1,000,000 Un…					Fixed		Fixed	High
	N. America	S. America	Europe	Asia	Africa	Cost ($)	Capacity	Cost ($)	Capacity
N. Americ…	81	92	101	130	115	6.000	10	9.000	20
S. America	117	77	108	98	100	4.500	10	6.750	20
Europe	102	105	95	119	111	6.500	10	9.750	20
Asia	115	125	90	59	74	4.100	10	6.150	20
Africa	142	100	103	105	71	4.000	10	6.000	20
Demand	12	8	14	16	7				

Cost Data (in Thousands of Dollars) and Demand Data (in Millions of Units) for SunOil

Facility Location Example

the decision variables x_{ij} and determine the amount produced in a supply region and shipped to a demand region

decision
correspo
low-cap

decision variables y_i corresponding to the high-capacity plants

	Demand Region - Production Allocation (Million Units)					Plants	Plants	Total
Supply Region	N. America	S. America	Europe	Asia	Africa	(1=open)	(1=open)	Plants
N. America	0	0	0	0	0	0	0	0
S. America	0	0	0	0	0	0	0	0
Europe	0	0	0	0	0	0	0	0
Asia	0	0	0	0	0	0	0	0
Africa	0	0	0	0	0	0	0	0

Facility Location Example

Just ahead.

the capacity constraints

Constraints

Supply Region	*Excess Capacity*
N. America	0
S. America	0
Europe	0
Asia	0
Africa	0

the demand constraints

	N. America	S. America	Europe	Asia	Africa
Unmet Demand				16	7

The objective function is the total fixed cost plus the variable cost of operating the network

Objective Function

Cost =	$ -

Excel File 1

Facility Location Example

Steel Appliances (SA), a manufacturer of high-quality refrigerators and cooking ranges.

SA has one assembly factory located near Denver, from which it has supplied the entire United States.

Demand has grown rapidly and the CEO of SA has decided to set up another factory to serve its eastern markets.

The supply chain manager is asked to find a suitable location for the new factory.

Three parts plants, located in Buffalo, Memphis, and St. Louis, will supply parts to the new factory, which will serve markets in Atlanta, Boston, Jacksonville, Philadelphia, and New York.

Facility Location Example

- Gravity models assume that both the markets and the supply sources can be located as grid points on a plane.
- All distances are calculated as the geometric distance between two points on the plane.
- These models also assume that the transportation cost grows linearly with the quantity shipped.
- We discuss a gravity model for locating a single facility that receives raw material from supply sources and ships finished product to markets

Sources/Markets	Transportation Cost $/Ton Mile ($F_n$)	Quantity in Tons (D_n)	Coordinates x_n	y_n
Supply Sources				
Buffalo	0.90	500	700	1,200
Memphis	0.95	300	250	600
St. Louis	0.85	700	225	825
Markets				
Atlanta	1.50	225	600	500
Boston	1.50	150	1,050	1,200
Jacksonville	1.50	250	800	300
Philadelphia	1.50	175	925	975
New York	1.50	300	1,000	1,080

Locations of Supply Sources and Markets for Steel Appliances

Excel File 2

Facility Location Example

TelecomOne

HighOptic

EDUCATION SOLUTIONS

- TelecomOne has a total production capacity of 71,000 units per month and a total demand of 32,000 units per month, whereas HighOptic has a production capacity of 51,000 units per month and a demand of 24,000 units per month.
- Each year, managers in both companies must decide how to allocate the demand to their production facilities as demand and costs change.

	Demand City Production and Transportation Cost per Thousand Units (Thousand $)							
Supply City	**Atlanta**	**Boston**	**Chicago**	**Denver**	**Omaha**	**Portland**	**Monthly Capacity (Thousand Units), *K***	**Monthly Fixed Cost (Thousand $) *f***
Baltimore	1,675	400	685	1,630	1,160	2,800	18	7,650
Cheyenne	1,460	1,940	970	100	495	1,200	24	3,500
Salt Lake City	1,925	2,400	1,425	500	950	800	27	5,000
Memphis	380	1,355	543	1,045	665	2,321	22	4,100
Wichita	922	1,646	700	508	311	1,797	31	2,200
Monthly demand (thousand units), D_j	10	8	14	6	7	11		

Capacity, Demand, and Cost Data for TelecomOne and HighOptic

Excel File 3

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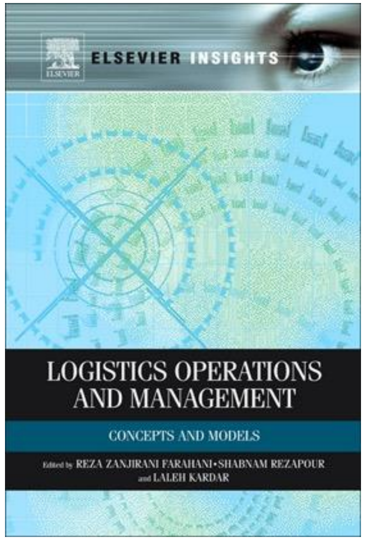
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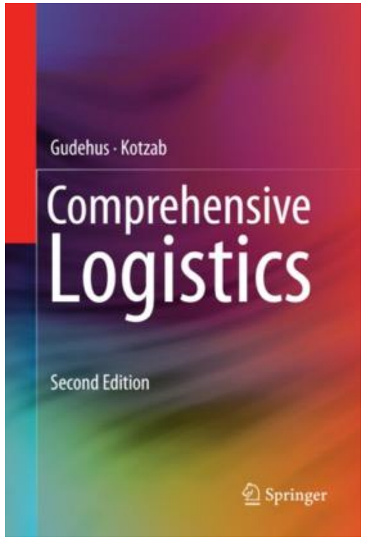
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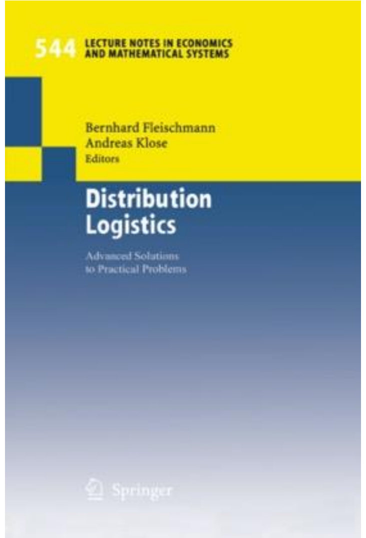
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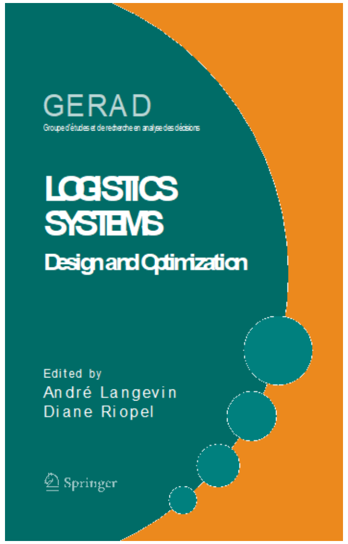
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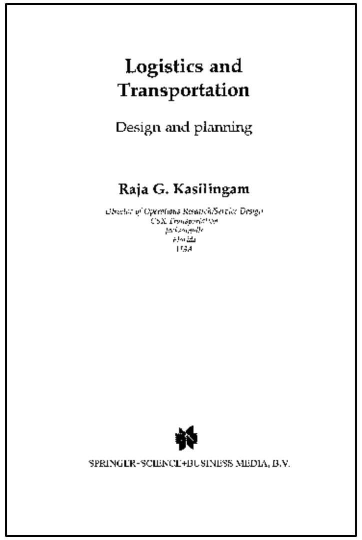
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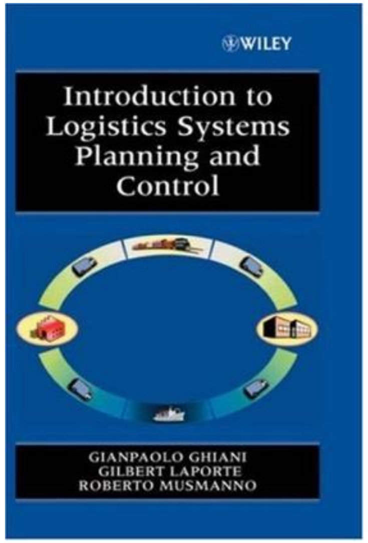
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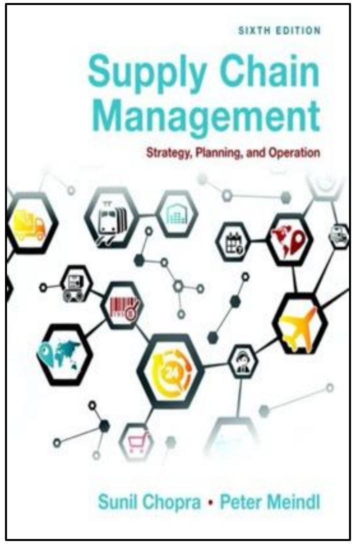
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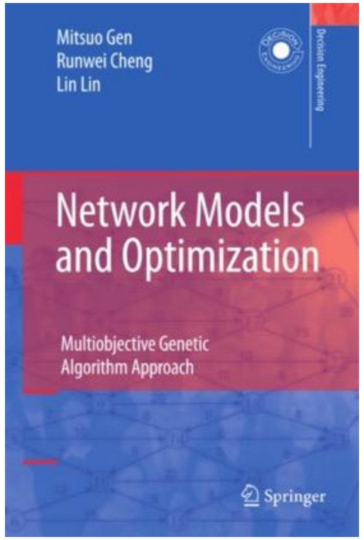
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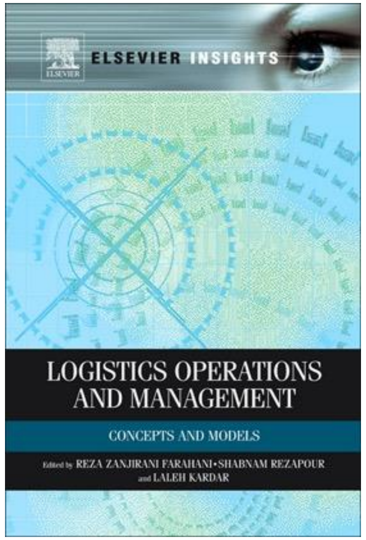
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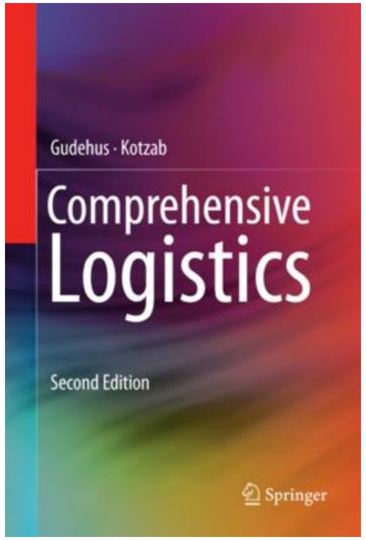
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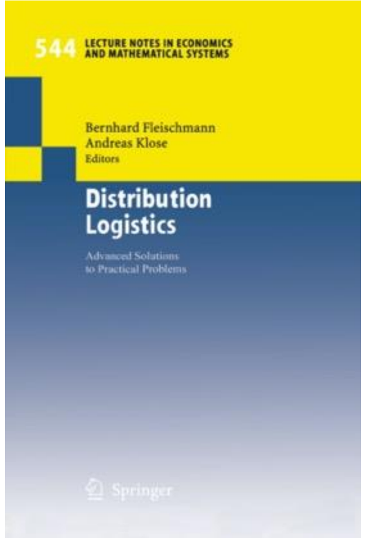
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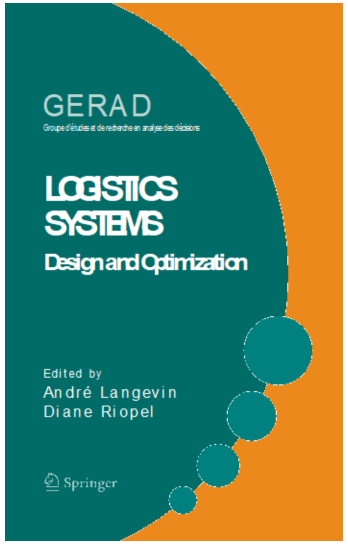
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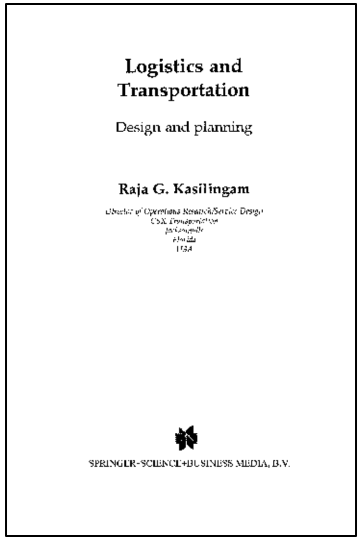
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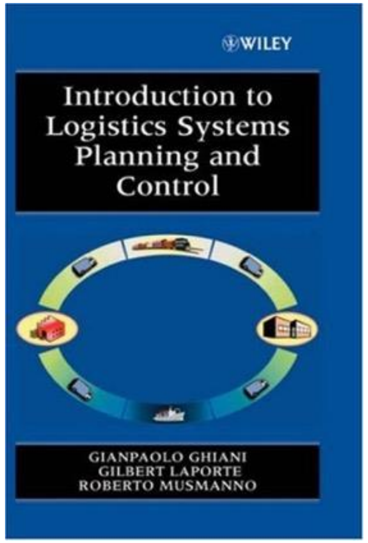
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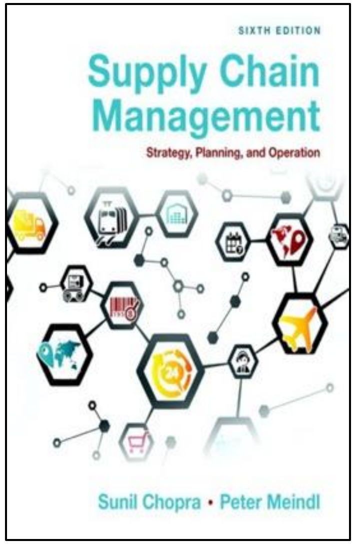
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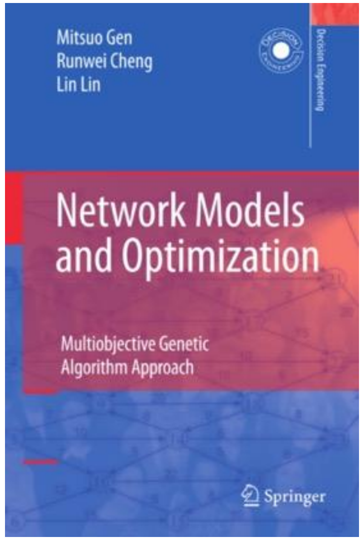
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