Intra- and Inter-facility Logistics

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LOGISTICS DECISIONS
What is Logistics?

• Council of Supply Chain Management Professionals (CSCMP) definition
  – “Logistics management is that part of supply chain management 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.”

• Key Ideas
  – Forward and reverse flow
  – Efficient and effective
  – Plans, implements, and controls
  – Part of supply chain management (SCM)
...forward and reverse flow...
...efficient, effective...

• Effectiveness: delivering on what is committed
  – Price
  – Quality
  – Response time
  – Flexibility

• Efficiency: using resources in the “best” way

Achieving desired **objective** while minimizing **costs**
...plans, implements, and controls...

Long Term

Strategic

- Corporate Objectives
- Number of Facilities
- Facility Location & Capacity
- Resource Requirements

Medium Term

Tactical

- Material Flow
- Resource Allocation
- Capacity Allocation
- Inventory Policies

Near Term

Operational

- Scheduling
- Routing
- Warehousing
- Tracking/Tracing
Supply Chain Network Importance

• Cost
  – 2016 logistics costs in the U.S.: 7.5% of GDP, or $1.39 trillion


• Environmental Impact
  – Packaging
  – Fuel emissions

• Competitive Advantage
  – Speed
  – Flexibility
Key Decisions

• Intra-facility logistics (warehousing)
  – Warehouse design
  – Which skus where
  – Equipment, technology

• Inter-facility logistics (transportation)
  – Mode choice
  – Comprehensive network planning
  – Routing
  – Fleet and driver assignment
DECISION SUPPORT TOOLS: MODE CHOICE
Mode Choice Problem

• Given the cost profiles of different modes for a particular shipment, which option is most economical?
  – Normalize all costs to common unit and time
  – Compare total cost of each mode
Logistics System Cost Classification

• Useful to classify costs under essential types, e.g.,
  – Transportation costs: movement via vehicle; loading/unloading
  – Handling costs: packing/unpacking boxes, bags, pallets; intra-facility storing and picking movements
  – Holding costs: opportunity cost of capital for time waiting
  – Facility rent costs: economic “rent” for facility space, storage infrastructure, and maintenance
Example

- 1 plant, 1 product
- Produce 10 units/day
- Keep no safety stock
- Space cost = $20/unit*year
- Item value = $500/unit

- 1 warehouse
- Avg demand 10 units/day
- Keep 100 units safety stock
- Space cost = $25/unit*year
- Item value = $512/unit

Inventory holding cost rate = 25% of value per year

- Railcar capacity = 400 units
- Cost = $1200/carload
- Transit time = 20 days

- Truck capacity = 100 units
- Cost = $700/truckload
- Transit time = 3 days
Example

• 1 plant, 1 product
• Produce 10 units/day
• Keep no safety stock
• Space cost = $20/unit*year
• Item value = $500/unit

Costs at the Plant
• Inventory space cost
  = (# units per shipment) x (space cost per unit*year)
  = q units x $20/unit*year
• Inventory holding cost
  = (avg inventory held) x (value per unit) x (inventory holding cost rate)
  = q/2 units x $500/unit x 25% per year
Example

**Costs at the Plant**
- **Inventory space cost**
  \[ \text{Inventory space cost} = (\# \text{ units per shipment}) \times (\text{space cost per unit*year}) \]
  \[ = q \text{ units} \times \$20/\text{unit*year} \]
- **Inventory holding cost**
  \[ \text{Inventory holding cost} = (\text{avg inventory held}) \times (\text{value per unit}) \times (\text{inventory holding cost rate}) \]
  \[ = q/2 \text{ units} \times \$500/\text{unit} \times 25\% \text{ per year} \]

**Costs at the Warehouse**
- **Inventory space cost**
  \[ \text{Inventory space cost} = (\# \text{ units per shipment} + \text{safety stock}) \times (\text{space cost per unit*year}) \]
  \[ = (q + 100 \text{ units}) \times \$25/\text{unit*year} \]
- **Inventory holding cost**
  \[ \text{Inventory holding cost} = (\text{avg inventory held}) \times (\text{value per unit}) \times (\text{inventory holding cost rate}) \]
  \[ = (q/2 + 100 \text{ units}) \times \$512/\text{unit} \times 25\% \text{ per year} \]
Example

- 1 plant, 1 product
- Produce 10 units/day
- Keep no safety stock
- Space cost = $20/unit*year
- Item value = $500/unit

Costs in Transit

- Pipeline inventory cost
  \[ = (\text{# units shipped}) \times (\text{time in transit}) \times (\text{value per unit}) \times (\text{inventory holding cost rate}) \]
  \[ = 3650 \text{ units} \times (\text{time in transit}) \times $506/\text{unit} \times 25\% \text{ per year} \]

- Transportation cost
  \[ = (\text{cost per shipment}) \times (\text{# shipments per year}) \]

- 1 warehouse
- Avg demand 10 units/day
- Keep 100 units safety stock
- Space cost = $25/unit*year
- Item value = $512/unit

Railcar capacity = 400 units
Cost = $1200/carload
Transit time = 20 days

Truck capacity = 100 units
Cost = $700/truckload
Transit time = 3 days
Example

<table>
<thead>
<tr>
<th>Mode</th>
<th>At Plant</th>
<th>At Warehouse</th>
<th>Pipeline Inventory</th>
<th>Transport</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rail</td>
<td>$33,000</td>
<td>$50,900</td>
<td>$25,300</td>
<td>$10,950</td>
<td>$120,150</td>
</tr>
<tr>
<td>Truck</td>
<td>$8,250</td>
<td>$24,200</td>
<td>$3,795</td>
<td>$25,550</td>
<td>$61,795</td>
</tr>
</tbody>
</table>

- What are the key factors?
  - Large container size, if used, increases inventory space costs
  - Long transit time increases inventory holding costs
- What’s missing?
  - Stochastic, dynamic components
  - Other costs, e.g., emissions
DECISION SUPPORT TOOLS: NETWORK PLANNING
Shipper Problem

• Given a demand profile, supply sources, and distribution network, what flow through the network optimizes total cost?
  – Choose appropriate planning horizon
  – Capture relevant costs
Physical Network Representation

- Production/Procurement
- Distribution Center
- Retail POS
Time-expanded Network Representation

Time

$t = 1$

$t = 2$

$t = 3$

$t = \ldots$
Time-expanded Network Representation

Time		$t = 1$

$P1$

$P2$

$DC$

$R1$

$R2$

$t = 2$

$DC$

$R1$

$t = 3$

$DC$

$R1$

$t = ...$

$P1$

$P2$

$DC$

$R1$

$R2$
Network Flow Optimization

Network Representation

- Arcs in the network
- Costs on each arc
- Capacities on each arc
- Nodes in the network

Optimization Model

- Decision variables (how much flow?)
- Objective function contribution
- Flow capacity constraints
- Flow conservation constraints (out = in)
Network Flow Optimization

• Easy case: “imaginary” mode with linear costs
  – Minimum cost network flow model
  – Easy (computationally) to solve, even for large-scale networks
  – Foundation of all network optimization approaches

• Generalizations
  – Multi-commodity flow
  – Economies of scale
Resources

• Warehouse management principles and tools
  – https://www.warehouse-science.com/

• MHI (formerly Material Handling Institute), material handling, logistics, and supply chain industry group
  – http://www.mhi.org/

• Council of Supply Chain Management Professionals
  – http://cscmp.org/

• Institute of Industrial and Systems Engineers
  – Main site: http://www.iise.org/Home/

• Institute for Operations Research and the Management Sciences
  – Main site: https://www.informs.org/
  – Transportation Science and Logistics Society: http://connect.informs.org/tsl/home
  – Railway Applications Section: http://connect.informs.org/railway-applications/home
  – Section on Location Analysis: http://connect.informs.org/sola/home