Chapter 14

Transportation in the Supply Chain

Transportation
- A key decision area within the logistics mix

Inventory Strategy
- Forecasting
- Storage decisions
- Inventory decisions
- Purchasing & supply planning ...

Transport Strategy
- Transport fundamentals
- Transportation decisions

Customer Service Goals

Network & Facility Strategy
- Network design
- Location decisions
- Facility decisions ...

Also refer to what you learnt from:
- Resource Allocation Techniques
- Decision Making under Uncertainty

The role of transportation in the SC
- a significant link between different stages in a global supply chain
- a critical component in a supply chain
- a competitive strategy
- a key to the success of on-line business

Transportation decisions
- Mode of transportation
- Transportation network selection
- Transportation routing and scheduling
- In house or outsource
- ...

Overall trade-off:
Responsiveness vs. Efficiency
(speed) (cost)
Factors affecting transportation decisions

**Shipper**
- Transportation cost
- Inventory cost
- Facility cost
- Processing cost
- Service level cost
- ...

**Carrier**
- Vehicle-related cost
- Fixed operating cost
- Trip-related cost
- Quantity related cost
- Overhead cost
- ...

Transportation Modes

- **Trucks**
  - TL
  - LTL
- Rail
- Air
- Package Carriers
- Water
- Pipeline

**Intermodal**
- Use of more than one mode of transportation to move a shipment to its destination
- Most common example: rail/truck
- Also water/rail/truck or water/truck
- Grown considerably with increased use of containers
- Increased global trade has also increased use of intermodal transportation
- More convenient for shippers (one entity provides the complete service)
- Key issue involves the exchange of information to facilitate transfer between different transport modes

Transportation System/Network Design

**Goal:** To achieve the desired degree of responsiveness at a low cost

**Case 1:**
- AC Delco: Very high value low volume parts
  - Three plants: Milwaukee, Kokomo, Matamoros
  - 21 assembly plants (customers for above plants)
- What are the distribution options?
- Which one to select?
- On what basis?

**Option 1: All Shipments Direct**

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<td>$4.0 Million</td>
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Total cost: $9.6 million

Suppliers

Retailers

Direct Shipment Network
Option 2: All Shipments Via Kokomo (with or without cross dock)

Kokomo - central distribution center (DC)

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$10.2 million

Option 3: Some Shipments Direct, Others Via Kokomo

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$9.5 million

Option 4: Milk Runs From Kokomo

Milk run - A product delivery (one trip) of one-to-many or many-to-one

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$9.6 million

Option 5: Milk Runs From Plants

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$8.1 million
Option 6: Cross Dock

This approach is useful if deliveries are time sensitive and there are several dropoffs in proximity, not all of which can be delivered on a single truck.

Crossdock – a process in which product is exchanged between trucks so that each truck going to a retail store has products from different suppliers.

Total Costs

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Design Options for a Transportation Network

- What are the transportation options? Which one to select? On what basis?
- Direct shipping network
- Direct shipping with milk runs
- All shipments via central DC
- Shipping via DC using milk runs
- Tailored network

Tradeoffs in Transportation System Design

- Transportation cost and inventory cost
  - Choice of transportation mode
  - Inventory aggregation
- Transportation cost and customer responsiveness
  - The transportation cost a SC incurs is closely linked to the degree of responsiveness the SC aims to provide
- System efficiency and responsiveness
Case 2: Transportation Model Selection at Eastern Electric Corporation

- Annual demand = 120,000 motors
- Cost per motor = $120
- Current order size = 3,000 motors
- Safety stock carried = 80% of demand during delivery lead time
- Holding cost = 25%

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**Key point:**
When selecting a mode of transportation, inventory costs must be accounted. Modes with high transportation cost can be justified if they result in significantly lower inventories.

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Physical Inventory Aggregation: Inventory vs. Transportation Cost

- As a result of physical aggregation:
  - Inventory costs decrease
  - Inbound transportation cost decreases
  - Outbound transportation cost increases
  - Inventory aggregation decisions must account for inventory and transportation cost.
  - Inventory decreases supply chain costs if the product has a high value-to-weight ratio and high demand uncertainty and large orders. Otherwise, inventory aggregation may increase supply chain costs.

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Inventory Aggregation at HighMed

**Current structure:**
- 24 territories, each with its own sales force. All product inventories are maintained locally and replenished from Madison every 4 weeks using UPS with the average lead time of one week.

**Two categories of products:**
- Highval ($200, 1 lbs/unit) demand in each of 24 territories
  - \( \mu_H = 2, \sigma_H = 5 \)
- Lowval ($30/unit, 0.04 lbs/unit) demand in each territory
  - \( \mu_L = 20, \sigma_L = 5 \)

**Two options under evaluation:**
- Option A: Keep the current structure. But replenish inventory once a week.
- Option B: Aggregate all inventories at Madison. Replenish the warehouse once a week.

**Two carries under consideration:**
- UPS rate: $0.66 + 0.26x (for replenishments)
- FedEx rate: $5.53 + 0.53x (for customer shipping)

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Inventory Aggregation at HighMed

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*If shipment size to customer is 0.5H + 5L, total cost of option 2 increases to $36,729.*
Trade-offs Between Transportation Cost and Customer Responsiveness

- Temporal aggregation is the process of combining orders across time.
- Temporal aggregation reduces transportation cost because it results in larger shipments and reduces variation in shipment sizes.
- However, temporal aggregation reduces customer responsiveness.

Tailored Transport

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

Routing and Scheduling in Transportation

- The most important operational decision related to transportation in a supply chain.
- Basic decisions:
  - Sequencing, routing, scheduling and dispatching
- Methods:
  - Mathematical programming
  - Heuristics
  - Simulation
  - Expert systems
- Commercial software:

### Vehicle Routing

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Vehicle Routing

Savings Matrix

- Represents the savings that accrue on consolidating two customers on a single truck.
- Savings may be evaluated in terms of distance, time, or money.

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</tbody>
</table>

Characteristics of routing and scheduling problems

1. Size of available fleet
   - one vehicle or multiple vehicle
2. Type of available fleet
   - only one vehicle type
   - multiple vehicle types
   - special vehicle types
3. Housing of vehicles
   - single depot or multiple depots
4. Nature of demands
   - deterministic (known) demands
   - stochastic demands
   - partial satisfaction of demand allowed
5. Location of demands
   - at nodes (not necessarily all)
   - in arcs
   - mixed
6. Underlying network
   - undirected
   - directed
   - mixed
   - euclidean
7. Vehicle capacity restrictions
   - imposed (all the same)
   - different vehicle capacities
   - not imposed (unlimited)
8. Maximum route times
   - imposed (all the same)
   - imposed (different)
   - not imposed
9. Operations
   - pickups only
   - drop-offs (deliveries) only
   - mixed
   - split deliveries (allowed or disallowed)

Characteristics of routing and scheduling problems (cont'd)

10. Costs
    - variable or routing costs
    - fixed operating or vehicle costs
    - common carrier costs (for un-serviced demands)
11. Objectives
    - minimize total routing costs
    - minimizing sum of fixed and variable costs
    - maximize utilization function based on service or convenience
    - maximize utility function based on customer priorities
    - ... and many more...

Heuristic approaches:

- Effective for solving many real-world or complex optimization problems
- Why using heuristics?
  - Analytical procedures not available
  - The problem is too large
  - Simplify complex problems
- Optimizing vs. satisfying
  - (exact optimal solution vs. near optimal solution)
- Basic heuristics
  - Nearest-Neighbor rule
  - Nearest (cheapest) Inserting rule
  - Geometric heuristic rule
  - Lagrangian relaxation, Tabu search, Simulated Annealing, Generic approach, Neural network...
- Multiple vehicle strategies
  - Routing first, clustering second
  - Clustering first, routing second
  - interactive
Optimal Route:
The solution by NN heuristics: