Logistics Systems Design: Supply Chain Systems

1. Introduction
2. Forecasting
3. Transportation Systems
4. Transportation Models
5. Inventory Systems
6. Supply Chain Systems

Common Logistics Questions

- Where to purchase?
- Where to produce?
- Where to assemble?
- Where to hold in inventory?
- How to transport?
- How to deliver?
- How to expand or retreat?
- How to recycle?

Supply Chain Networks

Supply Chains Are Global and Ever Changing
Duty Relieves

4.9% duty avoided in Europe

Taxes

34%
17%
12%
40% or more

Supply Chains Designs
Integrated and Comprehensive

Vendors, Inventory, Facilities, Customers, Objectives, Countries, Channels, Products, Time Periods

Traditional Design Stages

Transportation, Network Design, Material Deployment Strategy, Service Goals
Modern Design Stages

- Transportation
- Network Design
- Material Deployment Strategy

Service Goals

Objectives for Given Demand

- Cost minimization
  St. Service constraints
- Return on investment maximization
  St. Service constraints
- Reliability

Objectives for Variable Demand

- Profit maximization
  St. Budget constraints
- Service maximization
  St. Budget constraints
- Responsiveness
- Flexibility

Total System Cost

- Total cost of achieving a mission
  - Mission = set of customer service goals for a particular product
- Traditional accounting insufficient
  - Arbitrary allocation of overhead costs
  - Functional areas based rather than output based
- Based on activity based costing (ABC)
- Reduced to a common time frame
Cost Categories

- Controllable vs. Non-controllable
  - Avoided if the mission were discontinued
  - Transportation vs. Pension liabilities
- Fixed vs. Variable
  - Fixed are incurred when an activity is executed
  - Variable change with the intensity of the activity

Total System Cost Components

- Raw material costs
- Production costs
- Linehaul transportation costs
- Local delivery costs
- Facility costs
- Storage and handling costs
- System inventory costs

Costs Schematic

- Delivery Cost
- Supplies Cost
- Linehaul Transportation Cost
- DC Fixed Location Costs
- DC Variable Storage & Handling Costs
- DC Fixed Opening/Closing Cost
- Pipeline Inventory Cost
- Production Cost
- Cycle Inventory Cost
- Production Capability Cost
- Safety Stock Cost
- Cycle Inventory Cost

Depot Technology or Size Costs

- Cost vs. Throughput Quantity
  - Manual
  - Mechanized
  - Automated
Direct Shipping Cost Tradeoff

Plant → Expensive Delivery → Customer

Cheap Linehaul → Warehouse

Cross Docking Material Handling Tradeoff

Storage

Receiving → Shipping

Supply Chain and Warehousing Trends

Inventory, Facilities, Handling

Transactions, Transportation, Information

Data Sources

- Business operating documents
  - Sales orders, customer data, freight bills
- Business documents
  - Annual report, accounting (activity-based-costing)
- Logistics research data
- Published reference data
  - Trade magazines, census data, press
**Data Encoding**

- **Group technology and coding**
- **Product coding**
  - Bar codes, radio frequency tags, smart cards
- **Geocoding**
  - Zip codes
  - City and state names

**Geocoding**

- Converts alphanumeric location data into geographical data
  - From zip codes and city, state
  - To longitude-latitude or rectangular coordinates
- Grid overlay, spreadsheets, or reference databases
- User interface and display
- Numerical computations

**DEC Incinerator Data**

**DEC Incineration Geographical Schematic with Excel**
Geocoding Example: Customer Demand History Database

Geocoding Example: Customer Locations

Geocoding Example: Demand Summed by State
Geocoding Example: Average Customer Demand by State

Constraints
- Conservation of flow
- Capacity and demand
- Consistency or linkage
- Elastic or soft constraints with penalty cost

Units of Analysis
- Units of material flow and storage
- Monetary units
- Units of time (major and minor)
- Information units

Model Characteristics
- Multi-country
- Multicommodity
- Multi-echelon
- Multi-period
- Capacitated facilities
- Capacitated channels
- Deterministic or stochastic
Logistics Objects

- Products - commodities
  - In transformation
  - In transportation
  - In storage
- Countries
- Periods
- Resources

Logistics Objects Continued

- Facilities
  - Sources = suppliers
  - Sinks = customers
  - Intermediate = transformers
    (manufacturing and distribution)
- Transportation channels

Period Characteristics

- Major period
  - Strategic planning
  - Year, season
  - Ordered sequence
- Minor period
  - Demand process
  - Day, week
- Consistency

Period Edit Window

<table>
<thead>
<tr>
<th>Edit Period</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Name:</strong> Year 2000</td>
</tr>
<tr>
<td><strong>Label:</strong> Y2000</td>
</tr>
<tr>
<td>OK</td>
</tr>
</tbody>
</table>
Country Characteristics

- Differs from other countries by
  - Currency (exchange rate)
  - Tax rate
  - Duties
  - Minimum profit
  - Local content laws
  - Duty relief

- Limited number

Country Edit Window

Edit Country

Name: Bolivia
Label: BOL
Tax Rate: 0.4

Country-Period Edit Window (Input)

Edit Country BOL Period Y2000 Data

Input  Output
Exchange Rate: 4
Minimum Profit: 0

Country-Period Edit Window (Output)

Edit Country BOL Period Y2000 Data

Input  Output
Before Tax Profit: 0
Taxes: 0
After Tax Profit: 0
Product Types

- Convenience and commodities
  - Multiple sales points
  - Food items, office supplies
- Comparison shopping
  - Fewer sales points
  - Cars, fork lift trucks
- Specialty products
  - Very limited distribution
  - Art, specialized machines

Product Life Cycle Graph

Sales

- Growth
- Maturity
- Decline

Time

Introduction

Product Life Cycle Characteristics

- Introduction
  - Limited availability
  - Few sales points and channels
  - Centralize distribution
- Growth
  - Expanding channels and sales points
  - Flow quantity more important than cost

Product Life Cycle Characteristics (2)

- Maturity
  - Stable sales volume
  - Many sales points and channels
  - Optimization opportunity
- Decline
  - Declining sales volume
  - Decreasing sales points and channels
  - Centralized distribution
Product Characteristics

- Differs from other products
  - Size
  - Weight
  - Value
  - Urgency
  - Risk characteristics
  - Obsolescence
- Limited number, less than 12 to 20

Product Edit Window

Customer Types

- Customer types
  - Consumer products
  - Industrial products
**Customer Characteristics**

- Ultimate sink for all materials
- Differs from other customers
  - Location
  - Product demand
  - Service level
- Fixed location
- Demand for individual products
  - Customer-product matrix

**Customer Characteristics (2)**

- Single sourcing restrictions
  - None
  - By product
  - All products combined (depot)
- Service constraints
  - Maximum time
  - Maximum distance
- No more than a few hundred

**Customer Edit Window**

**Customer Demand Edit Window (Input)**
Customer Demand Edit Window (Output)

Product Sales Pareto Analysis

- Concentration / differentiation phenomenon
- Also called 80-20, ABC, fast-medium-slow

Product Sales Pareto Curves With Benders Formula

Pareto Curve Formulations

- $X=$ cumulative products,
- $Y=$ cumulative sales,
- $A=$ parameter

- Benders: $Y = \frac{(1 + A)X}{A + X}$
- Power: $Y = X^A$
- Exponential: $Y = 1 - e^{-AX}$
**Benders Pareto Formulation**

- **Curve** \( Y = \frac{(1 + A)X}{A + X} \)
- **Parameter** \( A = \frac{X(1-Y)}{Y - X} \)

**Benders Least Squares Parameter Estimation**

- **Minimize sum of squared deviations**
  \[
  \text{Min} \quad \text{SSE} = \sum_i \left( Y_i - \hat{Y}_i \right)^2 = \sum_i \left( Y_i - \left(\frac{1 + A}{A + X_i}\right) \right)^2
  \]
- **Set partial derivative equal to zero**
  \[
  \frac{d\text{SSE}}{dA} = \sum_i Y_i (X_i Y_i^2) - \sum_i (1 + A) (X_i^2 - X_i^3) = 0
  \]

**Benders Pareto Curves for Different A Parameters**

- **Observations**
  - More concentration / differentiation
  - Smaller A parameter
  - More skewed curve
  - ABC classification and curve name
  - Class breakpoints based on slope
  - Data - information - knowledge example
Benders Pareto Curve Example:

Data

Excel Solver

Solver Options

Curve Fitting
Customer Service

- Many components
- Many definitions
- Very qualitative

Customer Service Stages

- Pre-transaction
  - Declaring policies and procedures
- Transaction
  - Inventory levels and location
  - Transportation channels
  - Ordering and billing systems
- Post-transaction
  - Maintenance and service (CALS)
  - Warranties

Order Cycle Time

- Time between order placement and product receipt
- Wide range (instantaneous to 30 months)
- Components
  - Order processing
  - Production
  - Order assembly and order picking
  - Transportation
### Sales-Service Curves

- **Sales**
- **Service**
- **Sales Revenue**

### Sales-Cost-Service Curves

- **Sales**
- **Service**
- **Sales Revenue**
- **Logistics Costs**
- **Maximum Profit**

### Service Constraints

- Percentage of goods delivered out of stock
- Percentage of orders delivered within time limit
- Maximum time or distance from supply point
- Single sourcing

### Supplier Characteristics

- Initial source of all materials
- Differs from other supplier
  - Location
  - Fixed facility cost (opening or closing)
  - Total supply capacity
  - Supply parameters
- Fixed location
Supply Characteristics cont.

- Commodity Supply Parameters
  - Cost
  - Resource requirement

Supplier Edit Window

Edit Supplier-Period Window

Supplier-Period-Product Edit Window (Input)
Supplier-Period-Product Edit Window (Output)

Supplier-Period-Resource Edit Window

Supplier-Period-Product-Resource Edit Window

Transformation Facilities

- **Transformation types**
  - Manufacturing
  - Distribution

- **Intermediate facilities**
  - No creation or destruction of flow
  - Change of commodity

- **Moveable or fixed facilities**
  - Different possible types at a site
Transformation Facilities Characteristics

- Fixed and variable costs
- Throughput and storage capacities
- Resources
  - Resource costs
  - Resource consumption

Transformation Facility Edit Window

Transformation Facility Type Edit Window

Transformer-Type-Period Edit Window

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Transformer-Type-Period-Product Edit Window (Input)

Transformer-Type-Period-Product Edit Window (Output)

Transformer-Type-Period-Resource Edit Window

Transformer-Type-Period-Product-Resource Edit Window
Importance of Transportation

- Smaller, faster, more frequently, more on time shipments
- 50% of total logistics cost and rising

Transportation Performance Measures

- Accessibility
- Capacity
- Cost
- Speed
- Dependability
- Tradeoff with inventory for shipper
- Tradeoff with flow volume for carrier

Transportation Modes

- Pipeline
- Rail
- Road
- Water
- Ocean
- Air
- Space

Transportation Channel Edit Window (Input)
Transportation Channel Edit Window (Output)

Channel-Period Edit Window

Channel-Period-Product Edit Window

Channel-Period-Resource Edit Window
Supply Chain Strategies: Evaluation Criteria

- Total Logistics Costs
  - Economies of scale
  - Economies of scope
  - Inventory and transportation costs
- Simplicity of Control
- Responsiveness to changes
- Flexibility and robustness

Supply Chain Systems Strategies: Suppliers

- Centralization
- Regionalization
- Consolidation
- Dispersion

Supply Chain Systems Strategies: Transformation

- Manufacturing facilities strategy
  - Regionalization
  - Consolidation
  - Product Focus
  - Process Focus
  - Dispersion
Supply Chain Systems Strategies: Transformation

- Distribution network strategy
  - Consolidation
  - Customer Focus
  - Co-Location

Design Software Requirements

1. User Friendly
2. Generation of Reports, Maps, & Visuals
3. High Fidelity Economic Representation
4. High Degree of Optimization of the Results


Design Decision Support System Components

- System data and data base
- Design models
- Solution algorithms
- Reports, displays and interactive executive

CIMPEL

- Cost Minimization St. Service Constraints
- Neutral Data Base
- Comprehensive Integrated Model
- Algorithm Toolkit
- Standard Interactive Color Graphics Interface
CIMPEL Illustration

CIMPEL Structure

Enterprise Resource Planning (ERP) Software

- Logistics Systems Status
- “Bookkeeping”
  - Transactional
  - Data Warehouse
- Advantages
  - Enterprise Standardization
  - Data Integration
  - Up-To-Date Data
  - Multinational

ERP Vendors

- Growing Importance
- Major Vendors
  - SAP (Financial),
  - Baan (Manufacturing),
  - PeopleSoft (Human Resources)
  - ...
Supply Chain Management (SCM) Software

- Logistics Systems Configuration and Planning
- "Optimizing"
  - Operations Research
  - Constraint Based Logic
- Interface with ERP

SCM Vendors

- Strong Consolidation
- Major Vendors
  - I2 - InterTrans
  - Manugistics
  - Chesapeake - SupplyChain

Logistics Software Reference


Logistics Planning Software Catalogue
Supply Chain Design Challenges

- Integrated models are large and complex
  - More tactical effects (seasonal, inventory)
- Multi-objective performance measures
  - Cost/profit, flexibility, and responsiveness tradeoffs
- Strategic design as a continuous effort
  - Models, data, algorithms

Supply Chain Design Challenges Continued

- Technology transfer to logistics professionals and students
  - Toy cases and black-box software

From a Multicommodity Case...

...and Configuration by a Current Design Tool
To Design Tools for the Next Century