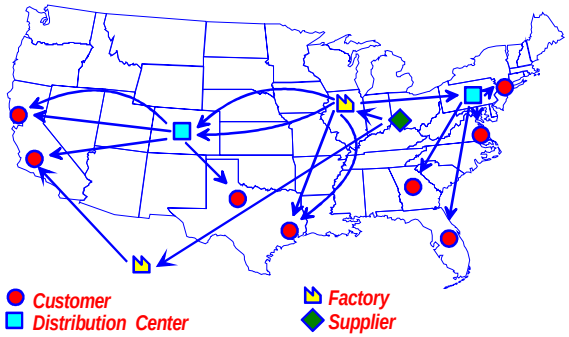
Logistics Systems Design: Supply Chain Systems

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

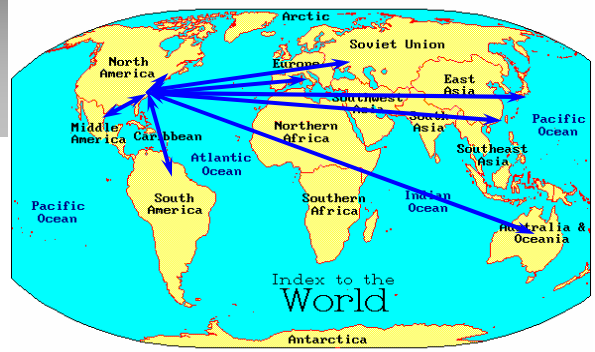
Supply Chain Networks



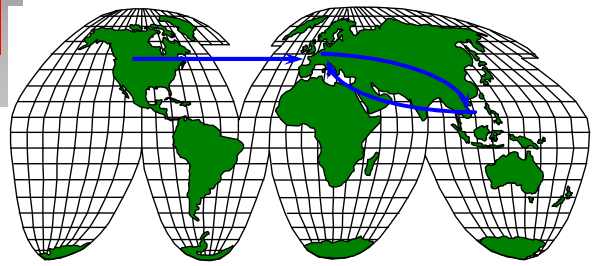
Common Logistics Questions

- 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 Chains Are Global and Ever Changing



Duty Relieves



4.9% duty
avoided in Europe

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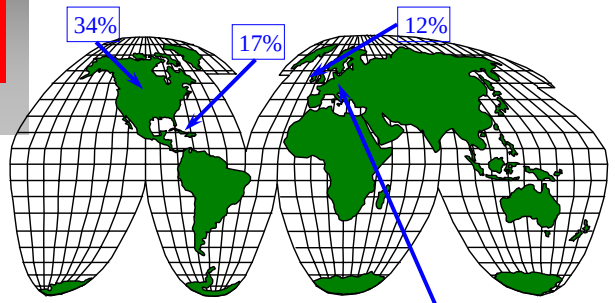
Taxes



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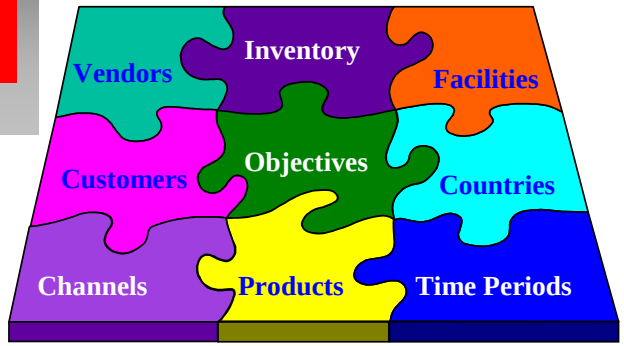
Supply Chains Designs Integrated and Comprehensive



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Traditional Design Stages

- Transportation
- Network Design
- Material Deployment Strategy
- Service Goals

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Modern Design Stages

Transportation
&
Network Design
&
Material Deployment Strategy

Service Goals

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Objectives for Given Demand

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

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Objectives for Variable Demand

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

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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*

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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*

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Total System Cost Components

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

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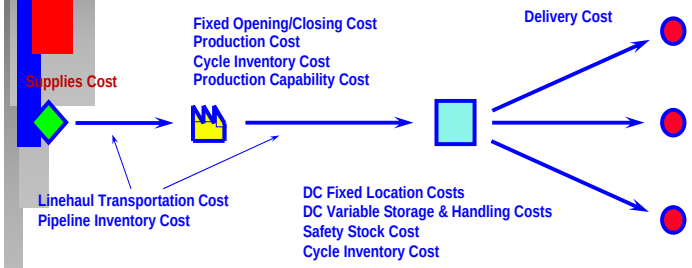
Costs Schematic



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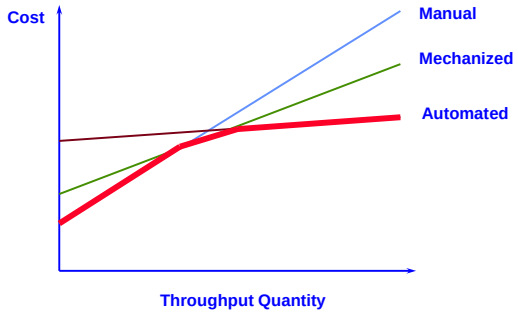
Depot Technology or Size Costs



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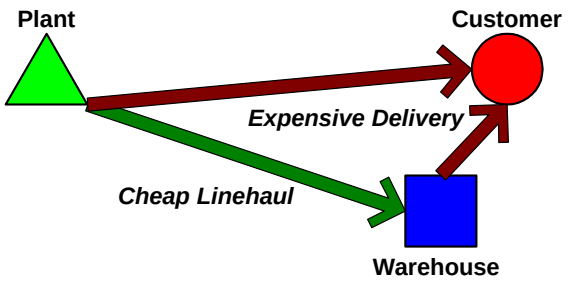
Direct Shipping Cost Tradeoff



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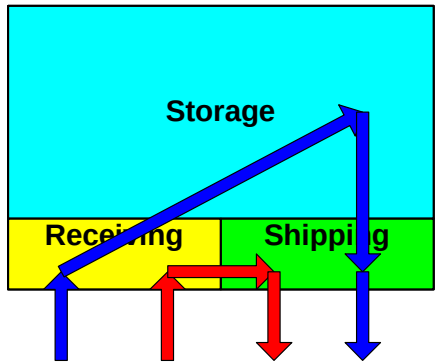
Cross Docking Material Handling Tradeoff



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Supply Chain and Warehousing Trends

Inventory
Facilities
Handling

Transactions
Transportation
Information

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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*

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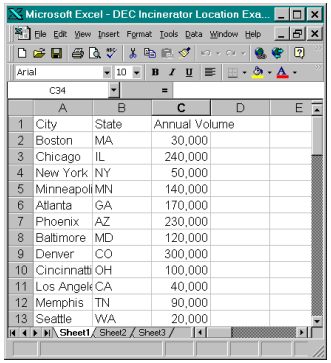
Data Encoding

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

Geocoding

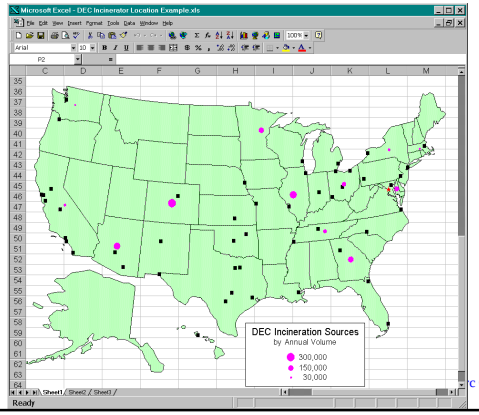
- Converts alphanumeric location data into geographical data
  - From zip codes and city, state
  - To longitude-latitude or rectangular coordinates
- Grid overlay, spreadsheets, or reference databases
- User interface and display
- Numerical computations

DEC Incinerator Data

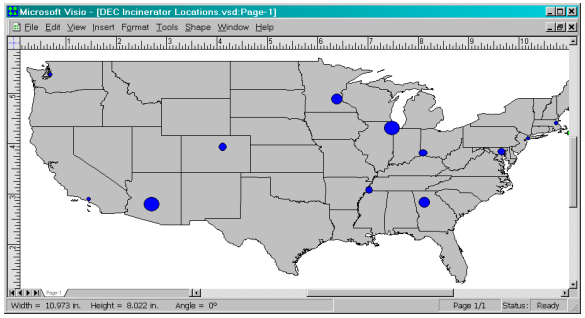


	A	B	C	D	E
1	City	State	Annual Volume		
2	Boston	MA	30,000		
3	Chicago	IL	240,000		
4	New York	NY	50,000		
5	Minneapoli	MN	140,000		
6	Atlanta	GA	170,000		
7	Phoenix	AZ	230,000		
8	Baltimore	MD	120,000		
9	Denver	CO	300,000		
10	Cincinnati	OH	100,000		
11	Los Angel	CA	40,000		
12	Memphis	TN	90,000		
13	Seattle	WA	20,000		

DEC Incineration Geographical Schematic with Excel



DEC Incineration Geographical Schematic with Visio Maps



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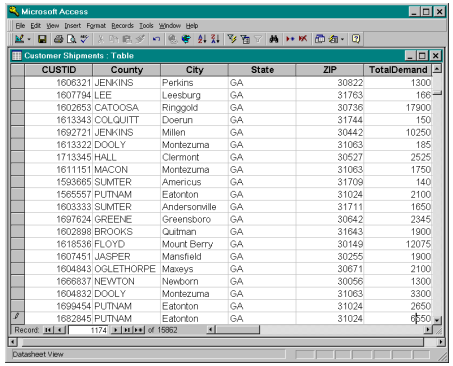
Geocoding Example: Customer Demand History Database



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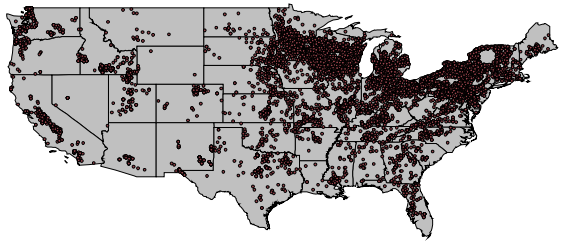
Geocoding Example: Customer Locations



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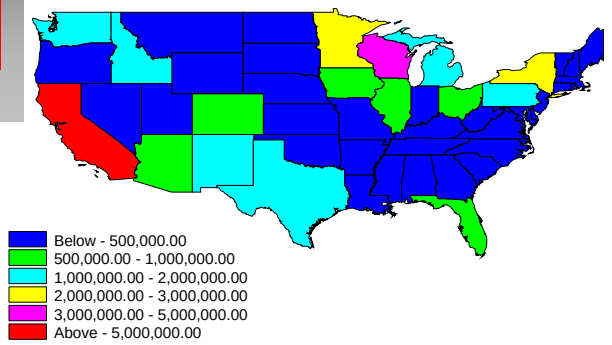
Geocoding Example: Demand Summed by State



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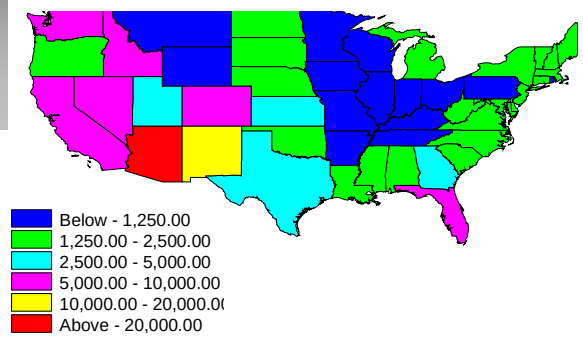
Geocoding Example: Average Customer Demand by State



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Constraints

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

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Units of Analysis

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

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Model Characteristics

- *Multi-country*
- *Multicommodity*
- *Multi-echelon*
- *Multi-period*
- *Capacitated facilities*
- *Capacitated channels*
- *Deterministic or stochastic*

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Logistics Objects

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

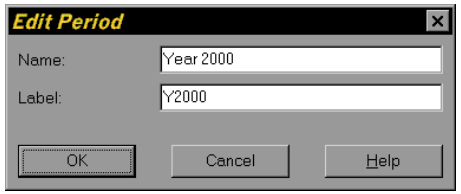
Logistics Objects Continued

- 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

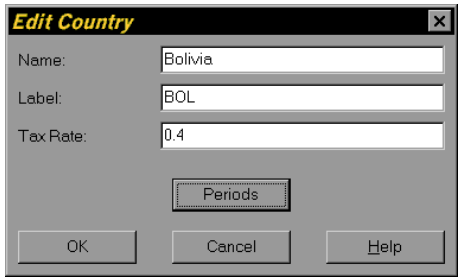
Period Edit Window



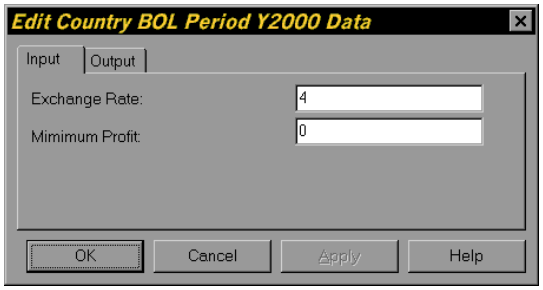
Country Characteristics

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

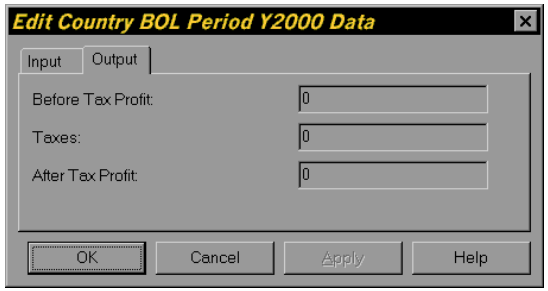
Country Edit Window



Country-Period Edit Window (Input)



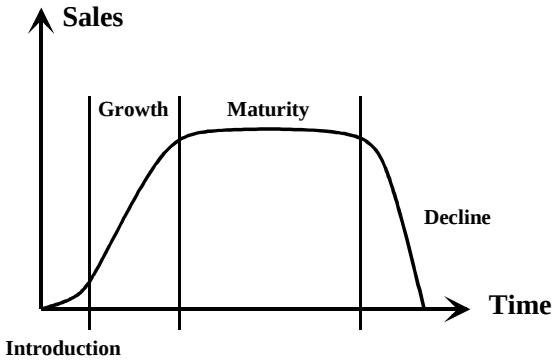
Country-Period Edit Window (Output)



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



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

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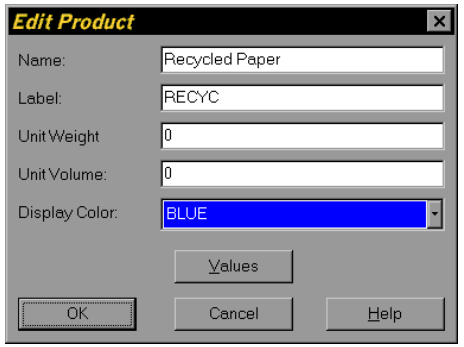
Product Edit Window



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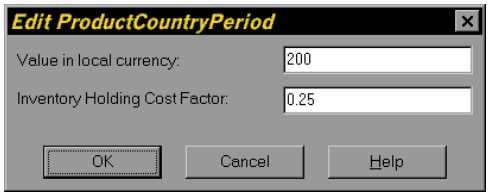
Product-Country-Period Edit Window



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Customer Types

- Customer types
  - Consumer products
  - Industrial products

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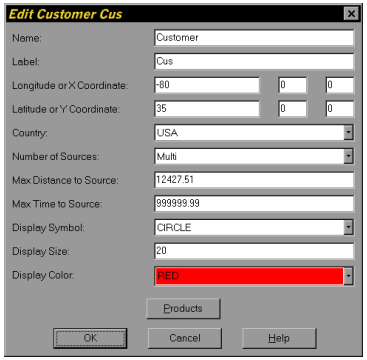
Customer Characteristics

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

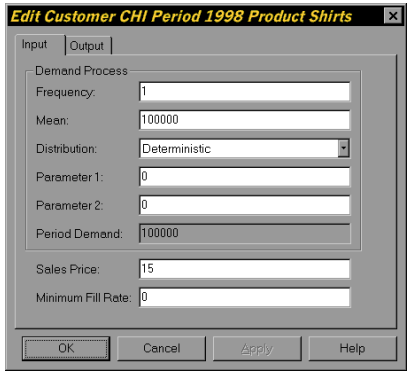
Customer Characteristics (2)

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

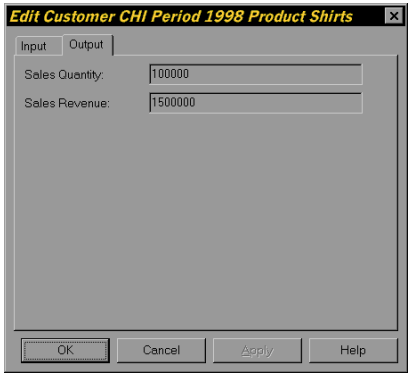
Customer Edit Window



Customer Demand Edit Window (Input)



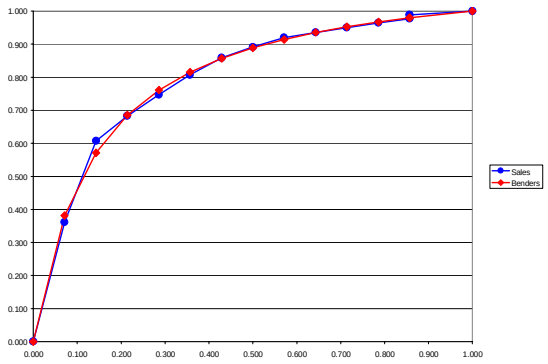
Customer Demand Edit Window (Output)



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

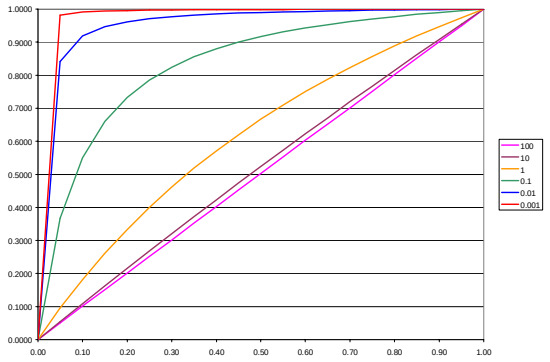
- Minimize sum of squared deviations

$$Min \quad SSE = \sum_i \left(Y_i - \hat{Y}_i\right)^2 = \sum_i \left(Y_i - \frac{(1+A)X_i}{A+X_i}\right)^2$$

- Set partial derivative equal to zero

$$\frac{dSSE}{dA} = \sum_i^N \frac{Y_i(X_i - X_i^2)}{(A+X_i)^2} - \sum_i^N \frac{(1+A)(X_i^2 - X_i^3)}{(A+X_i)^3} = 0$$

Benders Pareto Curves for Different A Parameters



Bender's Pareto Curve 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

Microsoft Excel - Pareto Analys...

File Edit View Insert Format Tools Data Window Help

	A	B	C	D
1	Product	Units Sold	Unit Value	Sales
2	101	31000	$0.10	$3,100
3	202	880000	$0.15	$132,000
4	303	13000	$0.90	$11,700
5	404	210000	$0.03	$6,300
6	505	120000	$0.02	$2,400
7	606	25000	$0.55	$13,750
8	707	70000	$0.35	$24,500
9	808	40000	$0.75	$30,000
10	909	90000	$0.10	$9,000
11	1010	5000	$0.08	$400
12	1111	6500	$0.07	$455

Data Curve Parameter

Benders Pareto Curve Example: Curve Fitting

Microsoft Excel - Pareto Analysis Example.xls

File Edit View Insert Format Tools Data Window Help

	A	B	C	D	E	F	G	H	I	J
1								Benders		Exponent.
2	Product	Units Sold	Unit Value	Sales	X	Y	BY	SSE	EY	SSE
3					0.000000	0.000000	0.000000		0.000000	
4	202	880000	$0.15	$132,000	0.090909	0.565056	0.538019	0.000731	0.433493	0.017309
5	808	40000	$0.75	$30,000	0.181818	0.693478	0.721292	0.000774	0.679070	0.000208
6	707	70000	$0.35	$24,500	0.272727	0.798356	0.813684	0.000235	0.818191	0.000393
7	606	25000	$0.55	$13,750	0.363636	0.857216	0.869363	0.000148	0.897004	0.001583
8	303	13000	$0.90	$11,700	0.454545	0.907301	0.906585	0.000001	0.941652	0.001180
9	909	90000	$0.10	$9,000	0.545455	0.945827	0.933223	0.000159	0.966945	0.000446
10	404	210000	$0.03	$6,300	0.636364	0.972796	0.953228	0.000383	0.981274	0.000072
11	101	31000	$0.10	$3,100	0.727273	0.986066	0.968804	0.000298	0.989392	0.000011
12	505	120000	$0.02	$2,400	0.818182	0.996340	0.981276	0.000227	0.993990	0.000006
13	1111	6500	$0.07	$455	0.909091	0.998288	0.991486	0.000046	0.996596	0.000003
14	1010	5000	$0.08	$400	1.000000	1.000000	1.000000	0.000000	1.000000	0.000004
15										
16				Sum				A	SSE	A	SSE
17				$233,605			0.093933	0.003001	6.250926	0.021214

Data Curve Parameter

Benders Pareto Curve Example: Excel Solver

Solver Parameters

Set Target Cell: H17 Solve

Equal To: Max Min Value of: 0 Close

By Changing Cells:

G17 Guess

Subject to the Constraints: Options

Add

Change Reset All

Delete Help

Benders Pareto Curve Example: Solver Options

Solver Options

Max Time: 100 seconds OK

Iterations: 100 Cancel

Precision: 0.000001 Load Model...

Tolerance: 5 % Save Model...

Convergence: 0.001 Help

Assume Linear Model Use Automatic Scaling

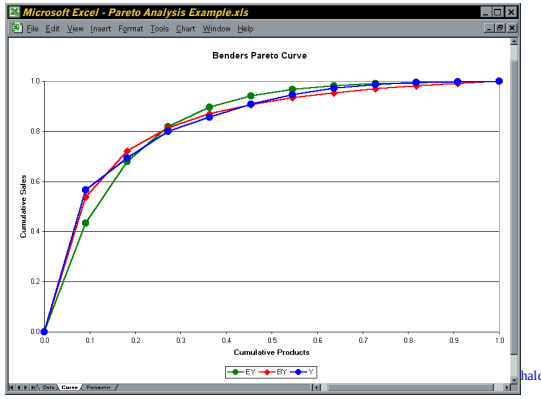
Assume Non-Negative Show Iteration Results

Estimates: Tangent Quadratic

Derivatives: Forward Central

Search: Newton Conjugate

Benders Pareto Curve Example: Excel Graph



Customer Service

- *Many components*
- *Many definitions*
- *Very qualitative*

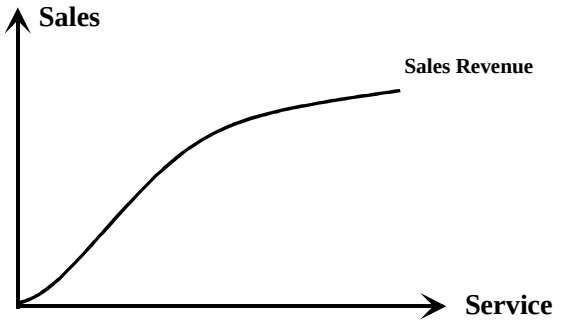
Customer Service Stages

- *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 Curve



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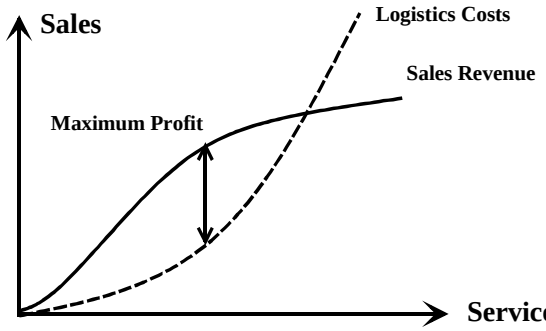
Sales-Cost-Service Curves



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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*

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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*

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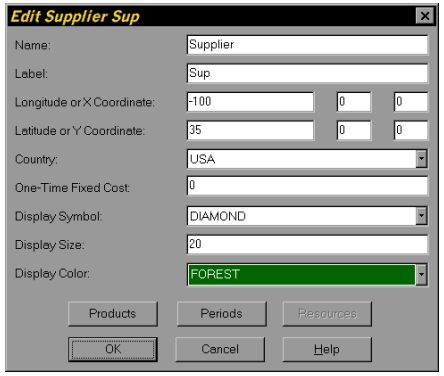
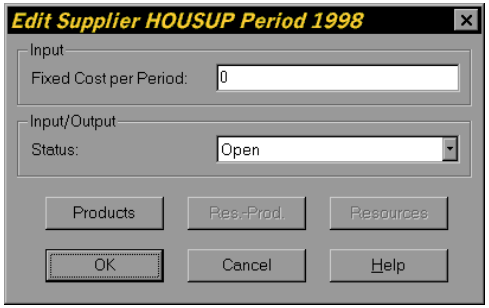
Supply Characteristics cont.

- *Commodity Supply Parameters*
  - *Cost*
  - *Resource requirement*

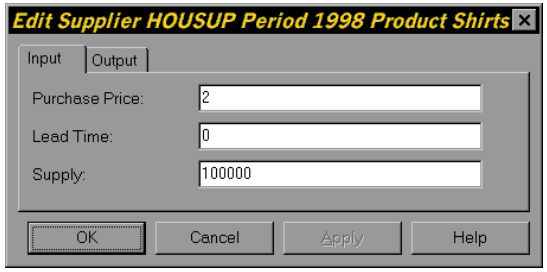
Supplier Edit Window



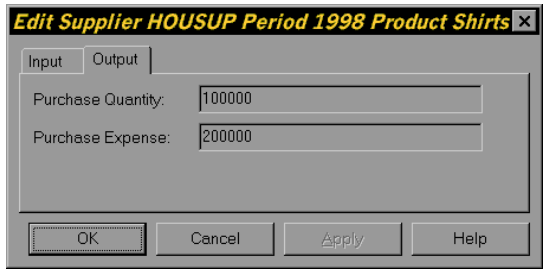
Edit Supplier-Period Window



Supplier-Period-Product Edit Window (Input)



Supplier-Period-Product Edit Window (Output)



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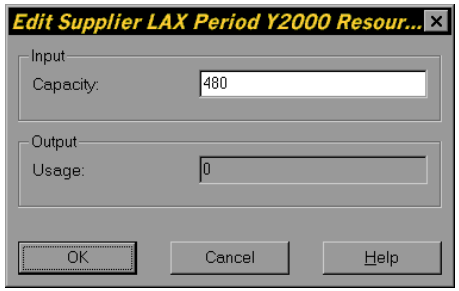
Supplier-Period-Resource Edit Window



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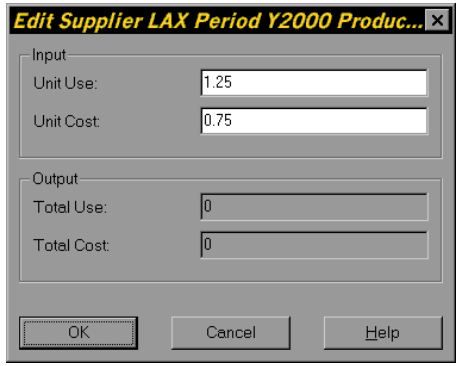
Supplier-Period-Product-Resource Edit Window



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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*

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Transformation Facilities Characteristics

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

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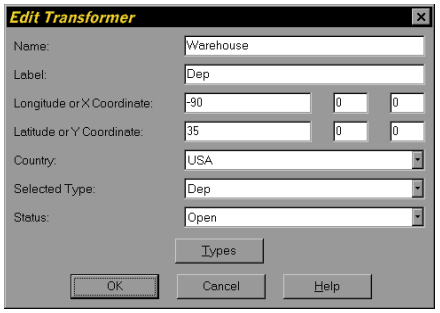
Transformation Facility Edit Window



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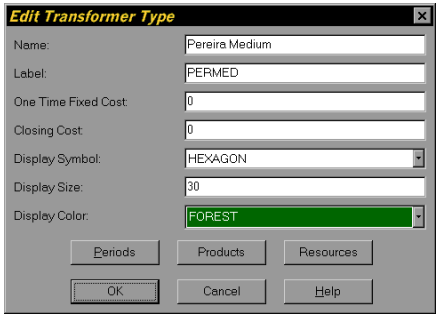
Transformation Facility Type Edit Window



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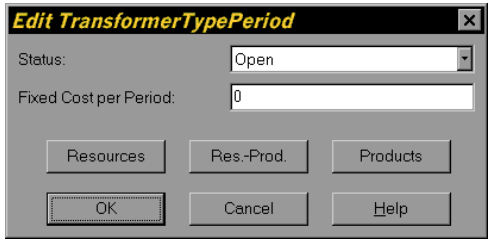
Transformer-Type-Period Edit Window



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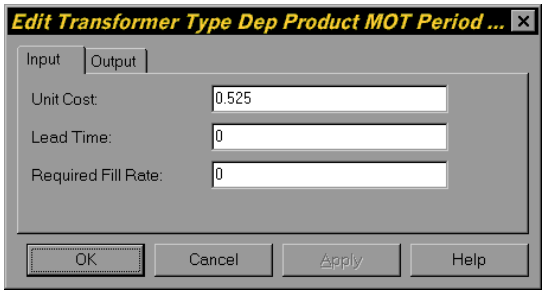
Transformer-Type-Period-Product Edit Window (Input)



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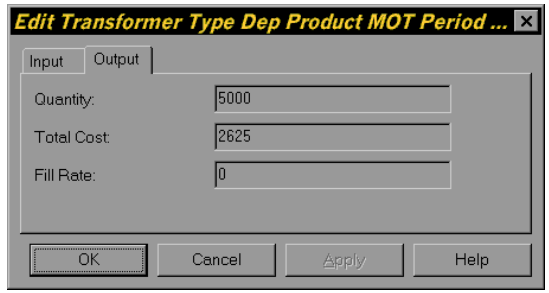
Transformer-Type-Period-Product Edit Window (Output)



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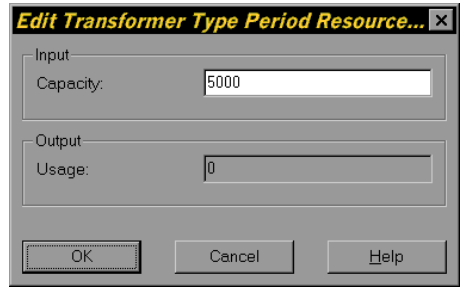
Transformer-Type-Period-Resource Edit Window



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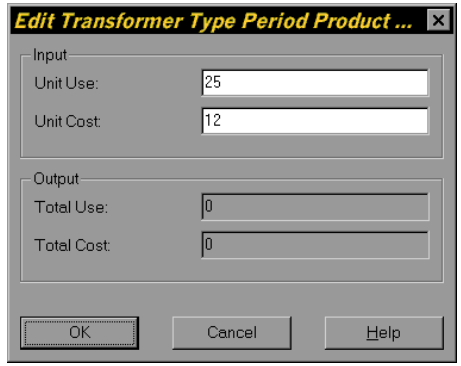
Transformer-Type-Period-Product-Resource Edit Window



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Importance of Transportation

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

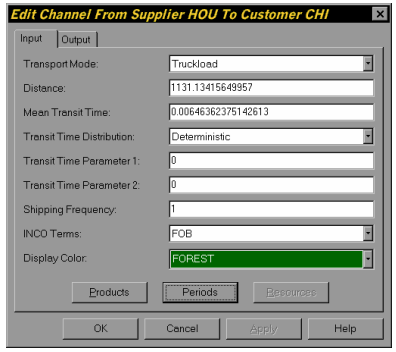
Transportation Performance Measures

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

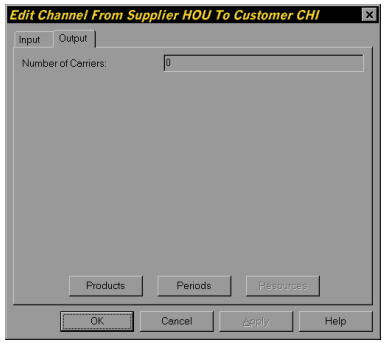
Transportation Modes

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

Transportation Channel Edit Window (Input)



Transportation Channel Edit Window (Output)



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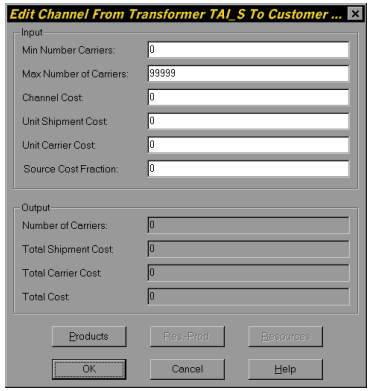
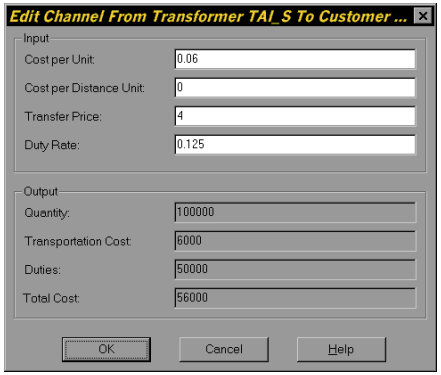
Channel-Period Edit Window



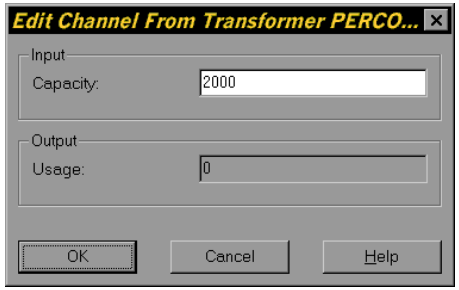
7-Mar-03 Logistics Systems Design Marc Goetschalckx

Channel-Period-Product Edit Window



7-Mar-03 Logistics Systems Design Marc Goetschalckx

Channel-Period-Resource Edit Window



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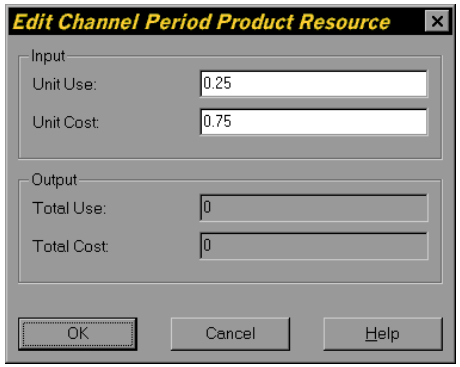
Channel-Period-Product-Resource Edit Window



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

Ballou & Masters, "Commercial Software for Locating Warehouses and Other Facilities," Journal of Business Logistics, Vol. 35, No. 2, 1993.

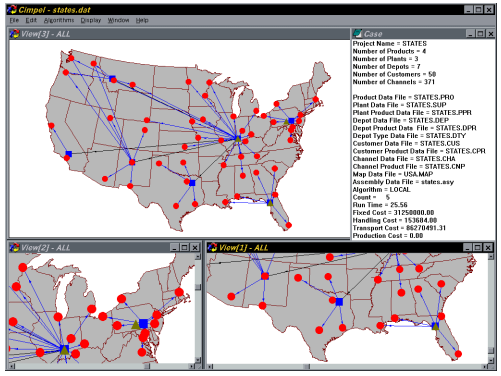
Design Decision Support System Components

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

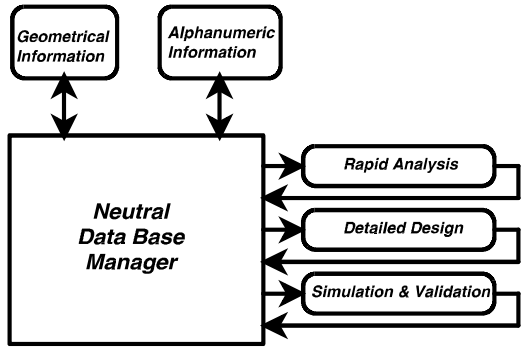
CIMPEL

- 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

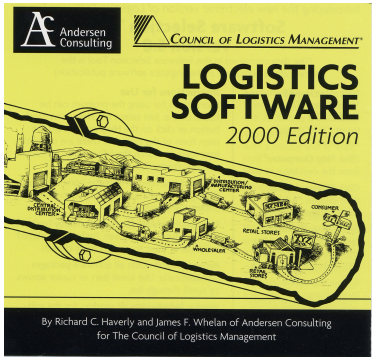
SCM Vendors

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

Logistics Software Reference

- Andersen Consulting, "Logistics Software," jointly with Council of Logistics Management, Oak Brook, IL, 1992 and yearly updates.

Logistics Planning Software Catalogue



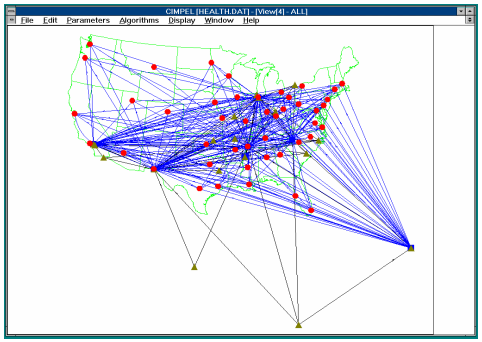
Supply Chain Design Challenges

- *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*

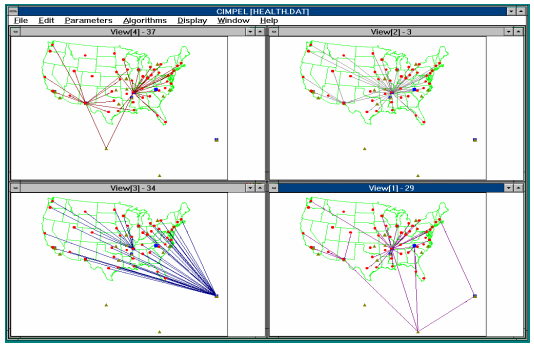
Supply Chain Design Challenges Continued

- *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

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