Logistics Systems Design: Introduction

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

Introduction Overview

- Logistics Definition
- Logistics Planning
- Engineering Design Process
- Modeling
- Algorithms

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Logistics Is

- Material, Information, and Economics
- Movement, Storage, Transformation, and Control
- On a Worldwide Scale
- From Raw Materials, to Consumer, to Recycling

CLM Definition

Logistics is the combination of transport, storage, and control of material all the way from the supplier, through the various facilities, to the customer, and the collection of all recyclable materials at each step.

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Logistics Characteristics

- Important and Pervasive
- Integrated
- Global
- Computers & Communications
- Radical Changes

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Logistics Size

- 680 Billion Annually (1996)
- 11 % GNP
- 20 % Product Sales Price
- 60 % of Combined Health Care + Social Security + Defense Costs
- World Trade Will Quadruple by 2010
- Number of Trucks Will Double by 2003

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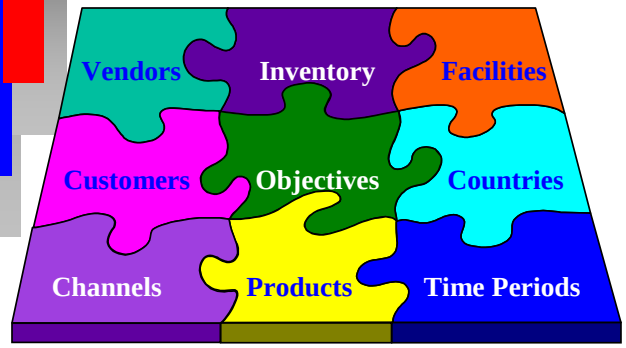
Logistics Functions are Integrated and Comprehensive



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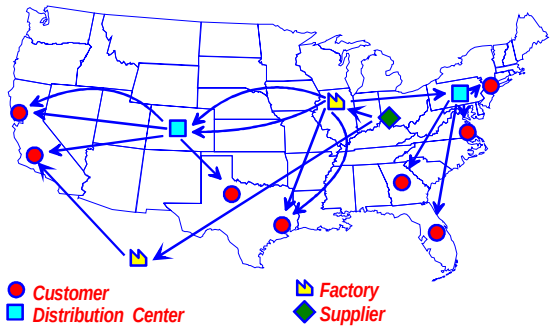
Supply Chain Networks



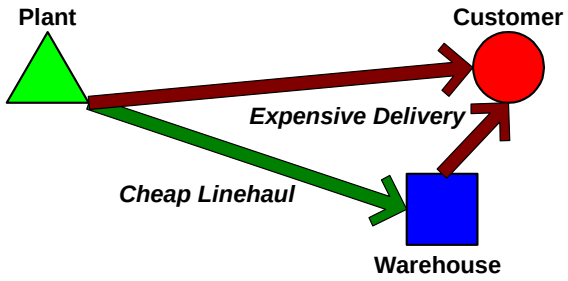
Business Value Types

- Form (Design and Manufacturing)
- Time (Logistics)
- Place (Logistics)
- Possession (Sales and Marketing)

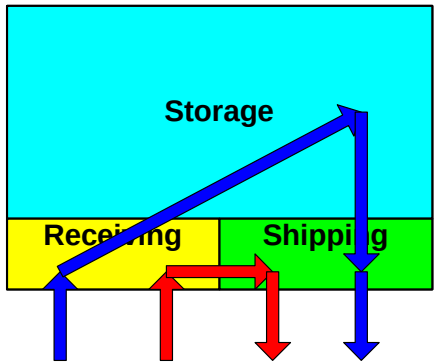
Logistics Connects Production with Sales

- Production
  - Economies of scale
  - Specialization
- Sales and Marketing
  - Customer service requirements
- Logistics
  - Utility of time and place
  - Essence of trade

Direct Shipping Cost Tradeoff



Cross Docking Material Handling Tradeoff



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Logistics Is Global

- *Mature Replacement Economies in the Industrialized Nations*
- *Fastest Growth in Developing Countries*
- *Global Corporations*
- *Intense Competition*

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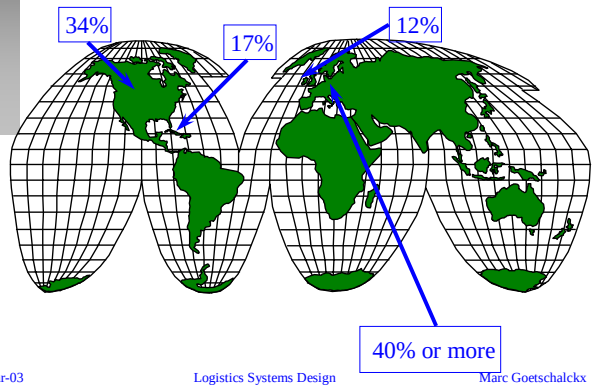
Different Corporate Tax Rates



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Communications & Computers

- *Dramatic Increase over Time*
  - *"Bubba" Period*
  - *Instantaneous Tracking and EDI*
  - *Electronic Commerce*
  - *Virtual Logistics Enterprise*

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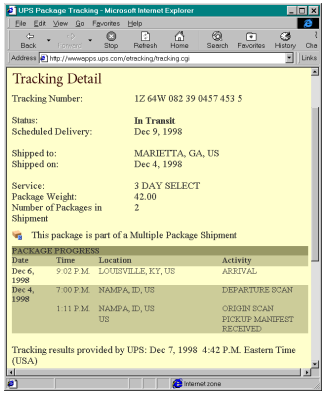
Web-Based Real-Time Tracking of Shipments



Logistics Experiences Dramatic Changes

- *New Logistics Strategies...*
  - *Outsourcing*
  - *Third Party Logistics (TPL)*
  - *Electronic Commerce*
  - *Vendor Managed Inventory (VMI)*

Logistics is Constantly Changing

- *Requires People with the Right Skills*
  - *Business Processes*
  - *Analytical Methods*
  - *Rapid Computer Implementation*
  - *Effective Communications with Users*
  - *Lifelong Continuing Education*

Introduction Overview

- *Logistics Definition*
- *Logistics Planning*
- *Engineering Design Process*
- *Modeling*
- *Algorithms*

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 ?

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Three Levels of Logistics Planning

- Operational
- Tactical
- Strategic

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Operational Logistics

- Examples:
  - What orders to load on a particular truck
  - Daily production scheduling
  - How much product to reorder
- Short Permanence of Decisions
- Extensive, Detailed, and Accurate Data Immediately Available
- Many but Small Penalties and Rewards

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Tactical Logistics

- Examples:
  - Monthly production schedule
  - Carrier Selection
  - Inventory Levels
- Medium Permanence of Decisions
- Data Available after some Processing
- Medium Penalties and Rewards

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Strategic Logistics

- *Examples:*
  - *Build a manufacturing plant*
  - *Select third party logistics*
  - *Define customer-product groups*
- *Long Range Permanence of Decisions*
- *Heterogeneous Data if Available*
- *Company Vision and Survival*

Matrix Organization of Planning Modules

Strategic	Stratetic Enterprise Planning			Strategic Demand Planning
Tactical	Master Production and Distribution Planning			Tactical Demand Planning
Operational	Material Requirem. Planning	Production Planning	Distribution Planning	Operational Demand Planning
Execution	Purchasing	Scheduling	Vehicle Dispatching	Demand Monitoring

Objectives for Mandated Customer Service

- *Cost Minimization*
  St. service constraints
- *Return on Investment Maximization*
  St. service constraints
- *Reliability*

Objectives for Dependent Customer Service

- *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
- Reduced to a Common Time Frame

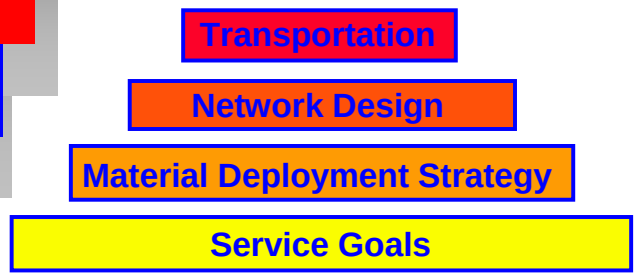
Cost Categories

- Controllable versus Invariant
  - Avoided if the mission were discontinued
  - Transportation versus pension liabilities
- Fixed versus 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

Traditional Design Stages for Logistics Planning



Modern Design Stages for Logistics Planning

Transportation
&
Network Design
&
Material Deployment Strategy

Service Goals

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),*
  - *Avensis (Baan) (Manufacturing, Transportation),*
  - *PeopleSoft (Human Resources)*
  - *...*

Supply Chain Management (SCM) Software

- *Logistics Systems Configuration and Planning*
- *"Optimizing"*
  - *Operations Research*
  - *Constraint Based Logic*
- *Interface with ERP*
- *Also called Advanced Planning Systems (APS)*

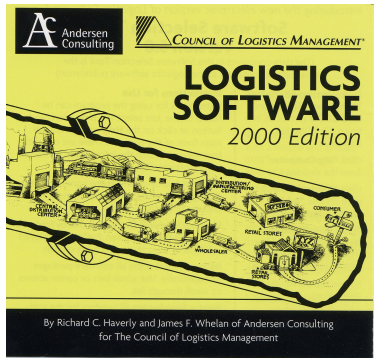
SCM Vendors

- Strong Consolidation
- Major Vendors
  - I2 - InterTrans
  - Manugistics
  - Chesapeake – SupplyChain
  - J.D. Edwards

Logistics Software Reference

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

Logistics Planning Software Catalogue



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Engineering Design Process

1. Formulate the Problem
2. Collect Data and Analyze the Problem
3. Generate Alternative Solutions
4. Evaluate Design Alternatives
5. Select the Preferred Design(s)
6. Specify the Solution
7. Evaluate the Design in Use

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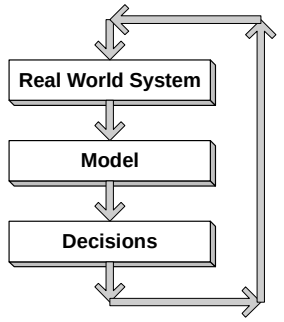
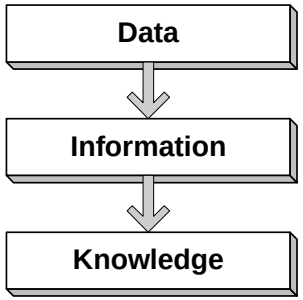
What is a Model

- Abstract Representation of a Real World System
  - Easier to manipulate
  - Provides better insight
- Everybody Uses Models to Make Decisions

Modeling Framework



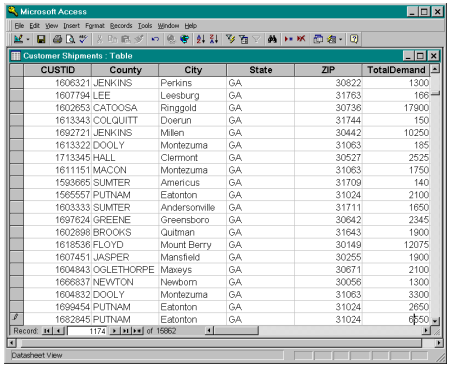
Modeling Data



Data Sources

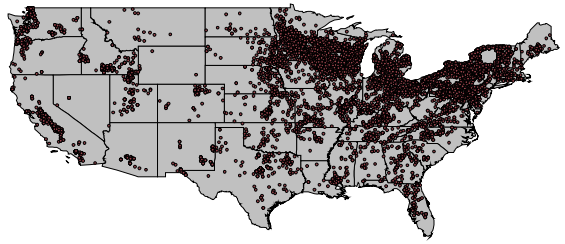
- *Business Operating Documents*
  - *Sales orders, customer data, freight bills*
- *Business Documents*
  - *Annual report, accounting (activity-based-costing)*
- *Logistics Research Data*
- *Published Reference Data*
  - *Trade magazines, census data, press*

Data Example: Customer Demand History Database

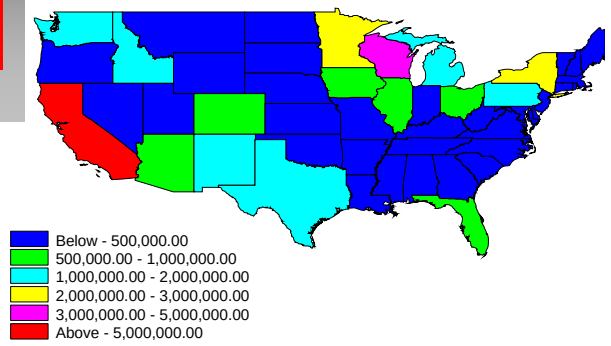


CUSTID	County	City	State	ZIP	TotalDemand
1606321	JENKINS	Perkins	GA	30822	1300
1607794	LEE	Leesburg	GA	31763	166
1602653	CATOOSA	Ringgold	GA	30736	17900
1613343	COLQUITT	Doerun	GA	31744	150
1692721	JENKINS	Millen	GA	30442	10250
1613322	DOOLY	Montezuma	GA	31063	185
1713345	HALL	Clermont	GA	30527	2525
1611151	MACON	Montezuma	GA	31063	1750
1593665	SUMTER	Americus	GA	31709	140
1565557	PUTNAM	Eatonton	GA	31024	2100
1603333	SUMTER	Andersonville	GA	31711	1650
1697624	GREENE	Greensboro	GA	30642	2345
1602898	BROOKS	Quitman	GA	31643	1900
1618536	FLOYD	Mount Berry	GA	30149	12075
1607451	JASPER	Mansfield	GA	30255	1900
1604843	OGLETHORPE	Maxeys	GA	30671	2100
1666837	NEWTON	Newborn	GA	30056	1300
1604832	DOOLY	Montezuma	GA	31063	3300
1699454	PUTNAM	Eatonton	GA	31024	2650
1682845	PUTNAM	Eatonton	GA	31024	6550

Information Example: Customer Locations



Information Example: Demand Summed by State



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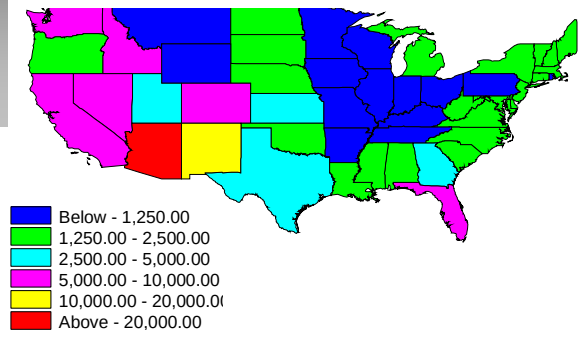
Knowledge Example: Average Customer Demand by State



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Model Validation

- *Scientific validation method requires repeatability*
  - *From possible for operational*
  - *To impossible for strategic*
- *Historical benchmark*
- *Component validation*
- *Sanity check*

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Model Types

- *Physical*
- *Analog*
- *Mathematical*
  - *Descriptive*
  - *Normative*

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Highway Map: a Printed Analog Model

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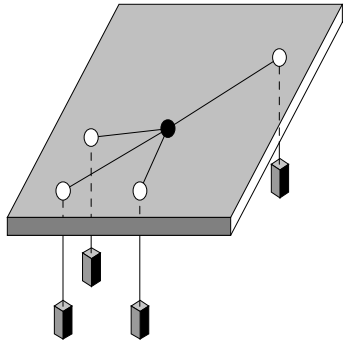
Varignon Frame: A Mechanical Analog Model



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Network Flow Formulation: A Mathematical Normative Model

$$Min \quad \sum_{i}^{N}\sum_{j}^{N} c_{ij} x_{ij}$$

$$s.t. \quad \sum_{h}^{N} x_{hi} - \sum_{j}^{N} x_{ij} = b_i \qquad \forall i$$

$$0 \le x_{ij} \le u_{ij} \qquad \forall ij$$

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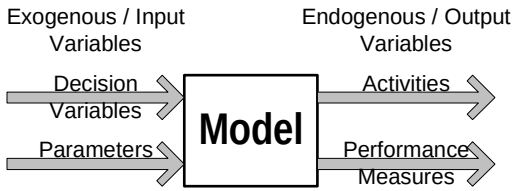
Modeling Terminology



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Modeling Classifications

- Deterministic versus stochastic (probabilistic)
- Deductive versus inferential

Successive Refinement of Models

1. Deterministic Descriptive
2. Stochastic Descriptive
   - Queuing Analysis
   - Simulation
3. Deterministic Normative
   - Mixed Integer Linear Programming
4. Stochastic Normative
   - Mixed Integer Non-Linear Programming

Modeling Advantages

1. Definition of Business Objectives, Practices, Structure, and Constraints
2. Definition and Establishment of Business Parameters and Costs
3. Systematic Evaluation of Alternative System Alternatives
4. Quick Response Sensitivity Analysis

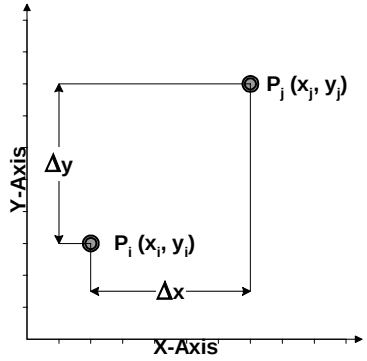
Modeling Difficulties

1. Requires Extensive, Accurate, and Expensive Data
2. Requires Specialized Knowledge and Software (and Computer Hardware)
3. Long Computation Times for some Design Algorithms

Modeling Summary

- *Realism versus Solvability*
- *Successive Refinement*
- *Decision Support versus Decision Making*

Modeling Example: Distance between Two Points



Distance Norms

- *Euclidean*

$$d_{ij}^{E} = L_2 = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}$$

- *rectilinear*

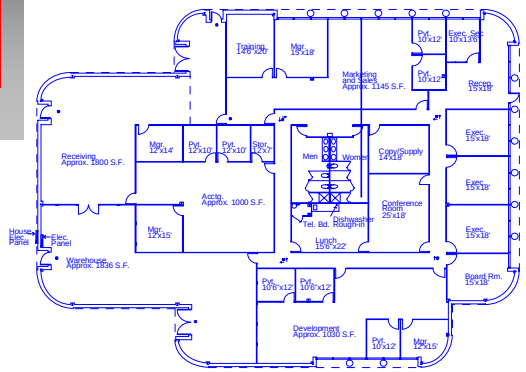
$$d_{ij}^{R} = L_1 = |x_i - x_j| + |y_i - y_j|$$

- *Chebyshev*

$$d_{ij}^{C} = L_\infty = \max\{|x_i - x_j|, |y_i - y_j|\}$$

- *Great Circle*

Rectilinear Distance Norm in an Office Facility



Rectilinear Travel Time: Order Picking Truck Illustration

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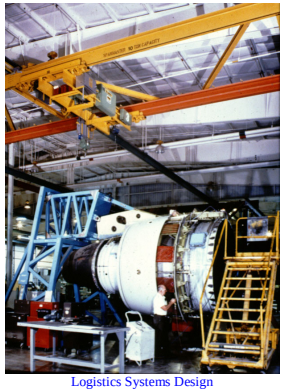
Chebyshev Travel Time: Bridge Crane Example



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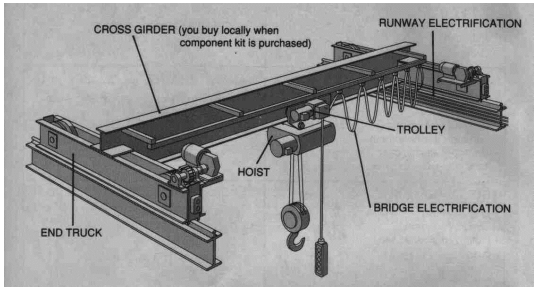
Chebyshev Travel Time: Bridge Crane Illustration



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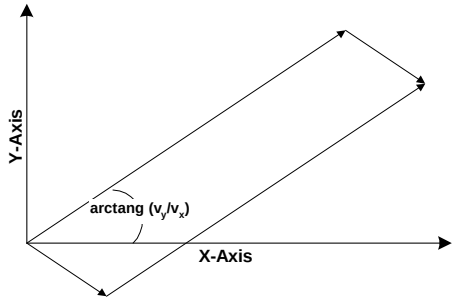
Chebyshev Travel Time: Travel Path Illustration



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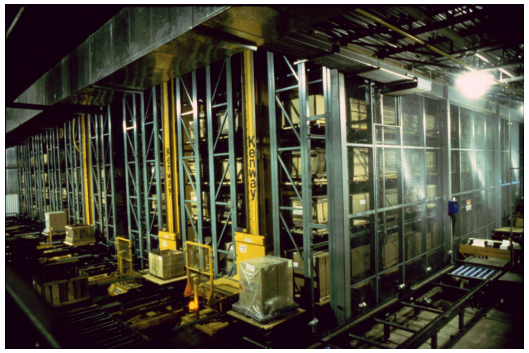
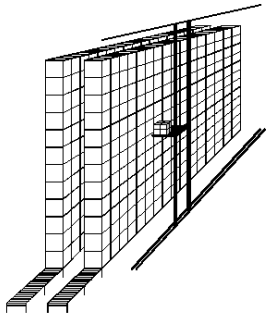
Chebyshev Travel Time: Unit Load AS/RS Example



Chebyshev Travel Time: Unit Load AS/RS Illustration



Norm Generalization

$$d_{ij}^{n} = L_n = \sqrt[n]{\left|x_i - x_j\right|^n + \left|y_i - y_j\right|^n}$$

- Rectilinear $n = 1$
- Euclidean $n = 2$
- Chebyshev $n = \infty$

Great Circle Distance Norm

- Modeling Intercontinental Distances (angles in radians)
- Longitude and Latitude Obtained from Geocoding

$$d_{ij}^{GC} = R \cdot \arccos\begin{pmatrix} \cos(lat_i)\cos t\left(lat_j\right)\cos\left(lon_i - lon_j\right) \\ +\sin(lat_i)\sin\left(lat_j\right) \end{pmatrix}$$

Actual Distance Versus Distance Norms

- *Dependent on Local Highway or Railway Network Density*
- *"Standard Factors" for Developed Networks*
  - *(Ballou, 1998, pp. 557)*

	Euclidean	Great Circle
Road	1.21	1.17
Rail	1.24	1.2

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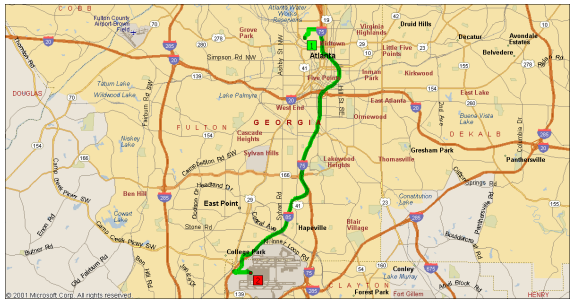
Route Planning to Atlanta Airport



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Point-To-Point Driving Instructions and Distances

Time	Mile	Instruction	For
Summary: 13.9 miles (23 minutes)			
5:00 PM	0	Depart 765 Ferst Dr NW, Atlanta, GA 30318 on Ferst Dr NW (North)	0.3 mi
5:01 PM	0.3	Turn LEFT (North) onto Dalney St NW	0.2 mi
5:02 PM	0.5	Turn RIGHT (East) onto 10th St NW	0.5 mi
5:03 PM	0.9	Turn RIGHT (South) onto Ramp	0.1 mi
5:03 PM	1.1	Merge onto I-75 [I-85] (South)	6.8 mi
5:12 PM	7.8	Continue (South) on I-85	3.6 mi
5:16 PM	11.5	At I-85 Exit 72, turn off onto Ramp	0.4 mi
5:17 PM	11.9	Continue (West) on Airport Blvd [S Terminal Pkwy]	1.0 mi
5:20 PM	12.9	Continue (South-West) on Airport Circle	0.2 mi
5:21 PM	13.1	Bear RIGHT (East) onto N Terminal Pkwy	0.6 mi
5:22 PM	13.7	Turn RIGHT (East) onto Local road(s)	0.2 mi
5:23 PM	13.9	Arrive Hartsfield-Atlanta International Airport	

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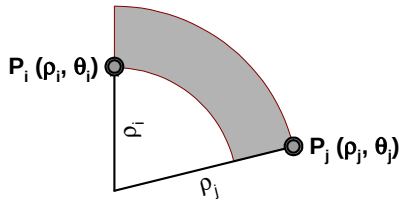
Ring-Radial Norm

- *Old Medieval City Centers*



$$d_{ij}^{RR} = \min\{\rho_i, \rho_j\} \min\{|\theta_i - \theta_j|, 2\pi - |\theta_i - \theta_j|\} + |\rho_i - \rho_j|$$

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Algorithm Definition

- Algorithm = Set of Rules to Determine System Activities and Configuration

Algorithm Characteristics

- Efficient versus Effective
- Optimal versus Heuristic
- Primal versus Dual
- Construction versus Improvement
- Alternative Generating versus Alternative Selecting

Running Time Order of an Algorithm

- n = Measure of Problem Size
- T = Run Time of the Algorithm
- Order Notation

$$if \begin{cases} T \le a_m n^m + a_{m-1} n^{m-1} + \ldots + a_1 n + a_0 \\ a_m > 0 \end{cases}$$

$$then \; O(n^m)$$

Running Time of an Algorithm: Growth Illustration

	Problem Size			
	10	20	40	80
Run Time				
n	0.001 seconds	0.002 seconds	0.004 seconds	0.008 seconds
n^3	0.001 seconds	0.008 seconds	0.064 seconds	0.512 seconds
2^n	0.001 seconds	1.024 second	12.43 days	37.43 million millenia

Discussion of Running Time Order of Algorithm

- *For Sufficiently Large n*
  - *Order m is better than order m+1*
  - *Leading a_m coefficient usually ignored*
- *For Smaller n*
  - *Better depends on all a_k coefficients*
  - *Better depends on implementation*

Worst Case Performance of an Heuristic

- *Worst Possible Quality Ratio of the Heuristic for any Instance*

$$\min z \Rightarrow \frac{z_{heuristic}}{z_{optimal}} \leq K$$

- *Available Only for Very Simple Heuristics*
- *Usually Much Larger than Average Quality Ratio*
- *A Priori Bound*

Asymptotic Worst Case Performance

- *Worst Case Performance for Very Large Problem Sizes*
- *No Worse and Usually Better Than Worst Case Ratio*

Optimality Gap

- Gap Between Best Feasible Solution and Best Bound for a Specific Instance
- Upper Bound on Deviation of Optimality of Feasible Solution
- Bound Quality
- Composite Algorithms

Primal and Dual Algorithms

- Primal
  - Maintains feasibility, strives for optimality
  - Feasible at premature termination
    - Rough draft of all sections of report then refine all sections
- Dual
  - Maintains optimality, strives for feasibility
  - Computes bounds on optimal solution
    - Refine introduction section of report until it is perfect before starting next section

Alternative Generating Algorithms

- Fast Automatic Generation
- May be Infeasible
- Exceptions are Difficult to Handle
- Approximate Costs
- Problems that have Simple Structure

Alternative Selecting Algorithms

- External Generation Might be Time Consuming
- Always Feasible
- Extensions are Easy to Handle
- Accurate Costs
- Problems that have Complex Solution Structure

Solution Algorithms Types

- Manual
- Spreadsheet
- Simulation
- Optimization & Heuristics
- Expert Systems

Manual Algorithms

- "Back-of-Envelope" and "Executive Privilege"
- No Formalized Objective, Model, or Solution Algorithm
- As Good as the Decision Maker

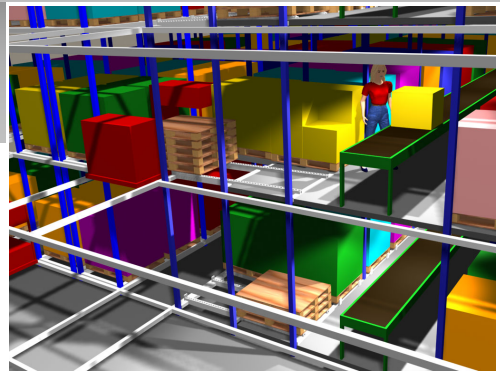
Spreadsheets

- Alternatives (Columns) and Costs (Rows)
- Alternatives are Pre-generated
- Costs are Pre-computed
- As Good as the Preprocessing

Network Simulation

- Simulation of Stochastic Network
- One Alternative at the Time
- Very High Fidelity
- Simulation Model Needs to be Created
- Limited Number of Alternatives
- As Good as the Alternatives

Simulation and Animation of a Material Handling System



Optimization and Heuristics

- Alternative Generating or Alternative Selecting
- Exact or Approximate Solutions
- Primal or Dual Algorithms
- As good as the Heuristic
- Long Computation Times

Expert Systems

- Available for operational and scheduling decisions
- Non-existent for tactical and strategic problems

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