Freight Transportation I

1.224 Carrier Systems

Chris Caplice

Agenda

- Transportation Systems Basics
- Commercial Transport Market Overview
- Direct Transportation
- Consolidated Transportation

Transportation Operations

Consolidated operations (CO)

- Bus/rail transit
- LTL
- Rail
- Airlines
- Ocean carriers/liner service
- Package delivery

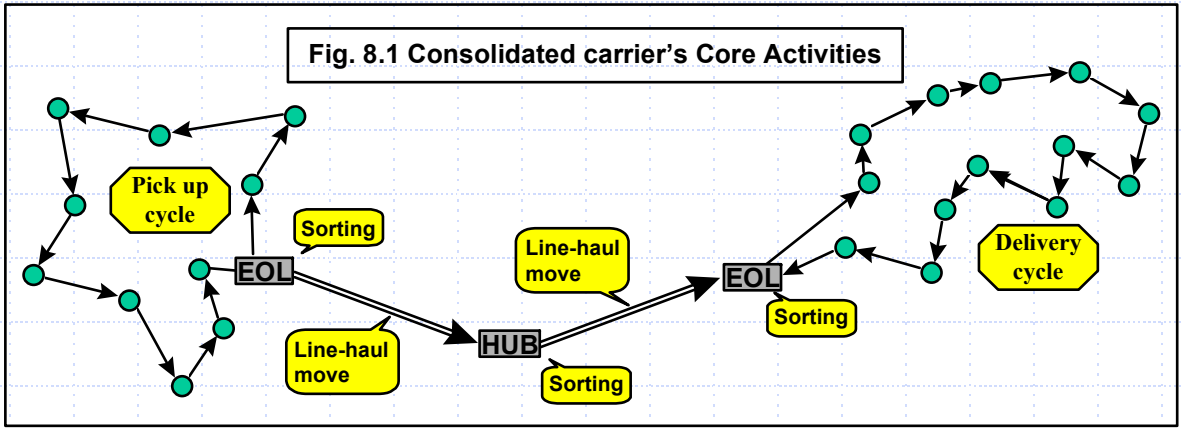
Direct operations (DO)

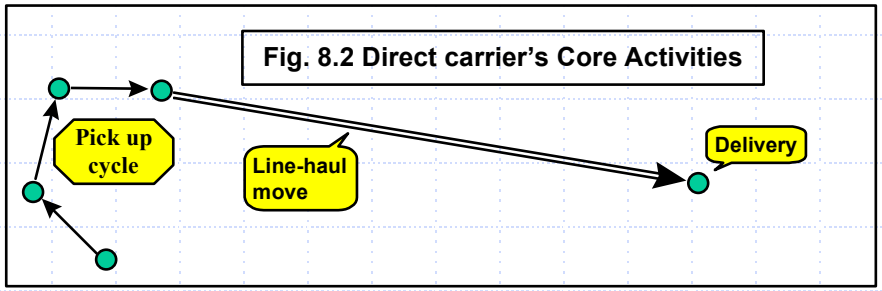
- Taxi
- TL
- Unit trains
- Charter/private planes
- Tramp services
- Courier

DO conveyances on CO carriers (sub-consolidation)

- Rail cars
- Ocean containers
- Air “igloos”

Core Activities



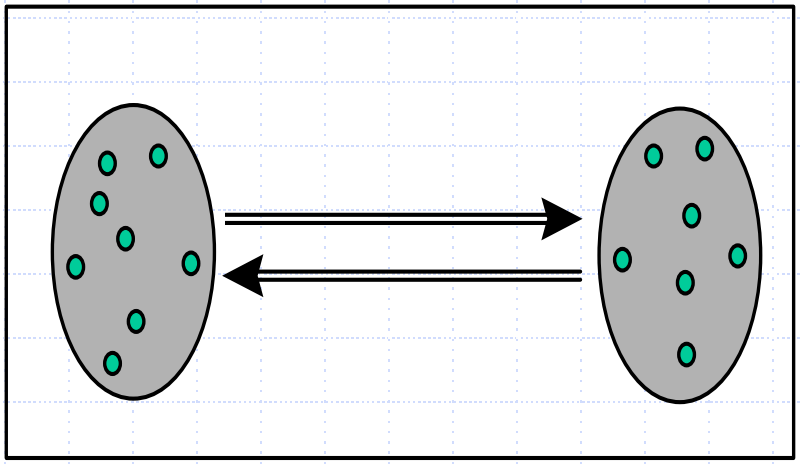


The Transportation Product

- Normal products - economies of scale
- What is the transportation product?
  - What is shipped?
  - When is it shipped?
  - Where is it shipped?
  - How is it shipped (requirements)?

Economies of Transportation

- Scale
- Balance (scope)
- Density



Economies of Scale

- Affect on costs when the volume on all lanes increase in the same proportion
- Effect on carrier costs from more freight is not clear. It depends on directionality (mainly DO carriers)
- CO carriers have more fixed costs - more EOS
- Terminal bypass operations for CO carriers

Economies of Balance

- Reverse flow mitigates the cost of repositioning. Strong for DO but also significant for CO carriers
- Economies of scope; subadditivity - the costs of serving a set of lanes by a single carrier is lower than the costs of serving it by a group of carriers
- cost complementarity - the effect that an additional unit carried on one lane has on other lanes

Economies of Density

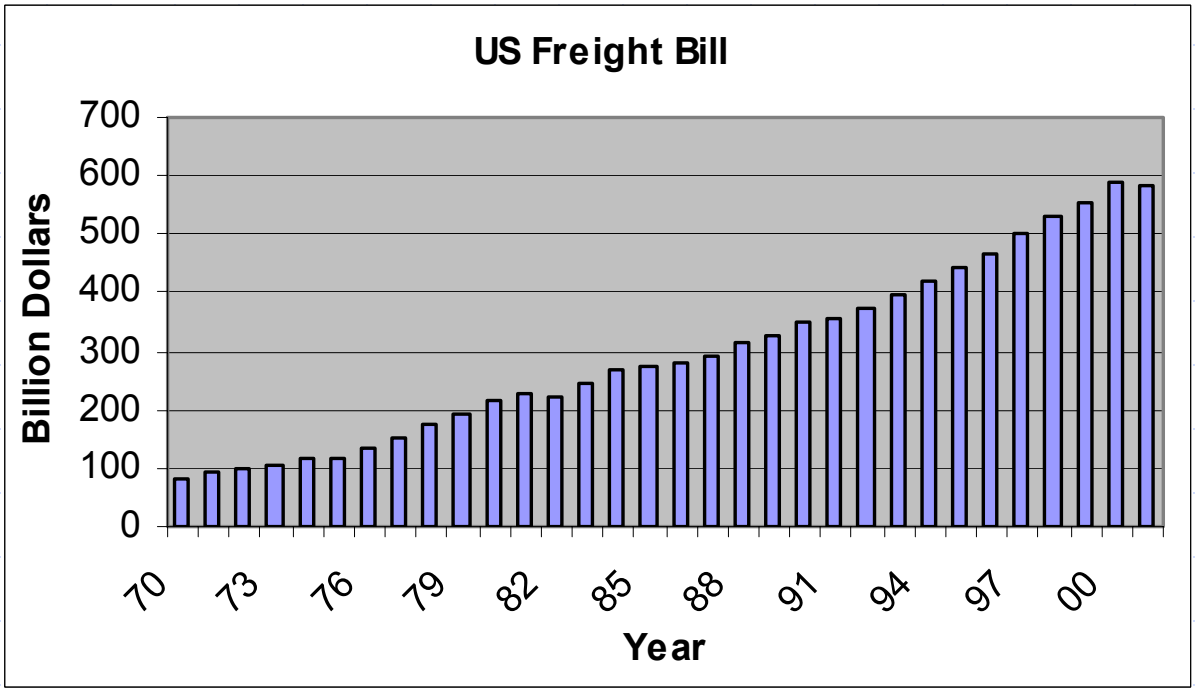
- Location density - number of customers per unit area
- Shipment density - average number of shipments at a customer location
- Both affect CO carriers in their PUD operations

Procurement Strategies

- DO carriers - strong economies of balance
- CO carriers - strong economies of density
- So:
  - Offer all CO freight originating in a location or in an area to a single carrier
  - Give DO carriers “lane sets” rather than individual lanes

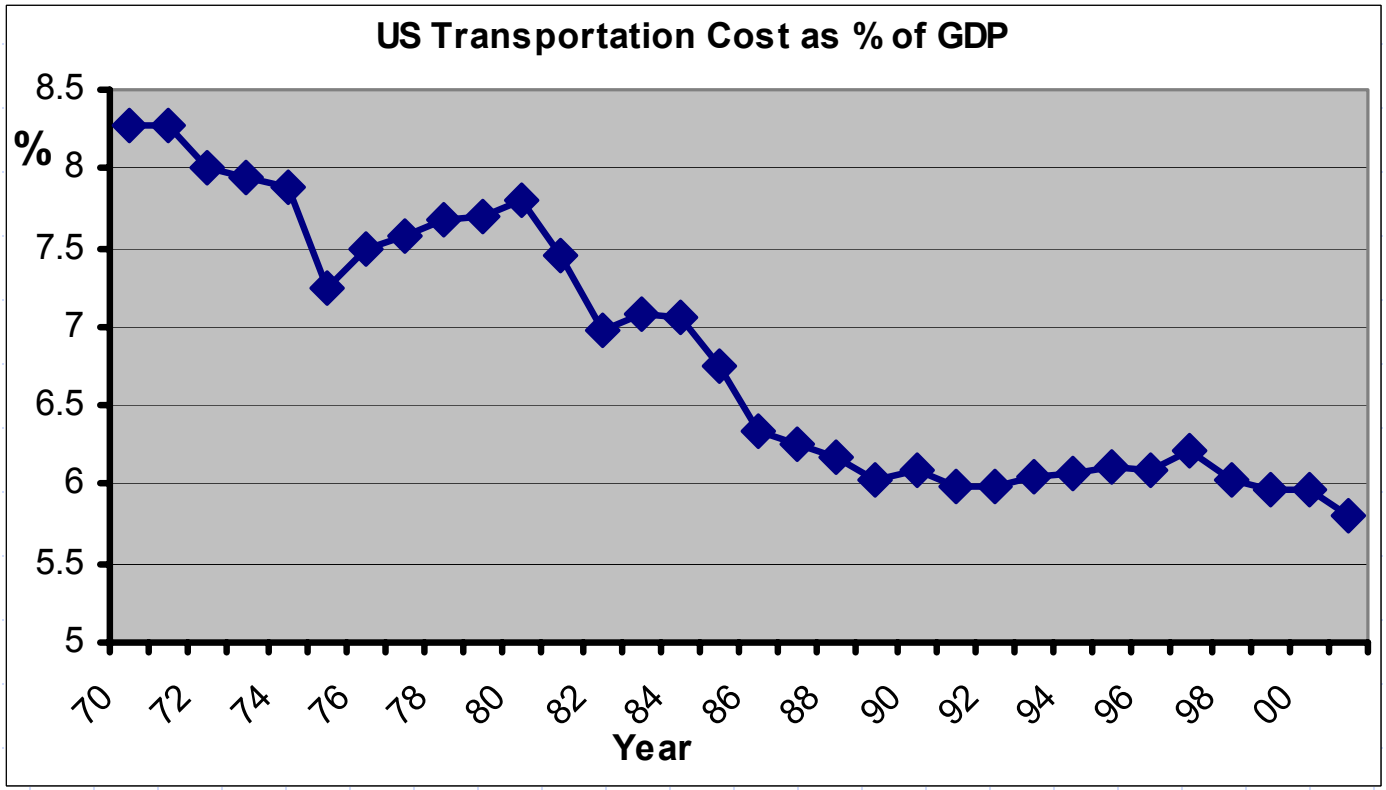
US Transportation Market

- US freight bill is increasing ~ $600-$700 Billion
- Average transportation expenditure is 4.1% of sales

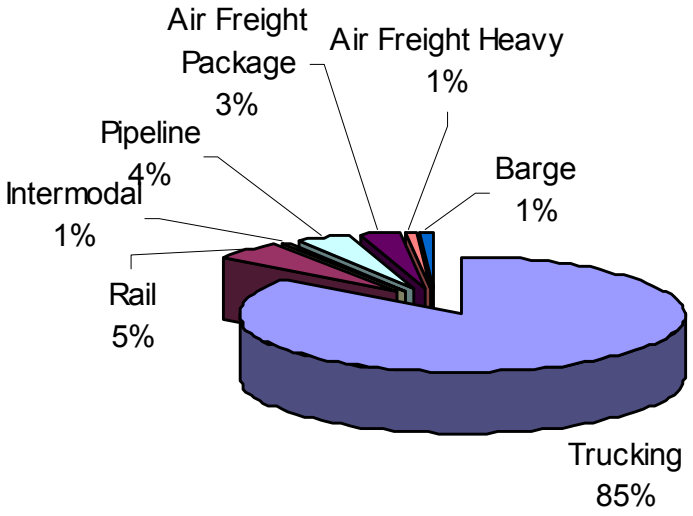


US Transportation Market

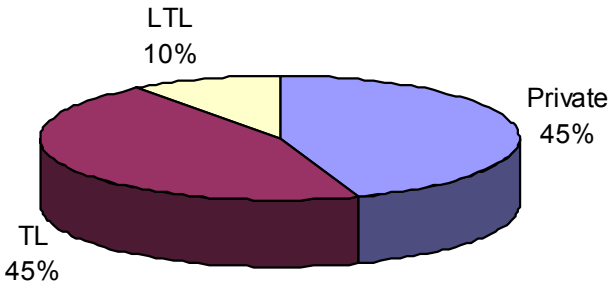
- While increasing absolutely, US freight bill has been decreasing markedly as % of GDP



Modal Shares 2001

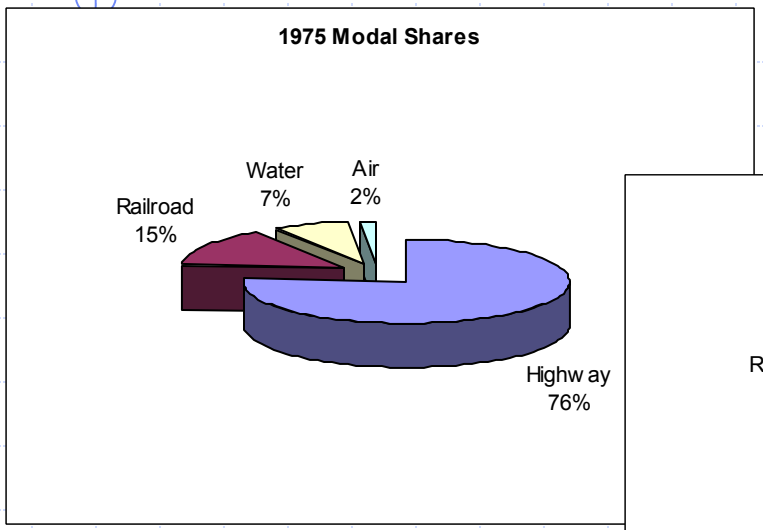


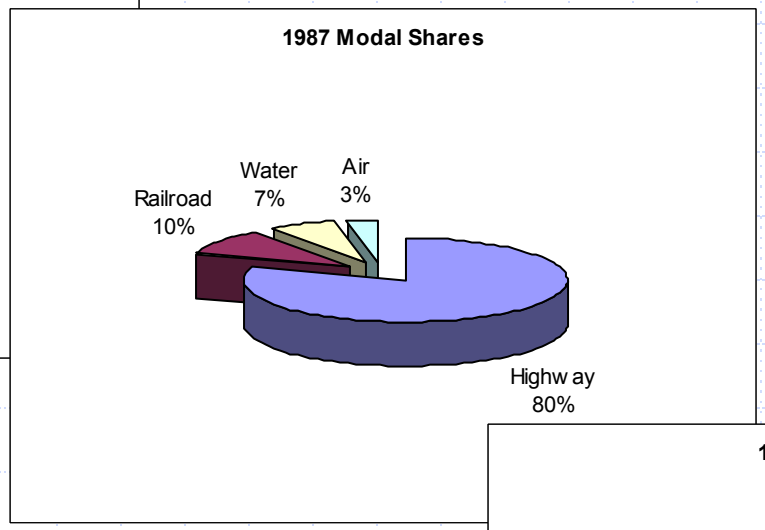
Mode	Ann Rev ($B)	Pct
Trucking	$ 610.2	86%
Rail	$ 35.4	5%
Intermodal	$ 6.7	1%
Pipeline	$ 27.2	4%
Air Freight Package	$ 20.0	3%
Air Freight Heavy	$ 6.0	1%
Barge	$ 8.1	1%
	$ 713.6	100%

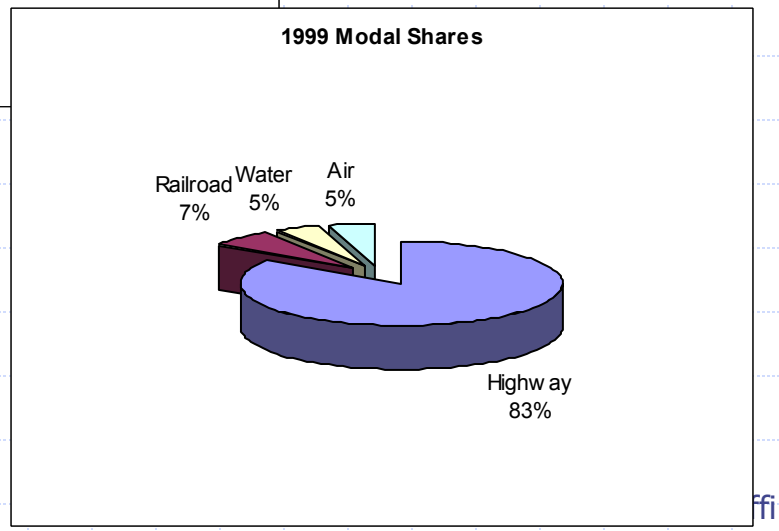


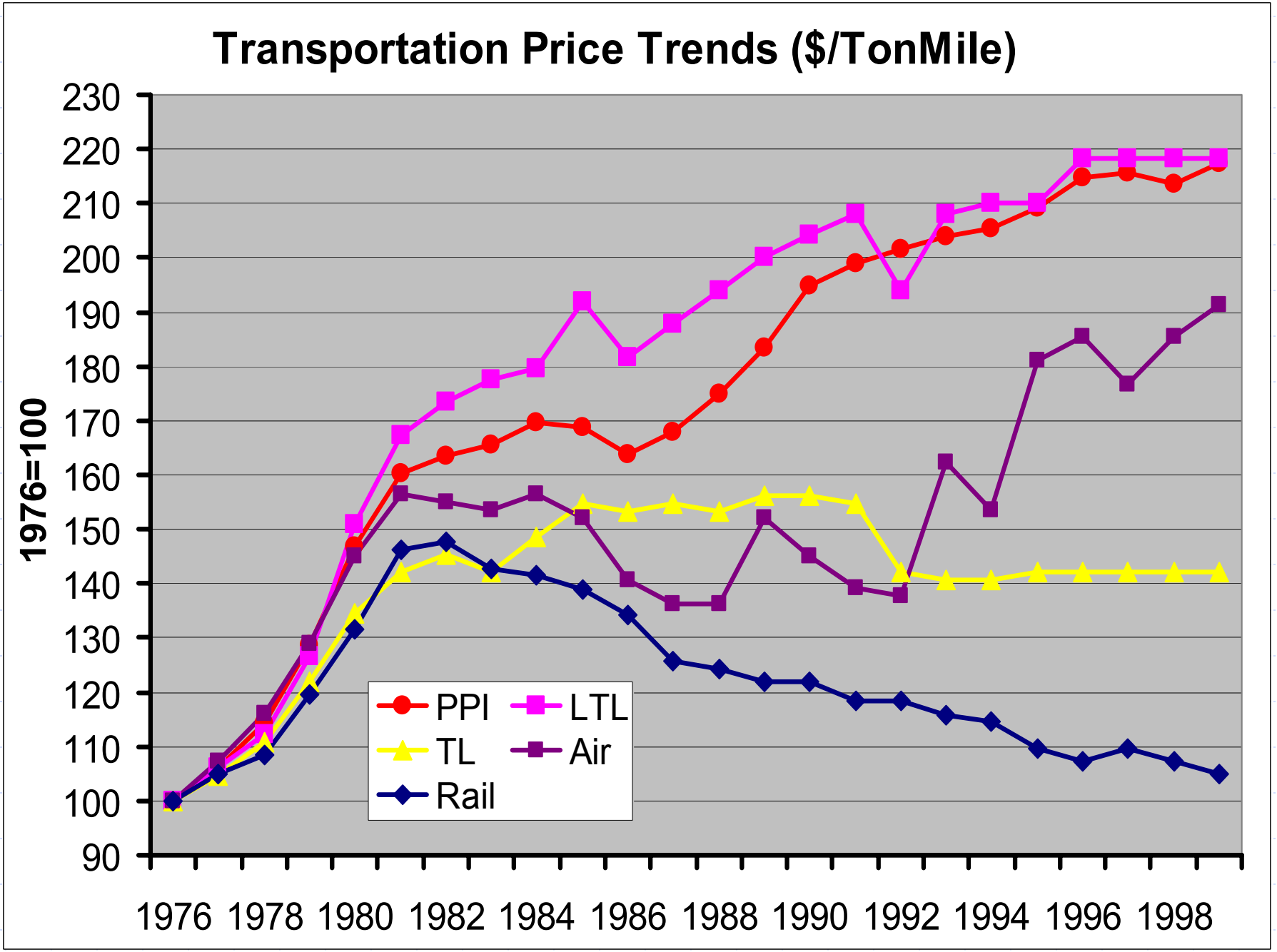
Trucking	Ann Rev ($B)
Private	$ 273.6
TL	$ 273.9
LTL	$ 62.7
	$ 610.2

Modal Shares 1975 - 1999

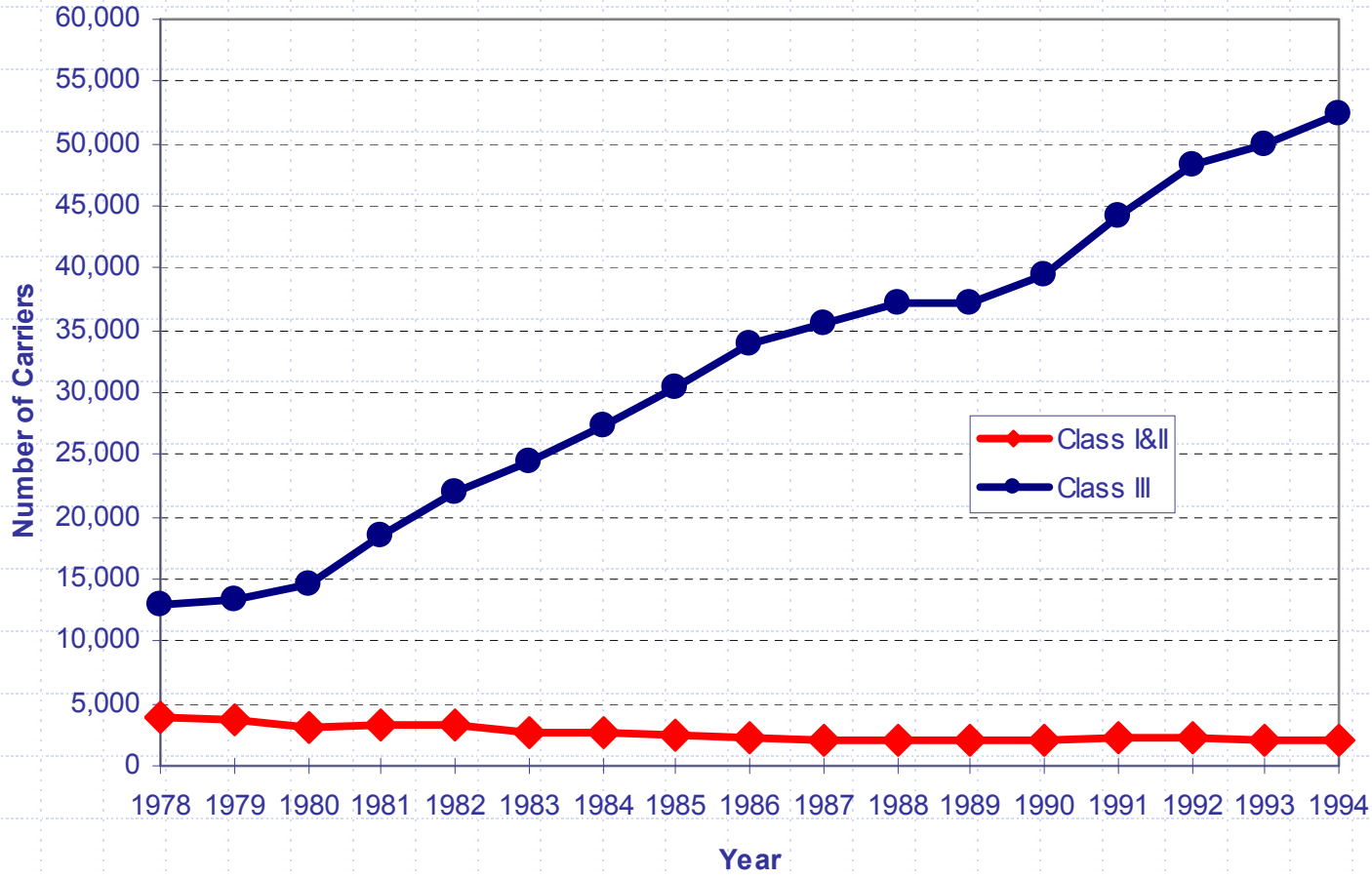








Effects of US Deregulation on TL Motor carriers



Direct Transportation

Outline

- TL Carriers
- Evaluating a single load/move
- Calculating the regional potentials
- Optimizing the dispatch decision
- Other TL decision support systems

A “Simple” Operation

- A customer calls in
- A vehicle is sent for pick up
- The vehicle is loaded and drives to the destination
- The vehicle is unloaded
- The customer pays

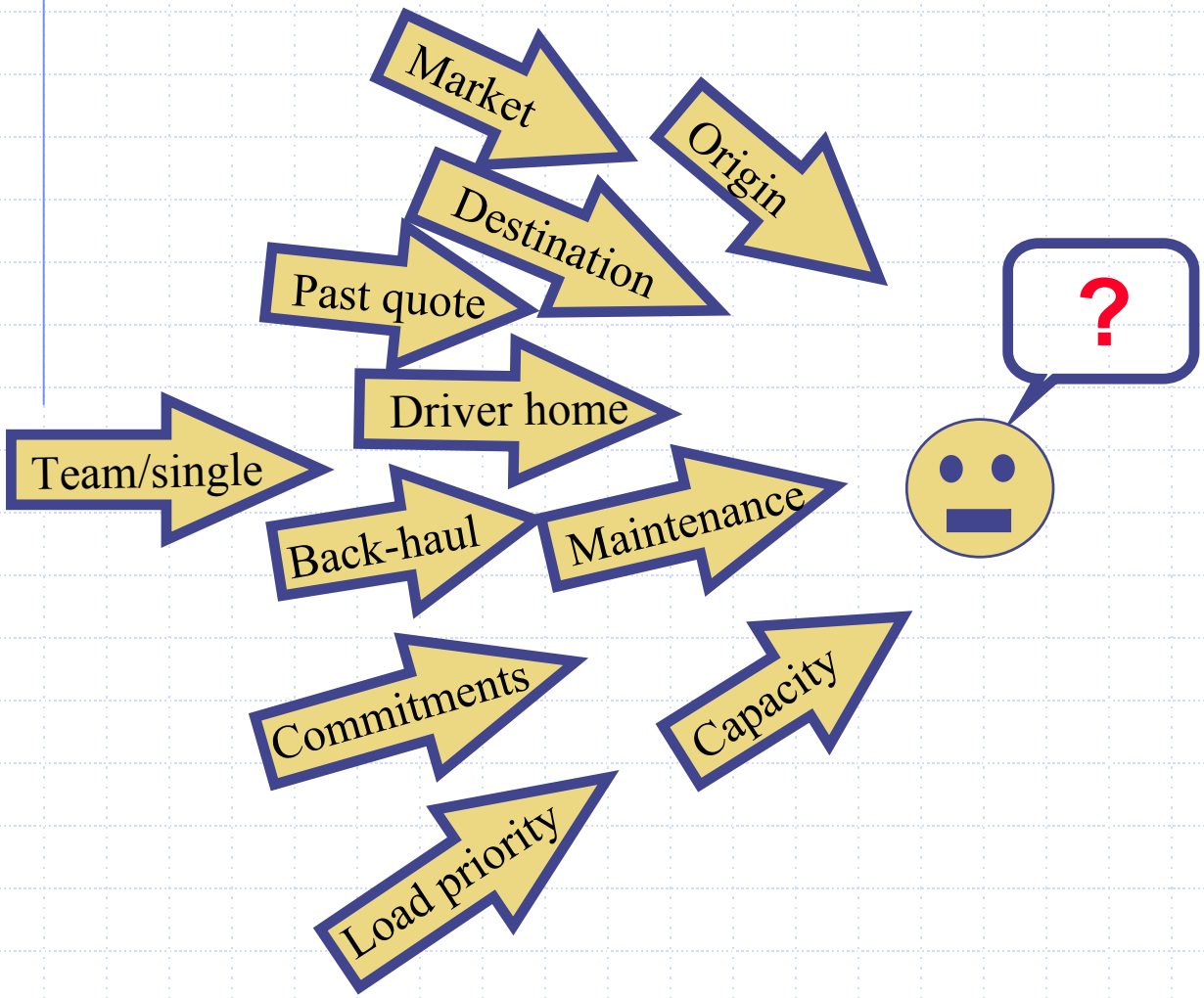
Characteristics of the TL Industry

- Little barriers to entry/exit
- Little differentiation
- Uncompromising service requirements
- Structural load imbalances
- Driver shortage
- Results:

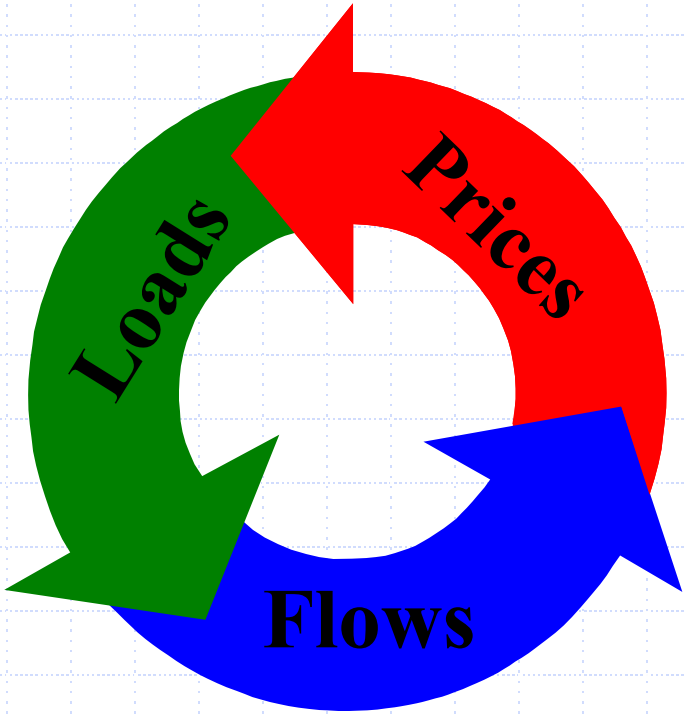
Challenges:

- Ensure that each truck keeps moving in revenue service
  - "Bring the truck to the load"
  - "Bring the load to the truck"
- Operations: minimize empty miles when going to the next load
- Marketing: generate enough loads so there will be follow on loads
- Markets: contract and spot.

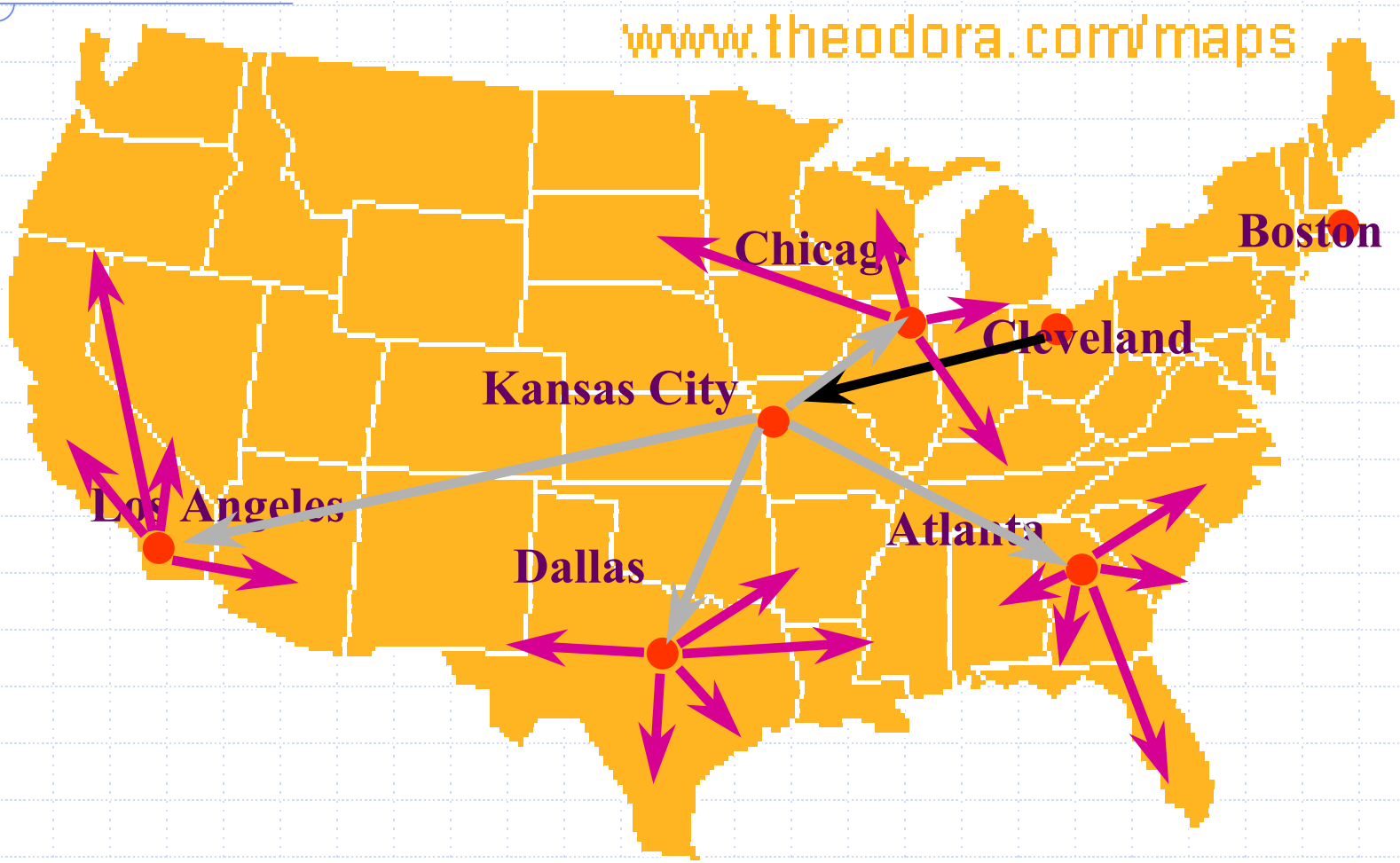
Operational Decision Making



Issues are Intertwined



Dispatching Considerations:
Evaluating a Single Load



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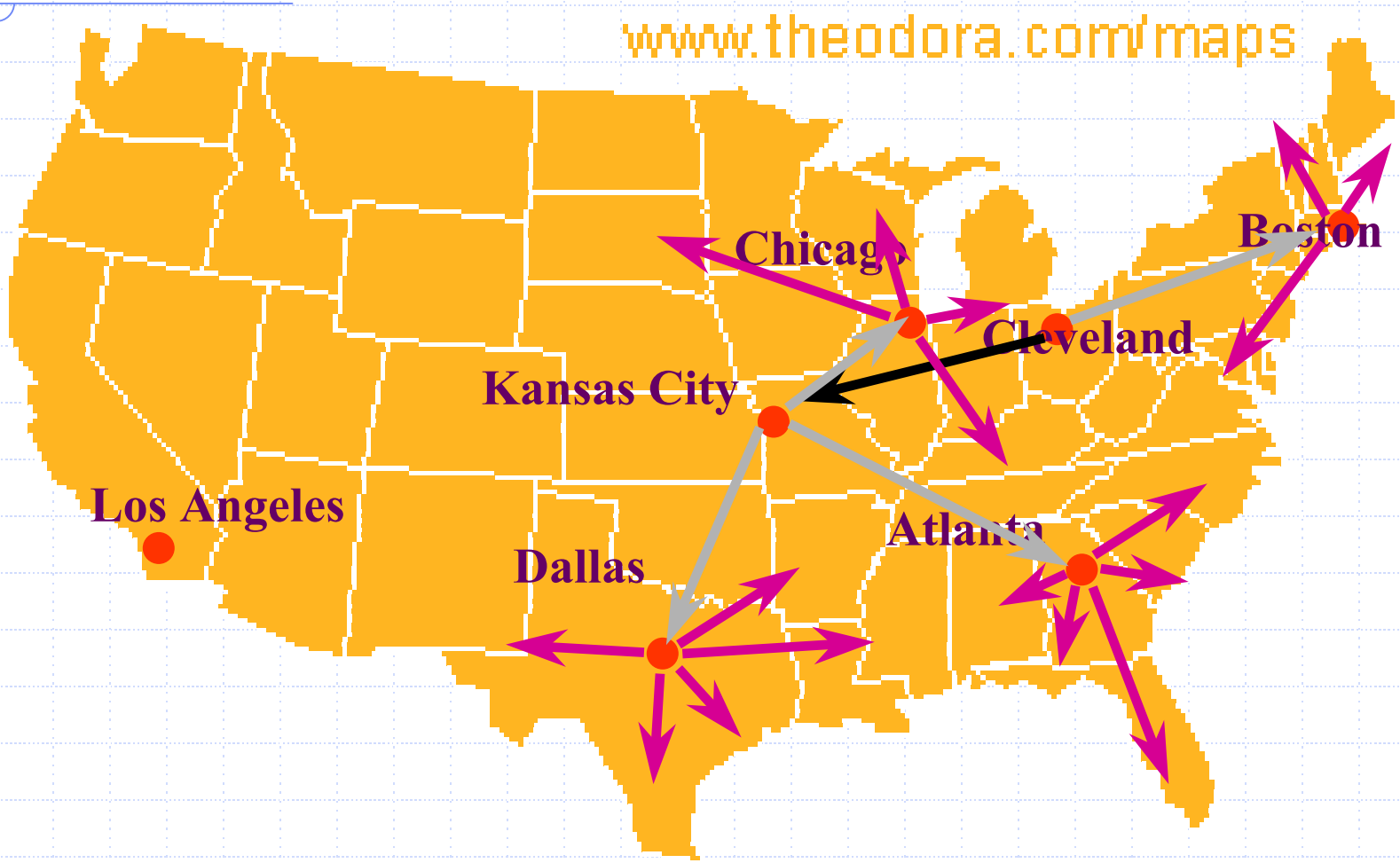

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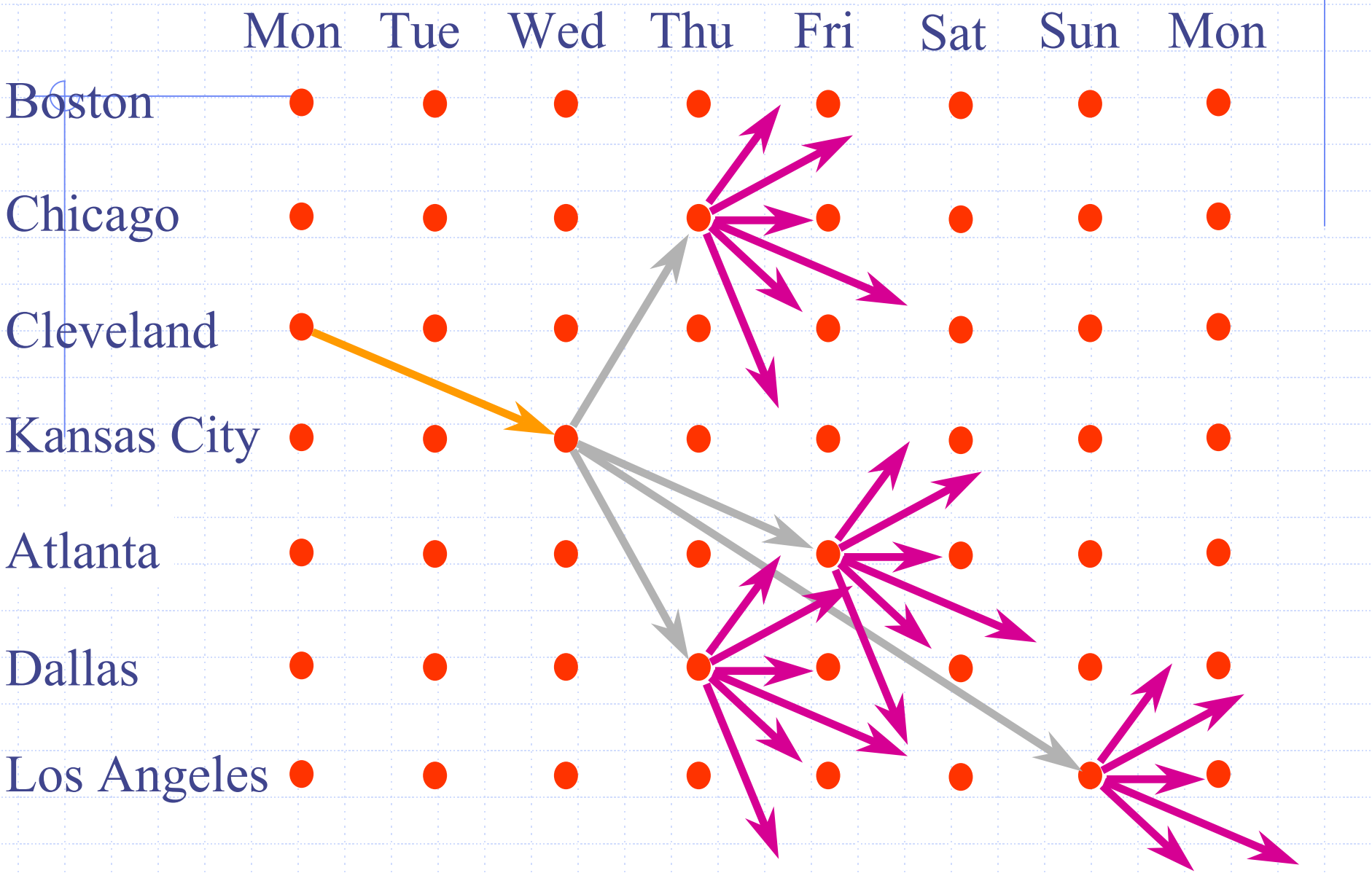
Time - Space Network Representation



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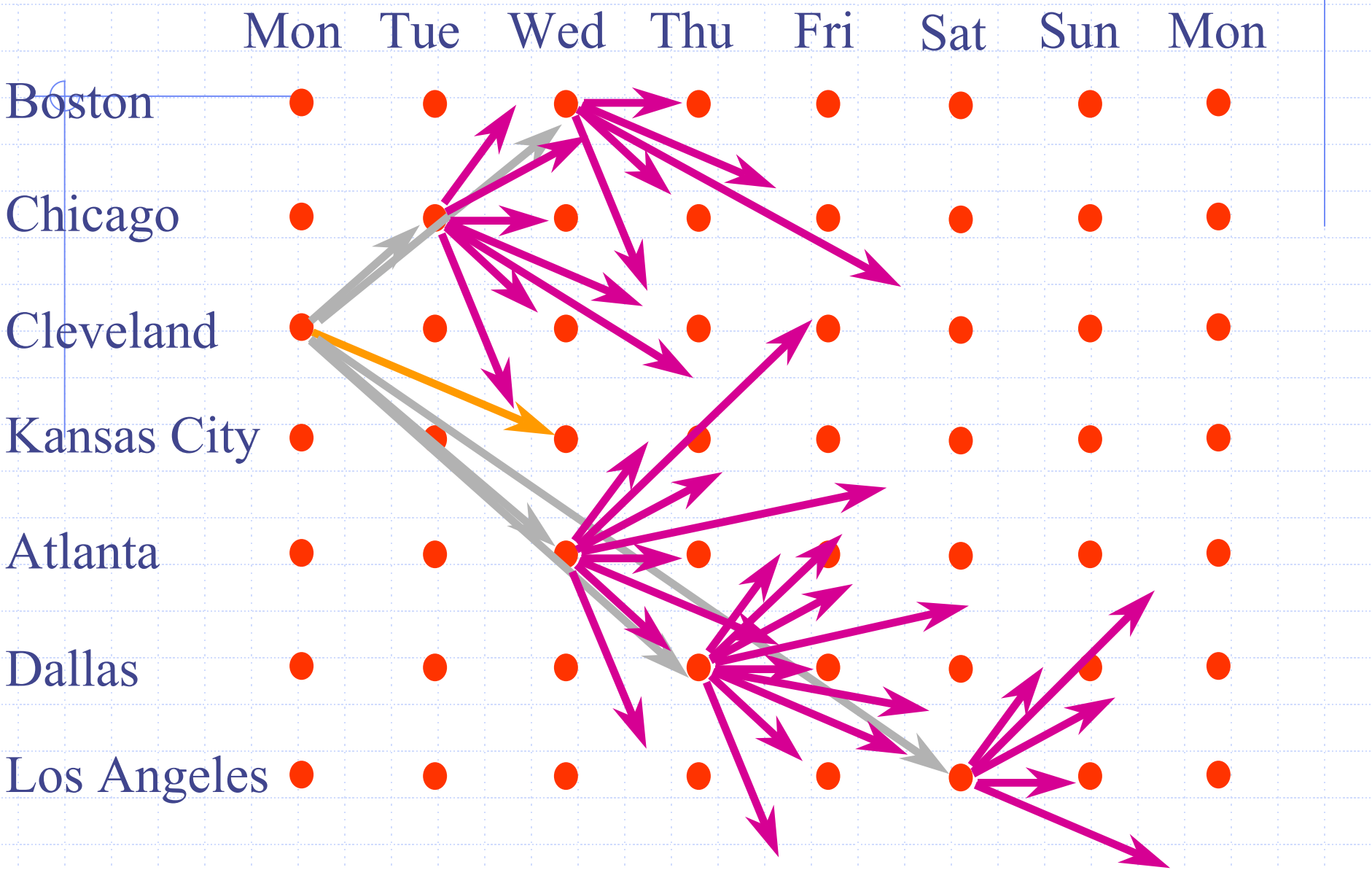

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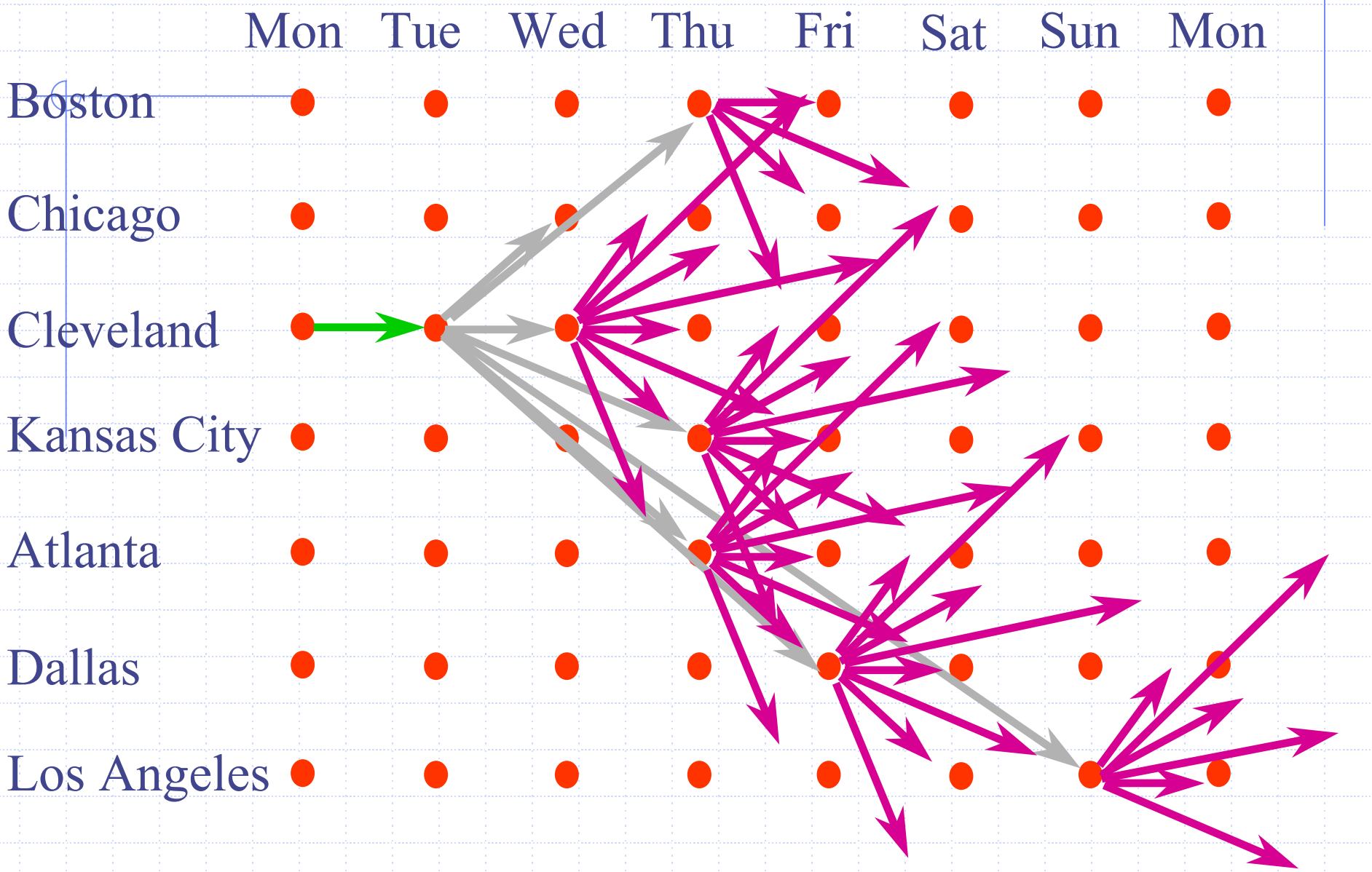
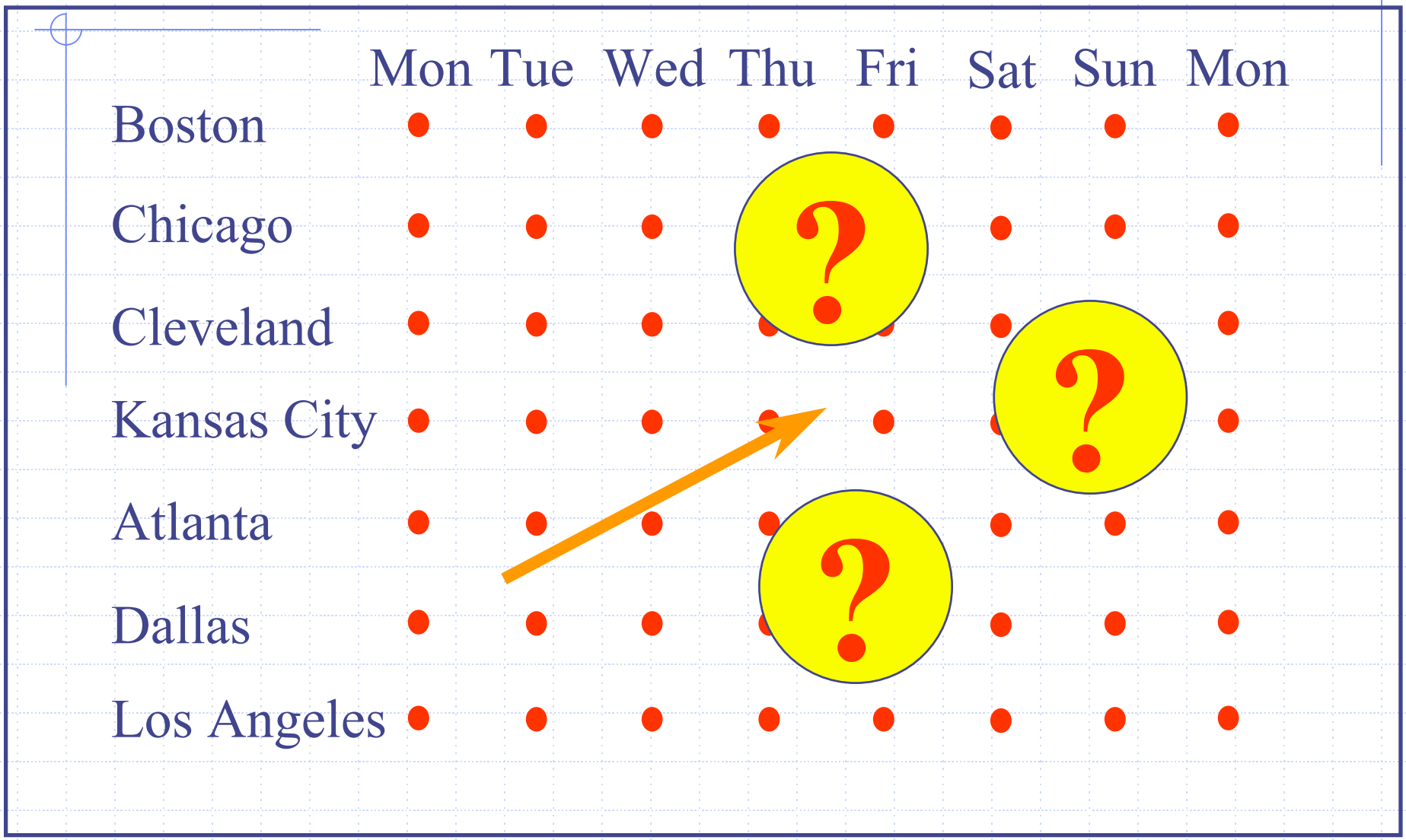


Challenges: Considerations for a Single Dispatch

- Looking only three moves beyond the first dispatch of a single truck (assuming 80 regions), involves 512,000 trajectories
- A medium-size truck line must simultaneously coordinate the moves of thousands of trucks
- Additional considerations include driver, maintenance, marketing and many other issues

Challenges:
Uncertainty; Design Horizon



System Contribution of a Load

- Regional potential: the expected contribution of a truck in a region.
- **P(A)** - Potential of region A
- **D(A-B)** - Direct cost for moving a truck from A to B
- **R(A-B)** - Revenue for the move from A to B

System Contribution of a Load

$$S(A\text{-}B) = \underbrace{R(A\text{-}B) - D(A\text{-}B)}_{\text{Direct contribution}} + \underbrace{P(B) - P(A)}_{\text{System impact}}$$

P(A) - the value of one more truck at region A
P(B) - the value of one less truck at region B

Dispatching rules:

Analysis of Movements

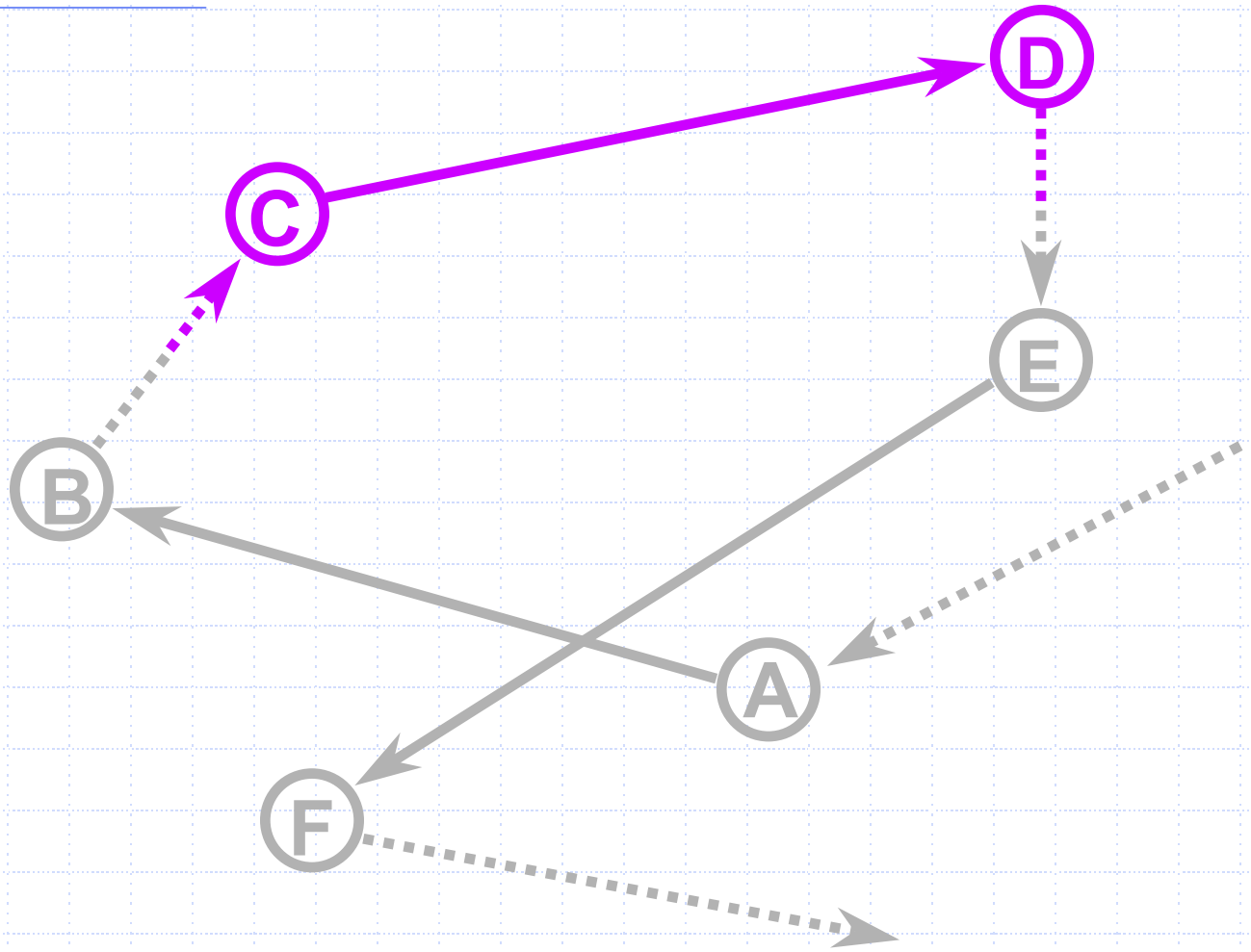
Head haul:

$$S(A\text{-}B) = R(A\text{-}B) - D(A\text{-}B) + P(B) - P(A)$$

Back haul:

$$S(A\text{-}B) = R(A\text{-}B) - D(A\text{-}B) + P(B) - P(A)$$

Loaded/Empty Pattern

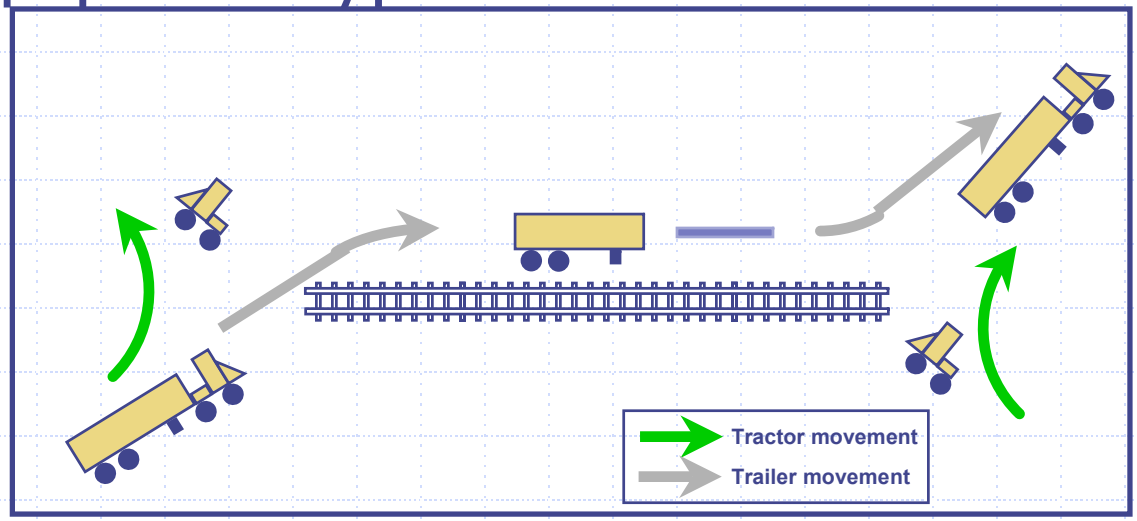


Uses of the Framework

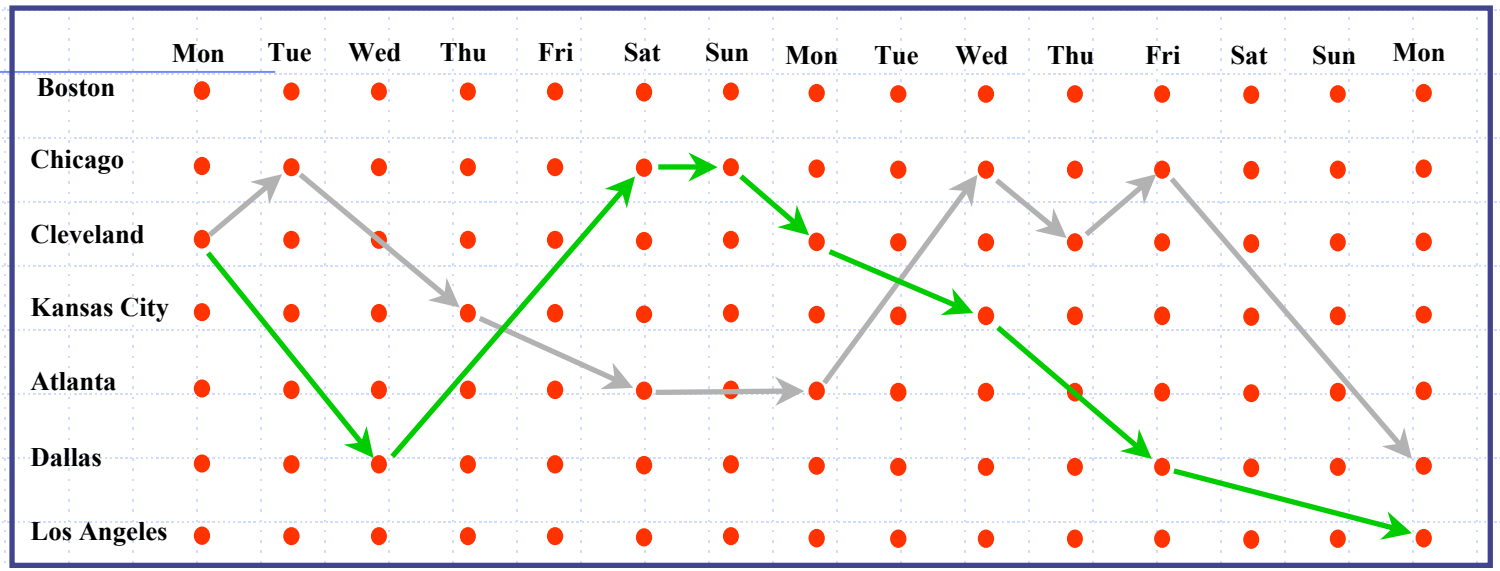
- Lane, region, and customer contribution
- Contribution of equipment types
- Performance evaluation of Marketing and Operations using the same criterion

Calculating Regional Potentials

- What is the worth of a given piece of equipment in a given region?
  - Sum of the contributions, starting at the region, over time.
- Strategic/tactical analysis Vs. Real time analysis
- By equipment type



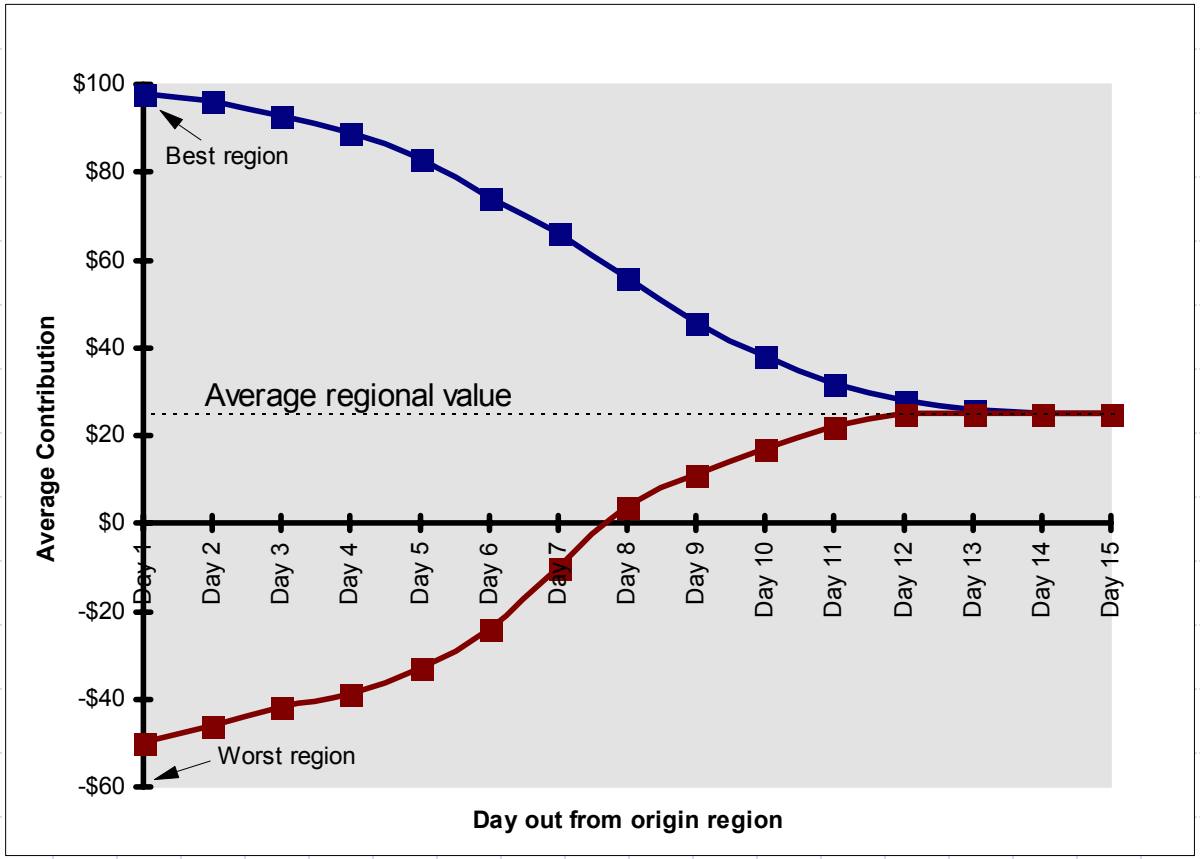
Trajectory-Based calculations



- Sum over time (average should not be day-specific for LT use; use different starting days)
- Use the same *design horizon* for all movements
- Normalize to get contribution/day for the regional potentials.

Design Horizon

- Average trajectories over 1, 2, 3,… days
- Wait for all regions to converge to the system average
- The 15 days regional potential is the integral about the time axis for each region



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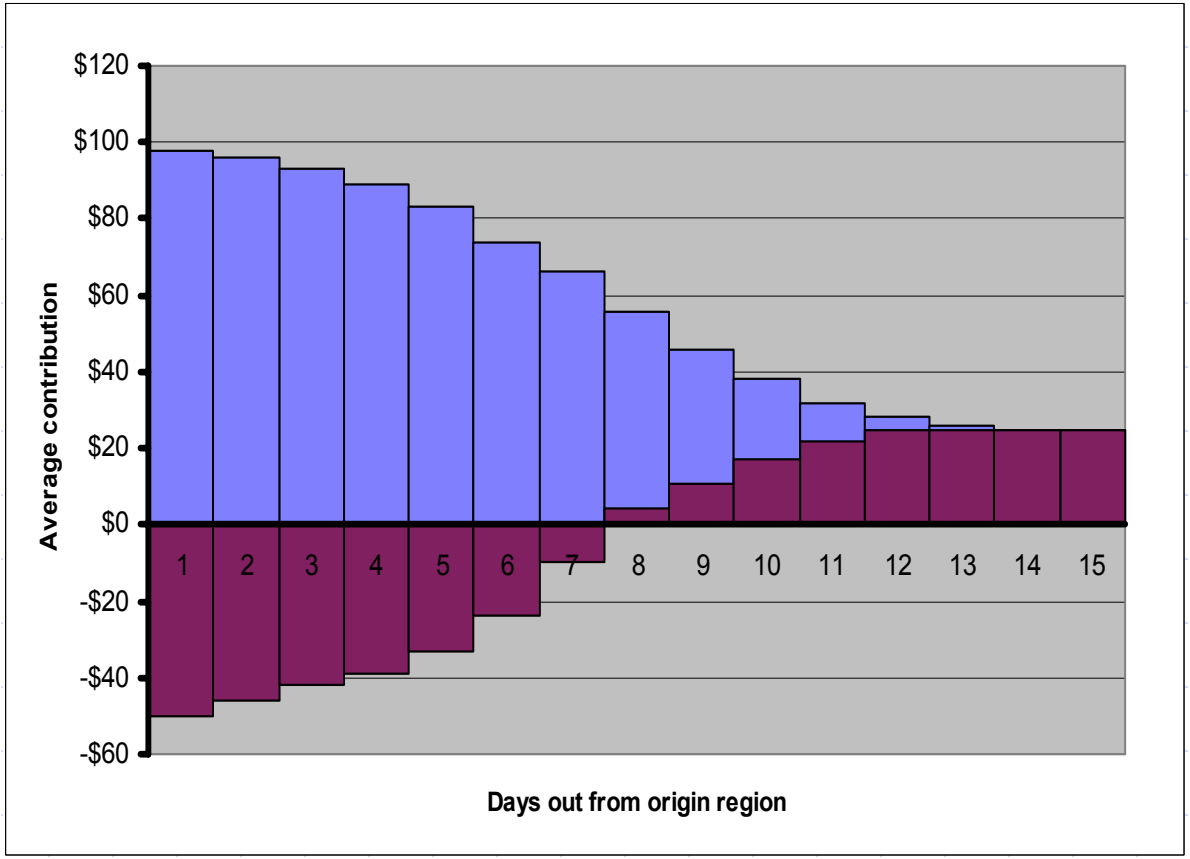
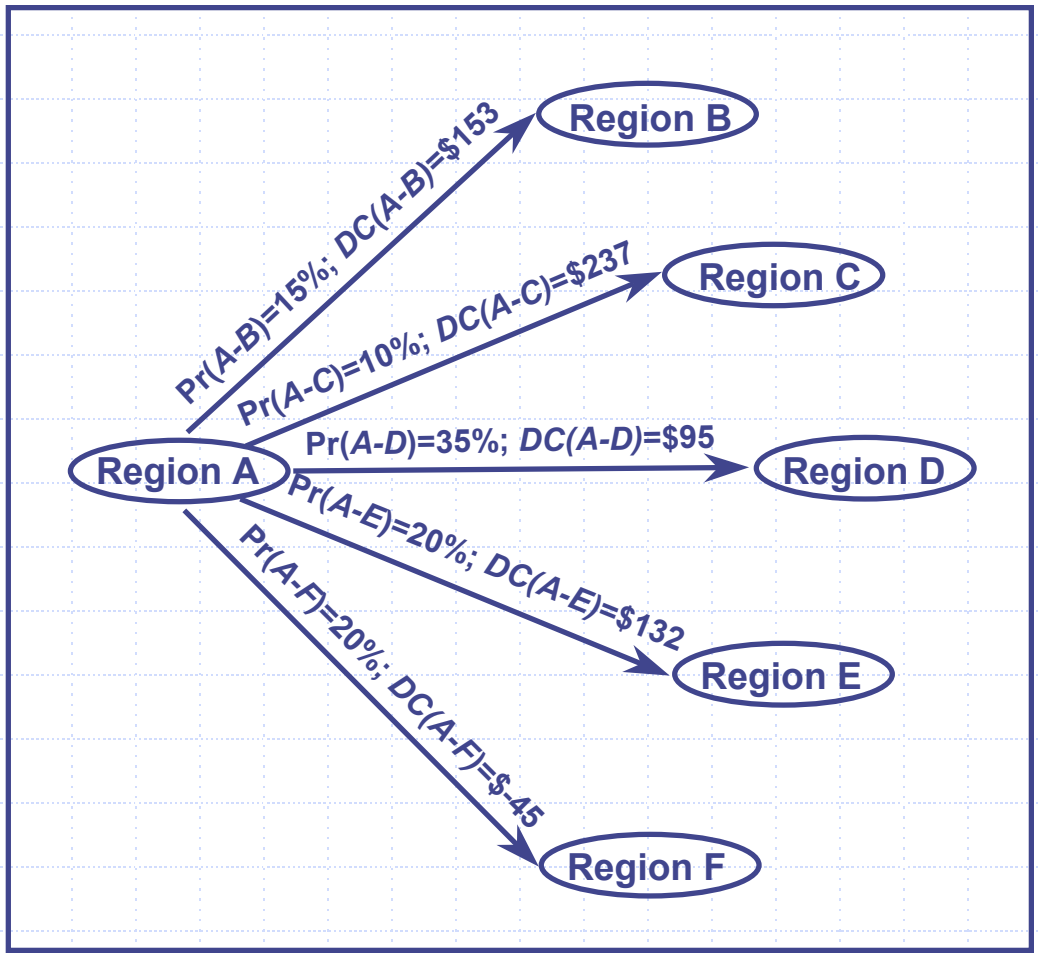


Size and Number of Regions

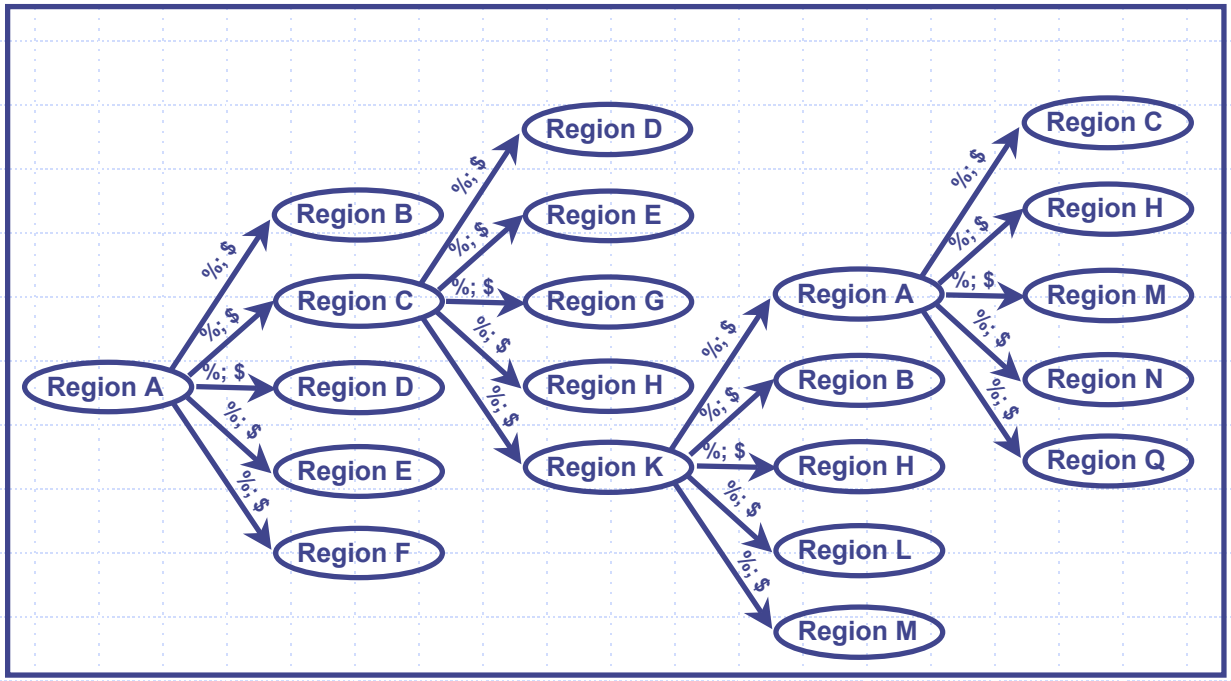
Recursive Calculations of Regional Potentials

- Pr(A-B) - the prob. that a piece of equipment in A will be moved to B next
- DC(A-B) - Average direct costs between A and B.

Outbound Probabilities



A Trajectory of Averages



Recursive Calculations

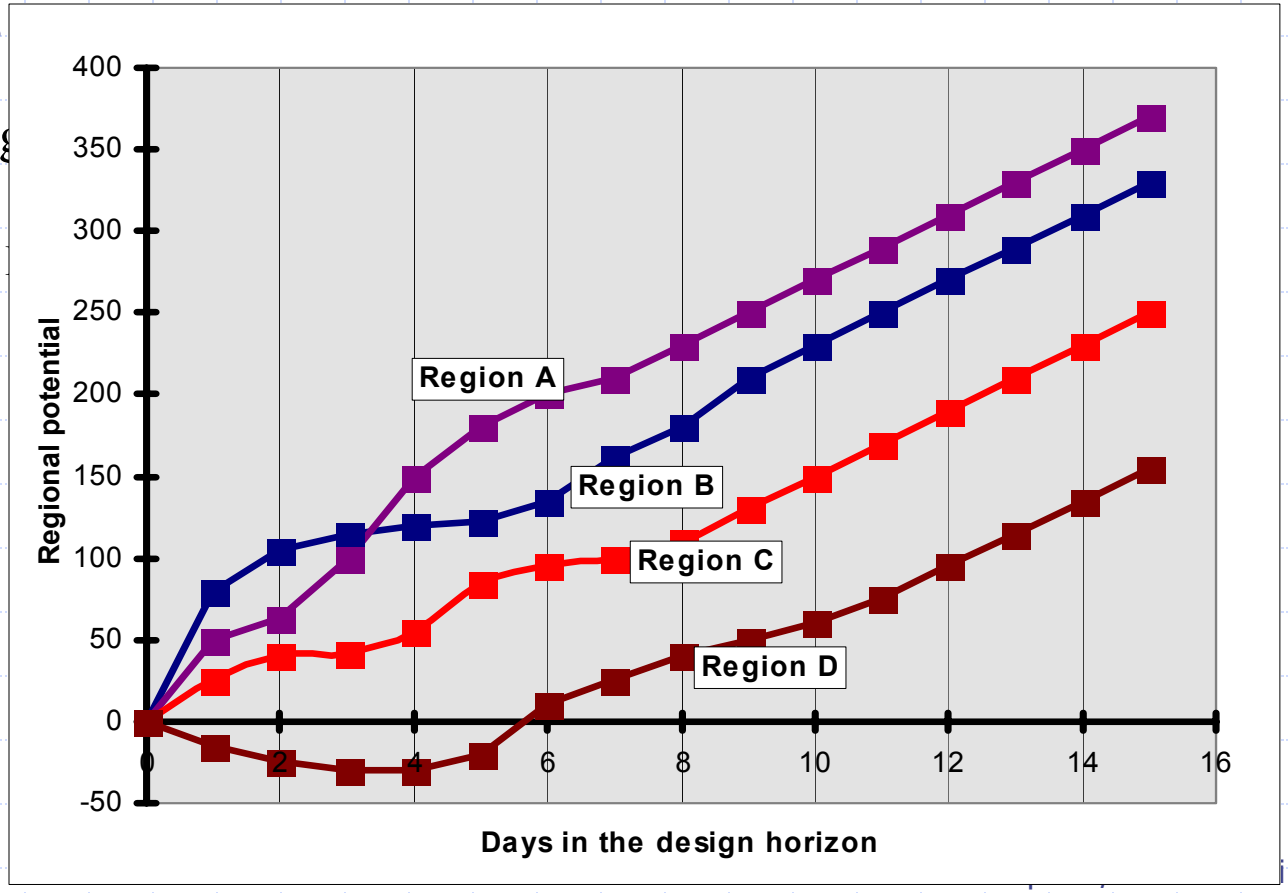
$P^n(A)$ = Potential of region A after the n^{th} iteration of the procedure.

$F(A)$= Intra-regional costs in region A

$P(A \rightarrow X)$ = Probability of a load in A going to region X

$DC(A \rightarrow X)$ = Direct costs

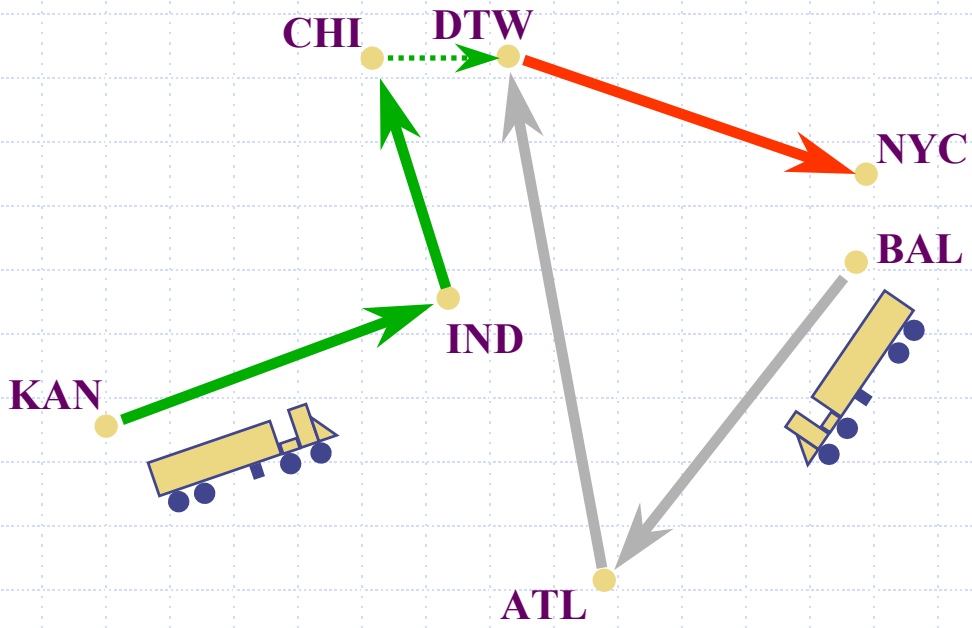
- $P^0(A) = 0$ for all reg
- $P^{n+1}(A) = F(A) + \sum_{\forall X}$



Regional Potentials

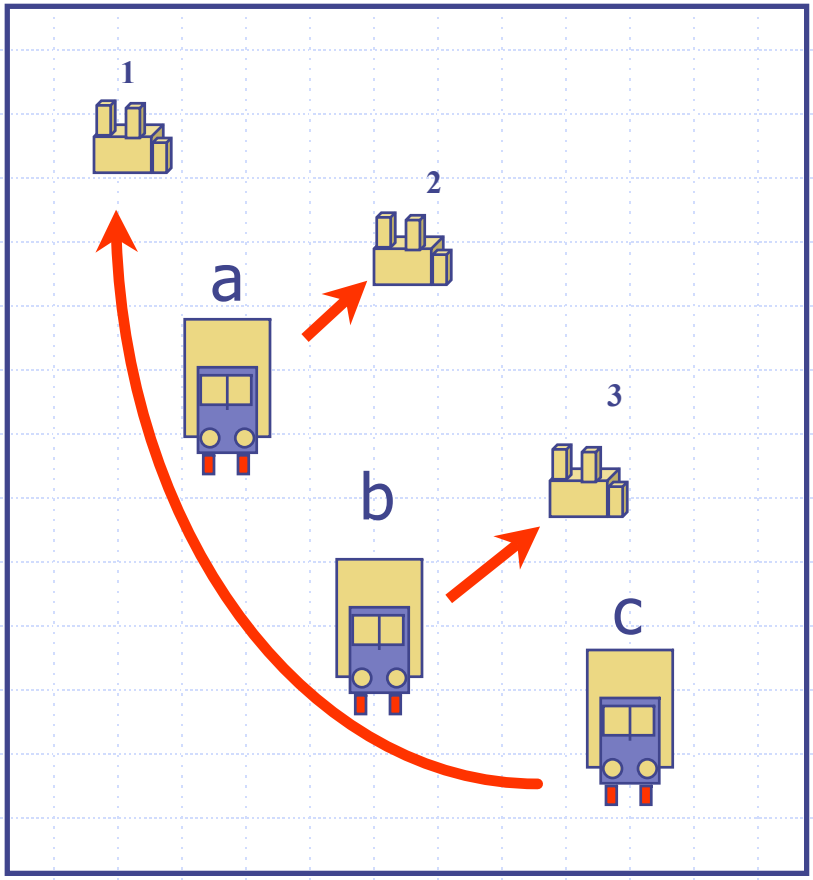
- Can be defined by season, quarter, month, etc. for use in evaluating bids.
- Seasonal potentials are relevant when the carrier is bidding on freight that may exacerbate imbalances reflected in the potentials.

Challenges:
Simultanous Dispatching



Dispatching

A simple version: which trucks should move what loads?



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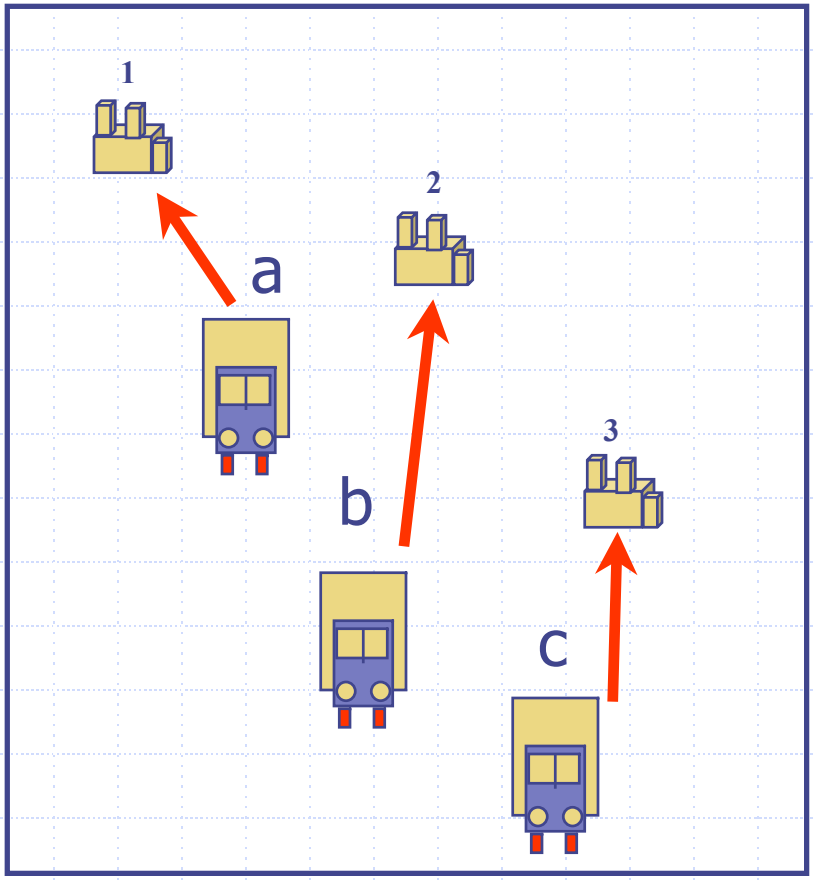
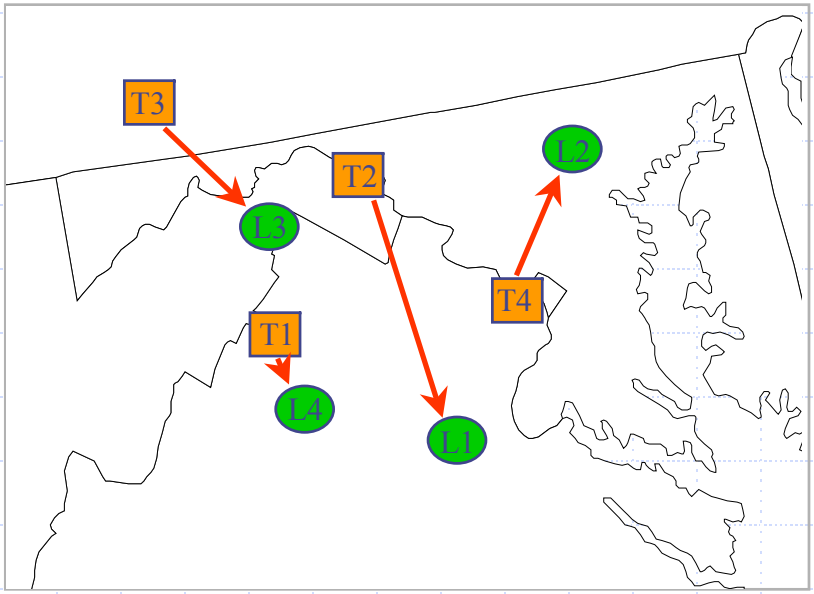
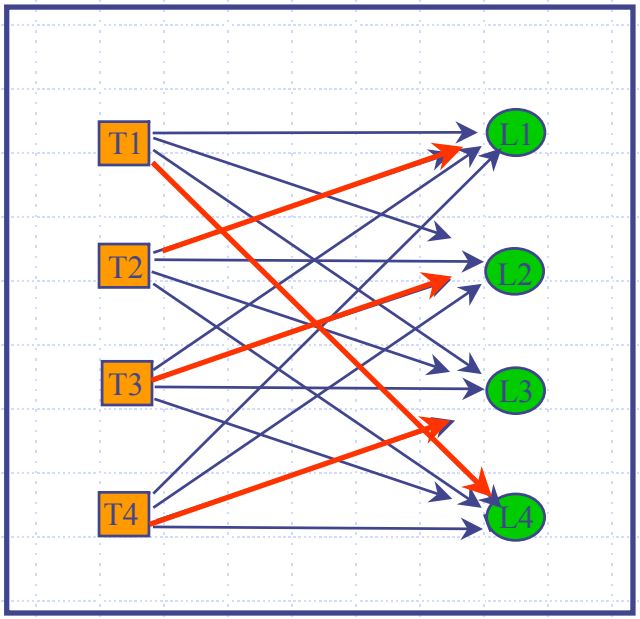


"Assignment" Optimization Model





The Assignment Program

$Let\ x_{i,j} = 0$ or 1

$Let\ x_{i,j} = 1$ if truck i picks up load j

$Let\ x_{i,j} = 0$ Otherwise

$Let\ c_{i,j}$ = be the costs associated with driver i picking up load j.

The Assignment Program

Minimize $$Z = \sum_{i=1}^{N}\sum_{J=1}^{N} c_{i,j} \bullet x_{i,j}$$

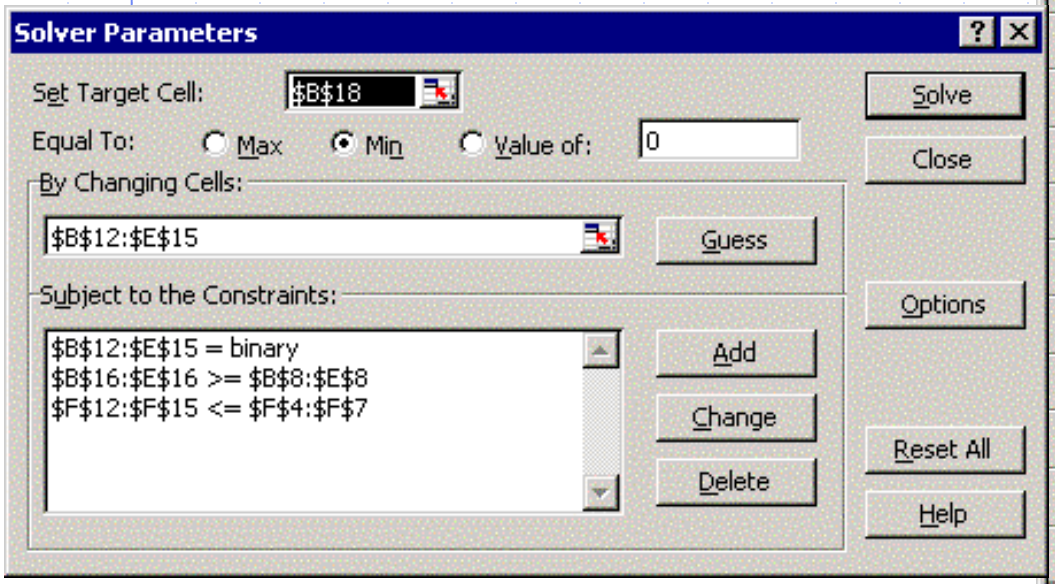
Subject to:

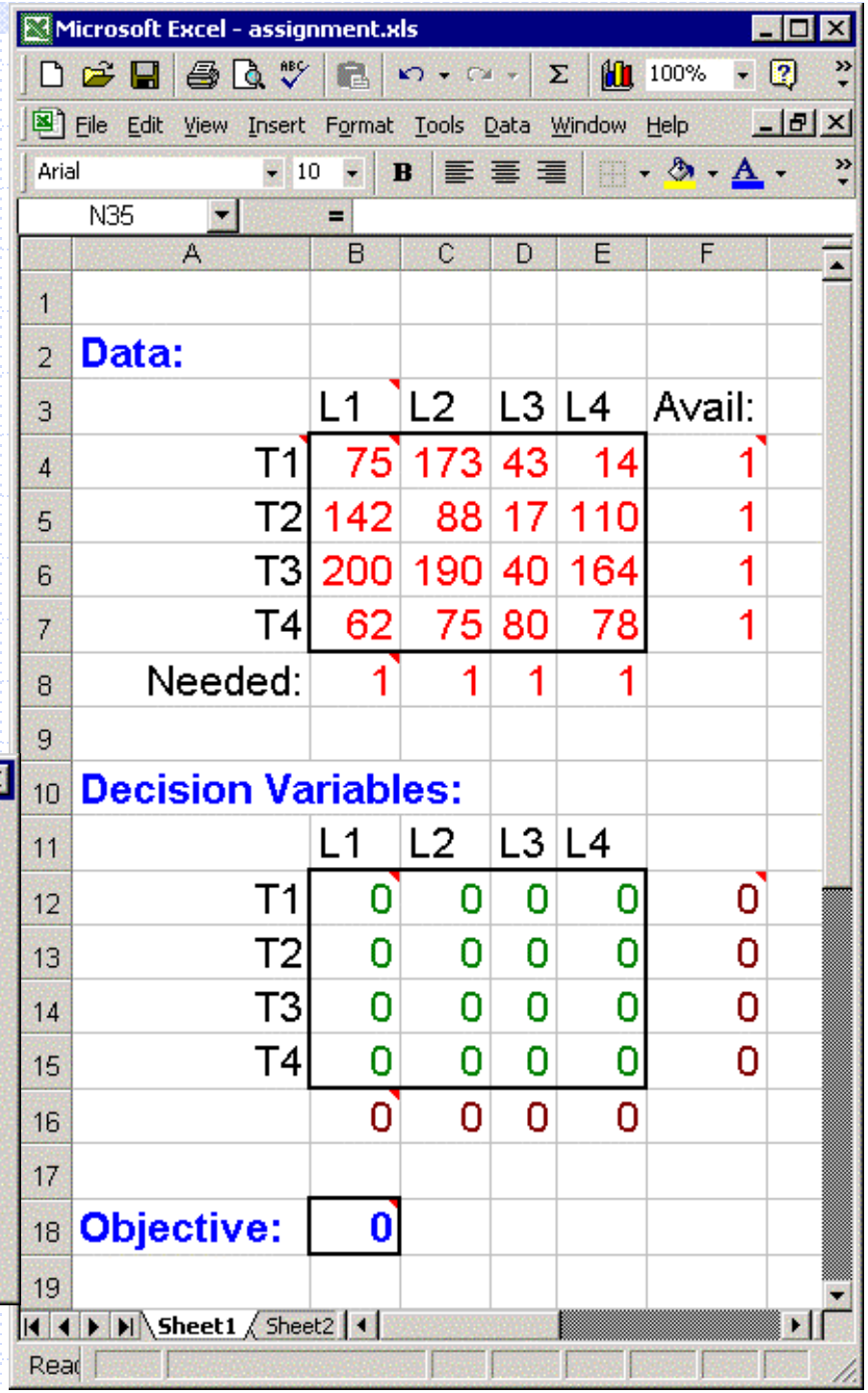
$$\sum_{j=1}^{N} x_{i,j} = 1 \quad \text{For each driver, } i.$$

$$\sum_{i=1}^{N} x_{i,j} = 1 \quad \text{For each load, } j.$$

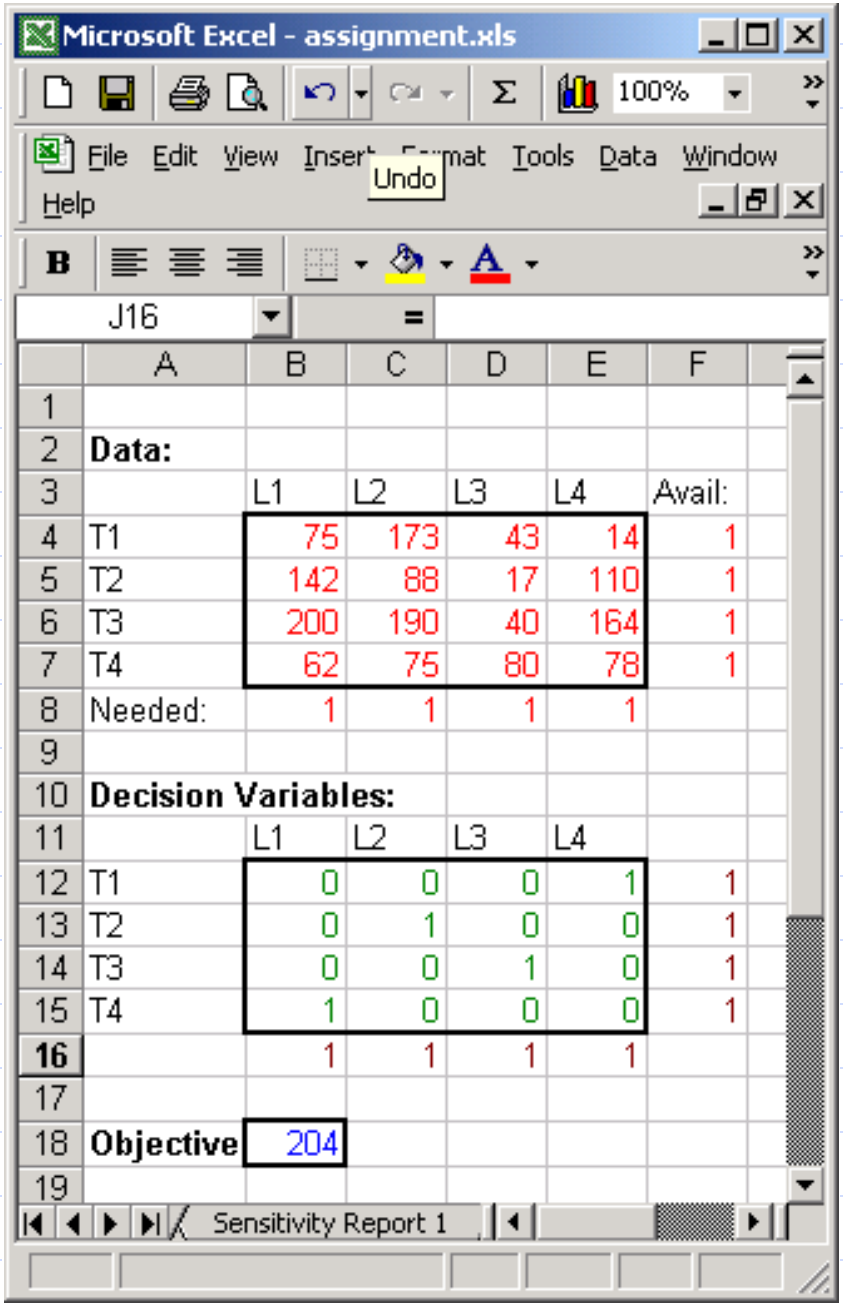
$$x_{i,j} = 0 \text{ or } 1$$

Optimization



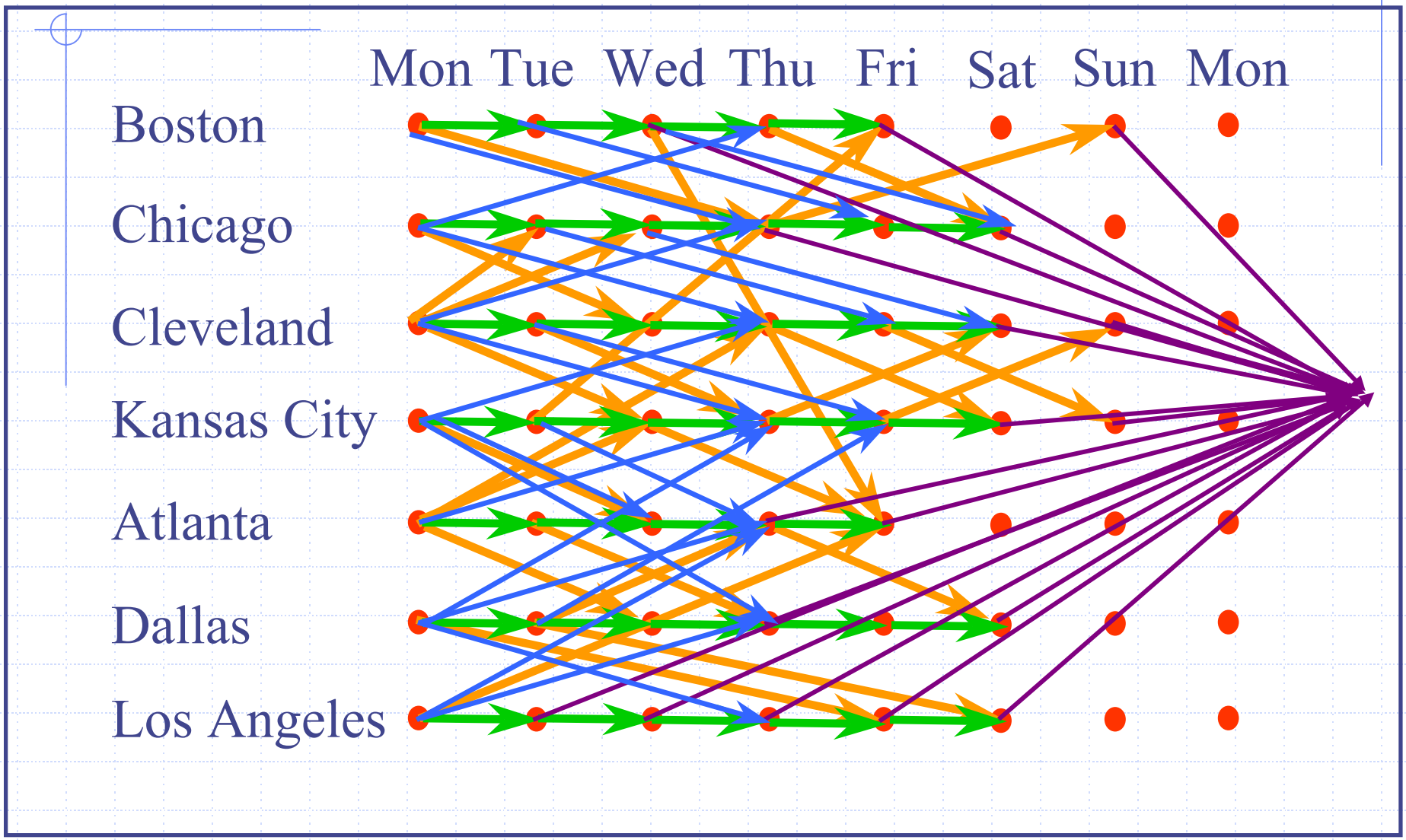


Optimization

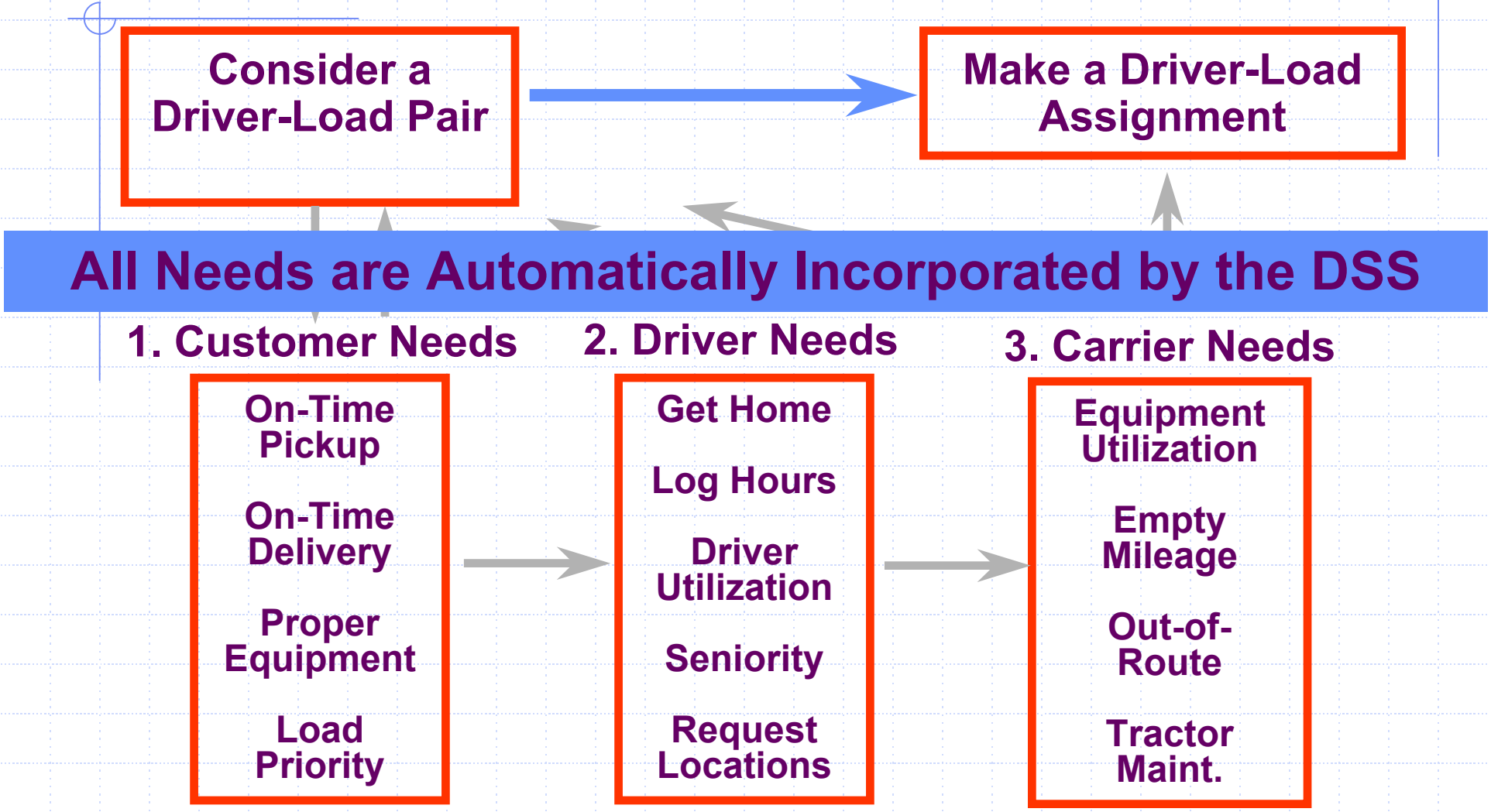


	A	B	C	D	E	F
1						
2	**Data:**					
3		L1	L2	L3	L4	Avail:
4	T1	75	173	43	14	1
5	T2	142	88	17	110	1
6	T3	200	190	40	164	1
7	T4	62	75	80	78	1
8	Needed:	1	1	1	1	
9						
10	**Decision Variables:**					
11		L1	L2	L3	L4	
12	T1	0	0	0	1	1
13	T2	0	1	0	0	1
14	T3	0	0	1	0	1
15	T4	1	0	0	0	1
16		1	1	1	1	
17						
18	**Objective**	204				
19						

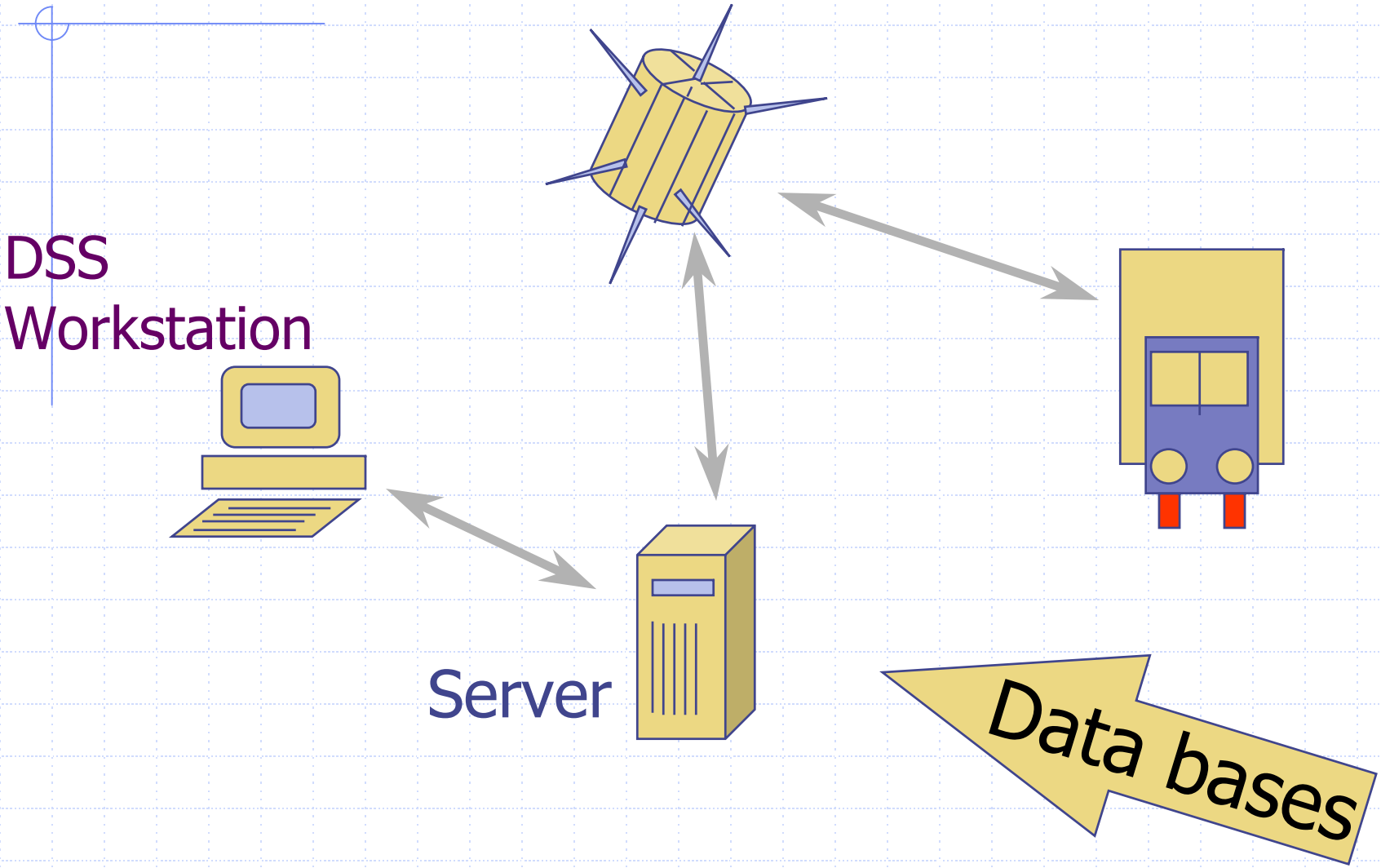
Accounting for Future Orders



Assignment Work Flow:



Information Flows

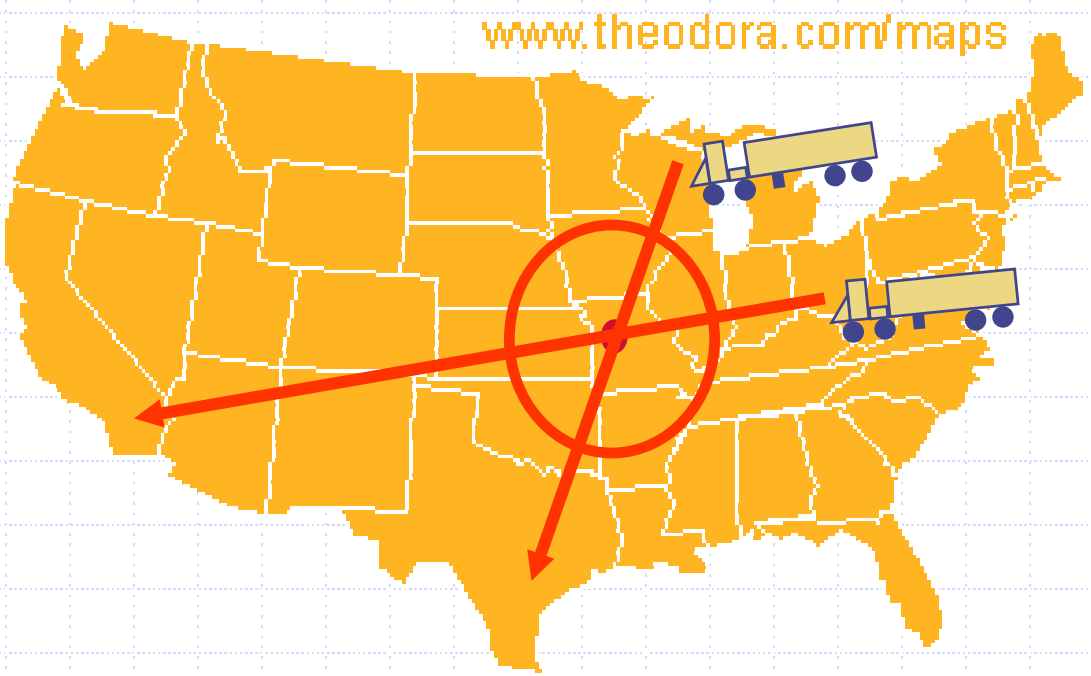


Model Output

- Load acceptance/rejection
- Split loads
- Driver assignments
- Empty repositioning recommendations
- Holding suggestions
- Load solicitation targets
- Reason codes

Post-Dispatch Optimization "Drop and Swap"

- Customer Service
- Tractor Utilization
- Get-Homes
- Maintenance
- Other Location Requests
- Comfort Zones



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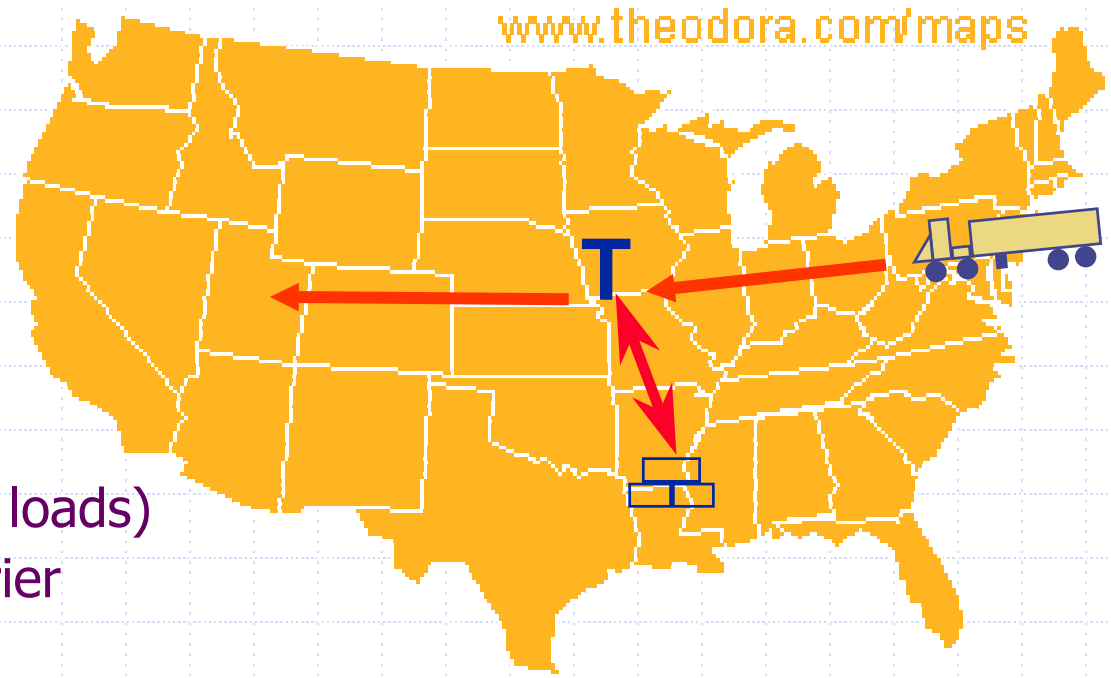
Capacity Maximization

- In--transit drivers can make local pickups
- Requirements:
  - Real-time positioning
  - Mobile communications
  - DSS
- Benefits:
  - Higher LOS (not refuse loads)
  - Higher revenue for carrier



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Changes to Management Philosophy with DSS

DSS in the Truckload Industry

- Load-Matching Optimization
- Post-Dispatch Optimization
- Capacity Maximization
- Strategic Profit Maximization
- Yield Management
- Bid Analysis
- Continuous moves
- Optimized Fuel Routing

Testimonials:

- Operation "North Pole"
  - 20% reduction in driver turnover
- Reduction in empty miles (7 miles/load; 10% of empty miles)
- Higher availability ("a model that makes money…" R. Buckley, CEO, North American Van Lines)

JB Hunt 1993 Annual Report

"J. B. Hunt recorded the biggest decrease in driver turnover ever—posting a 20% reduction."

JB Hunt 1993 Annual Report

"Operations management took a giant leap forward. A new software program called MICROMAP . . . is responsible for a reduction in empty miles of more than 10 percent, has contributed to getting drivers home on time and has assisted in the trailer trade-in program."