Ford Motor Company's
Finished Vehicle Distribution System
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Ellen Ewing
Project Director
UPS Logistics

Dr. John Vande Vate
Exec. Director EMIL
ISyE Georgia Tech

Agenda

- Introduction
- 1999 Environment
- Solution Approach
- Network Design
- Implement New Strategy
- Results to Date
- Summary

Objectives/Motivation

- Role of modeling
- Information in variables
- Stronger formulation
- Financial impact

The Need for Speed

Financial Incentives: Capital Utilization

- In 1996
  - Ford produced 3.9 million vehicles in the US
  - Avg. transit time 15+ days
  - Avg. vehicle revenue $18,000
  - Value of pipeline inventory: > $2.8 Billion
  - One day reduced transit time:
    - » $190 Million reduction in pipeline inv.
    - » 1,400 fewer railcars

The Need for Speed

Demand for land

- 22 Plants
- 54 Destination Ramps
- ~1,200 Load lanes
- ~8,400 vehicles waiting at plants
- $166 Million in inventory

The Need for Speed

Other Incentives

- Damage
- Flexibility
- Others?

The Price

- Inventory at the cross dock
- Added distance traveled
- Handling at the cross dock
- Capital costs of the cross dock

1999 Vehicle Network Delivery Conditions

- Record production levels
- Demand shift from cars to trucks
- Overburdened rail infrastructure
- Deteriorating rail service
- Shortage of transport capacity
- Mixing centers
- 15+ day transit time
- High inventory cost
- Dissatisfied customers

High 1999 Level Statistics

• Assembly plants	22
• Mixing centers	5
• Destination rail ramps	54
• Dealer locations	6,000
• Production volume Mil./Year	4.4
• Freight expense	$1.5 Bil.
• Dec. ‘99 avg. transit time	16.8 Days
• Pipeline Inventory	$4.1 Bil.

Ford Distribution Network

Old Delivery Design

- Push Network
- Vendor sub systems optimized for individual segments
- Little to no visibility
- Mixing Centers not used effectively

Ford Goals

Speed

- 1999: Average 15 days transit time
- Goal: Maximum of 8 days transit time

Precision

- 1998/1999: 37% on time within 1 week
- Goal: 95% on time within 1 day

Visibility

- 100 % Internet vehicle tracking from plant release to dealer delivery
- Guide the flow of vehicles
- Respond to variations
- Inform customers

Design Process

Truck vs Rail delivery

Allocate Dealers (FIPS)
to Ramps

Route Flows through
Rail Network

Single-Sourcing Allocation

```
Var Assign{FIPS, RAMPS} binary;
Minimize TotalCost:
        sum{fip in FIPS,ramp in RAMPS}
Cost[fip,ramp]*Assign[fip,ramp];
s.t. SingleSource{fip in FIPS}:
    sum{ramp in RAMPS}Assign[fip,ramp] = 1;
s.t. ObserveCapacity{ramp in RAMPS}:
    sum{fip in FIPS} Volume[fip]*Assign[fip,ramp]
<= Capacity[ramp];
```

Old Ramp Allocation
Southern US

Dealers sourced by multiple ramps

Maximum	Count
500	1039
5,000	504
50,000	128
75,000	1
130,000	2

New Ramp Allocation
Southern US

Dealers sourced by single ramps

Maximum	Count
500	2085
5,000	952
50,000	174
75,000	3
130,000	2

New Allocation of Dealers to Ramps
Mainland US

Maximum	Count
500	2085
5,000	952
50,000	174
75,000	3
130,000	2

Flows through the Rail Network

Objective is NOT Freight cost!

The Objective IS

Speed

Capital

Land

The Promise

Speed

Unit trains bypass hump yards

The Promise

Capital & Land

- 22 Plants
- 54 Destination Ramps
- ~1,200 Load lanes
- ~8,400 vehicles waiting at plants
- $166 Million in inventory

Each Plant to One Mixing Center

- ~22 Load lanes
- ~154 vehicles waiting at plants
- ~$3 Million in inventory

The Price

- Inventory at the cross dock
- Handling at the cross dock
- Capital costs of the cross dock
- Added distance traveled

Making the Trade-offs

Measuring Inventory

- In the rail network
- At the plants and Cross Docks

Load-driven system

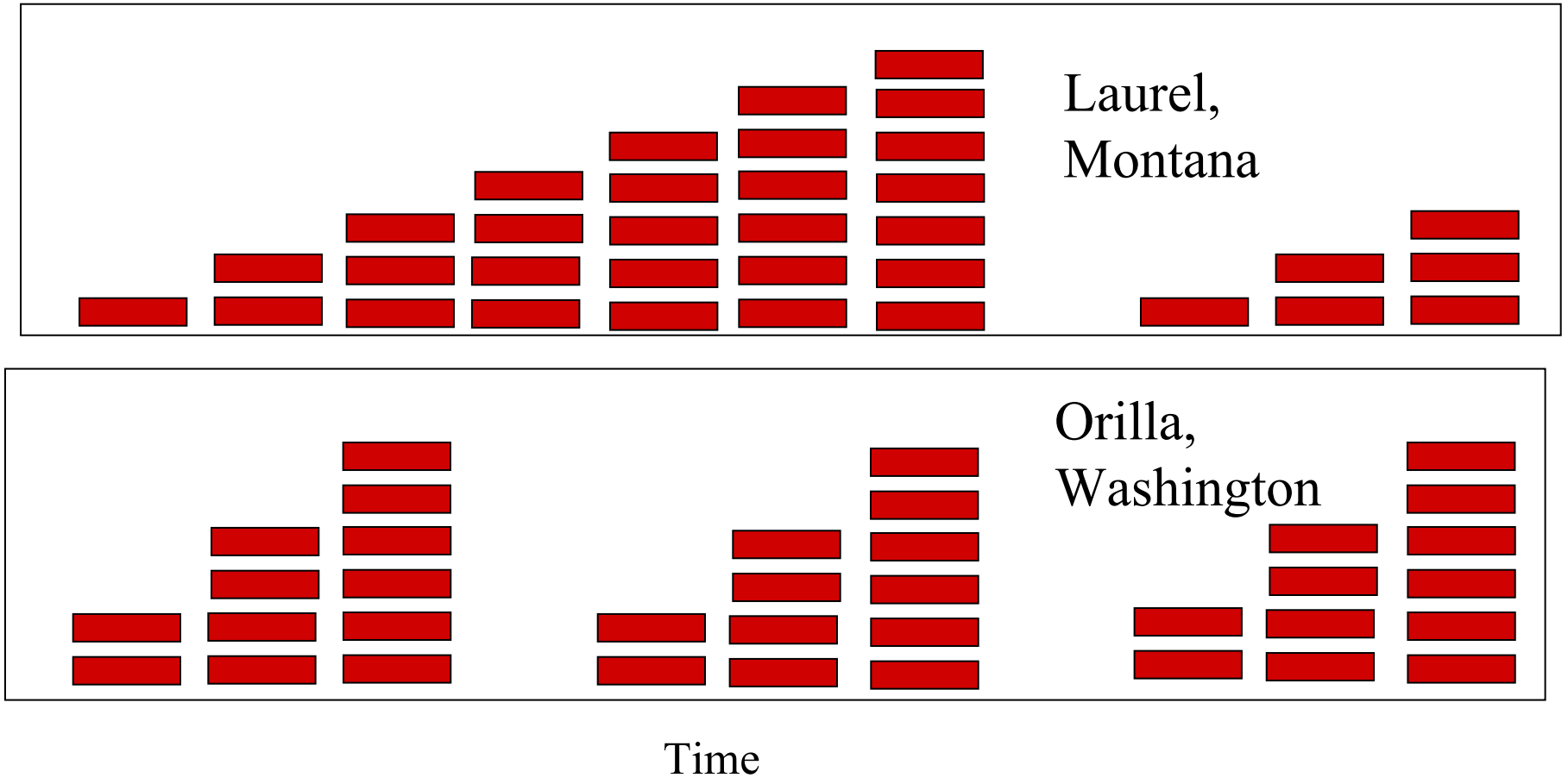
- Railcars depart when full

Relationship between

- Network Design and Inventory

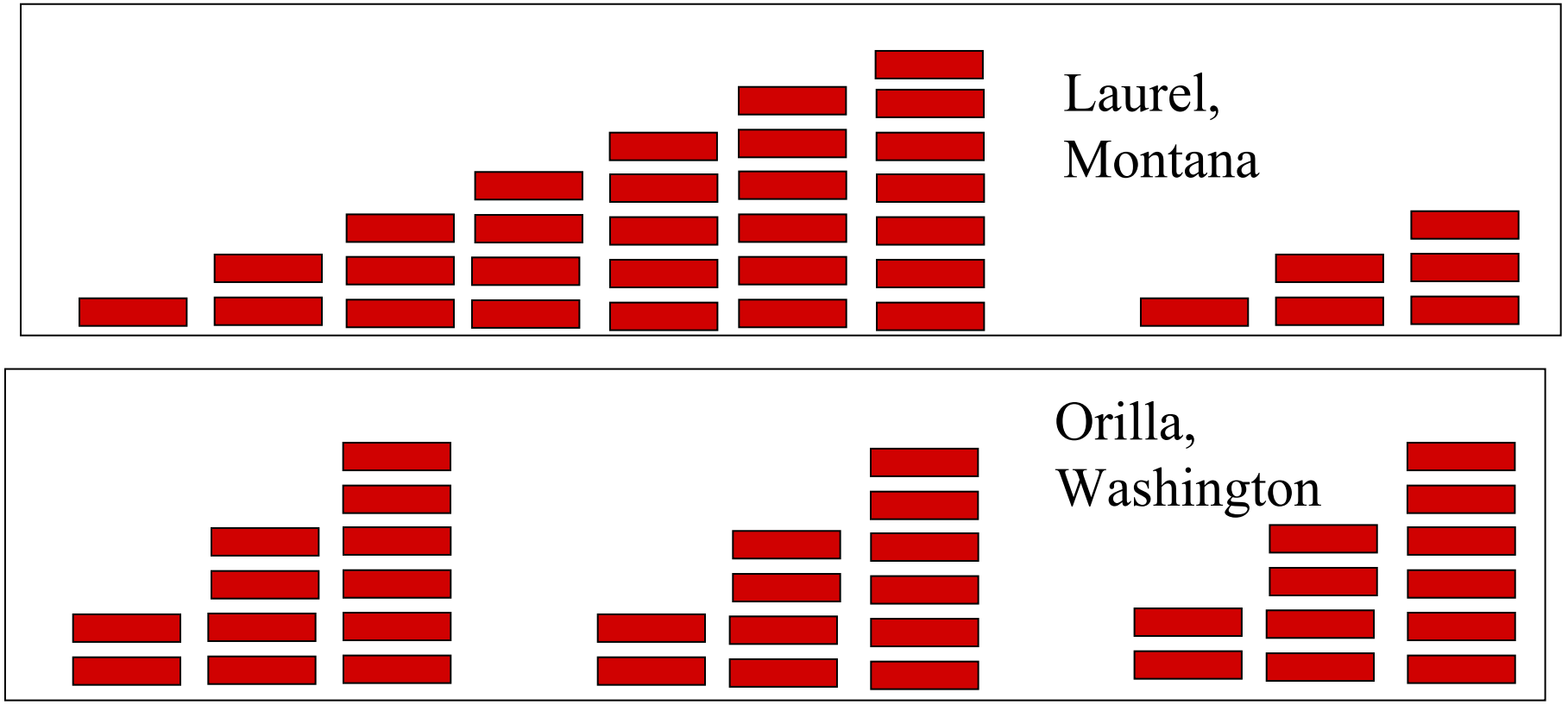
Inventory at the Plants

Half a rail car full for each destination



Inventory at the Mixing Centers

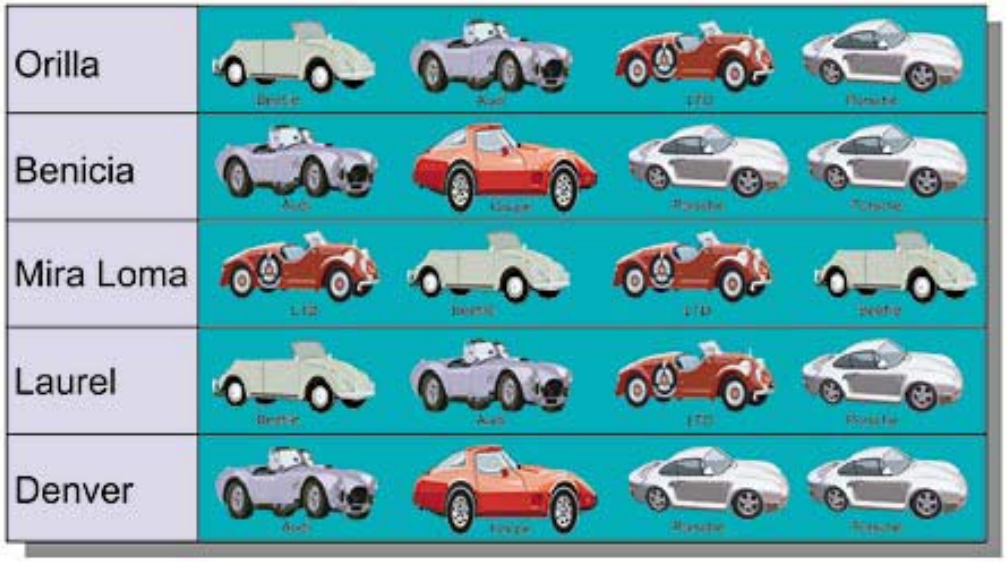
Half a rail car full for each destination



Workload at the Mixing Centers

Unpredictable

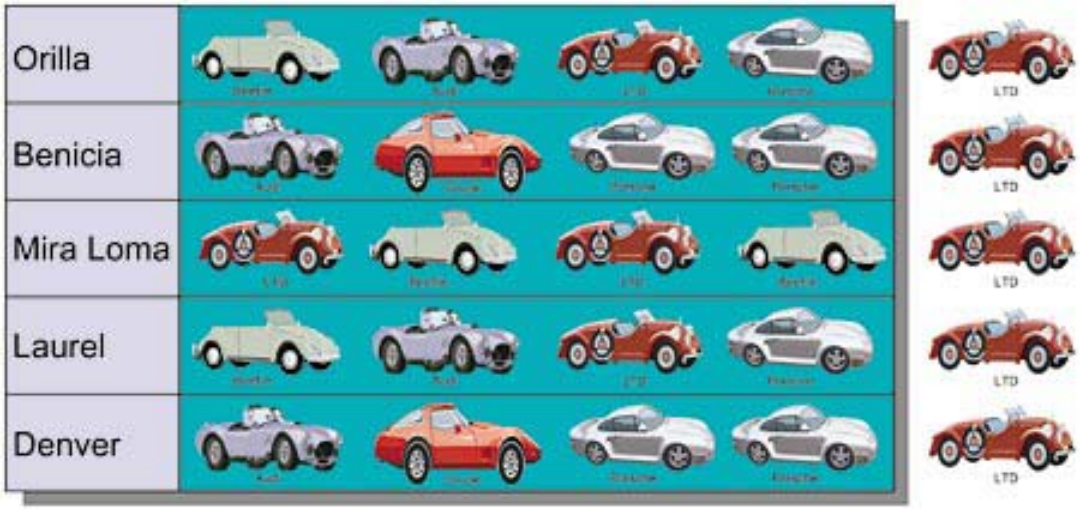
Rail car holds 5 vehicles



Workload at the Mixing Centers

Balanced: Only load cars you empty

Rail car holds 5 vehicles



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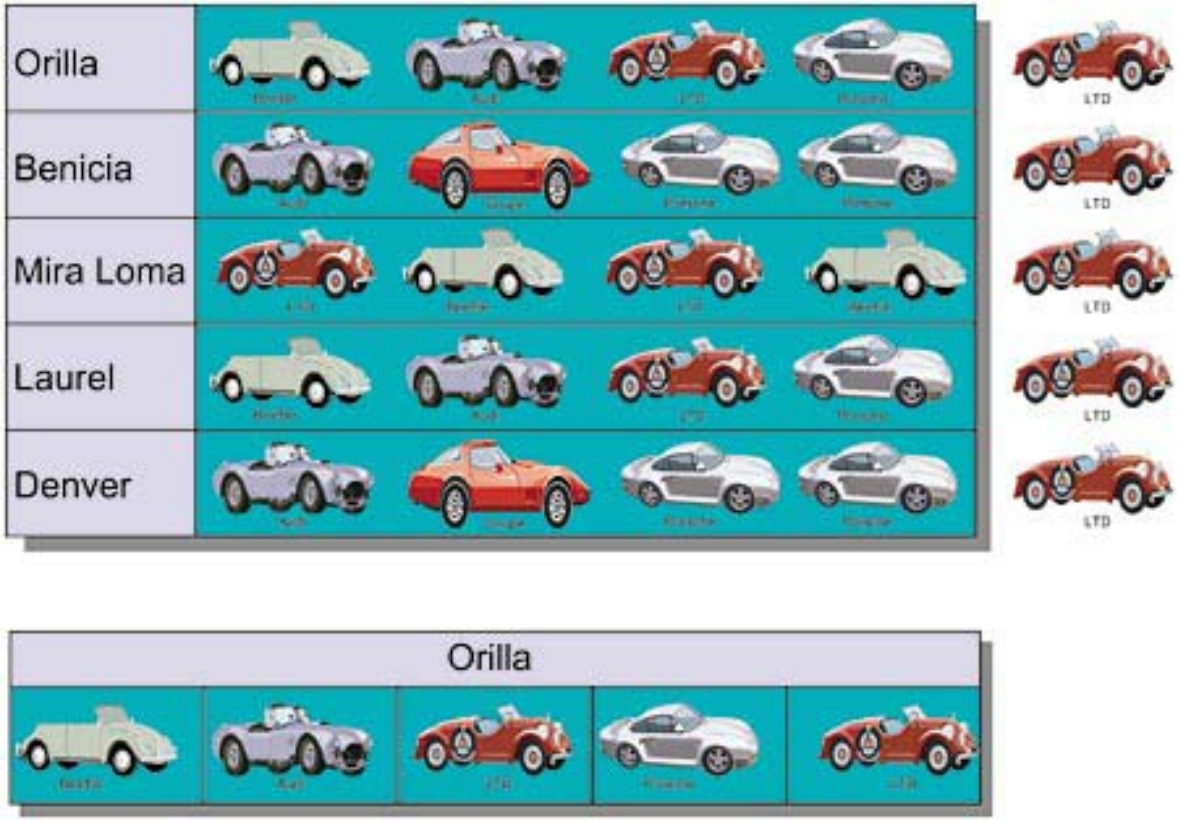

Effect on Inventory

- Inventory at Mixing Center slowly grows
  - to just over (ramps -1)(capacity -1) and remains there
- Roughly twice the inventory of before
- Still depends on the number of ramps the cross dock serves

Consolidation for Speed

- Unit Trains of 15-20 rail cars don’t stop at mixing yards
- Trade moving inventory for stationary inventory

Model

Paths
- Route from Plant to Ramp
- Mode used on each edge

Demand[ramp, plant]
- Combined demand at ramp for all products from the plant

Variables:
- PathFlow[path]:
  - Volume from the plant to the ramp on the path
- UseLane[fromloc, toloc, mode] binary
  - Did we use the mode between two locations

Model

Objective

Minimize the number of vehicles in the pipeline

- Moving Component (Transit times)
- Waiting Component (Mode Size)

Minimize PipelineInventory:

- sum{path in Paths} (Total Transit Time)*PathFlow[path];
- sum{(f,t,m)} (Size[m]/2)*UseLane[f,t,m]

Model

Satisfy Demand

The sum of flows on all paths between a plant and a ramp must meet demand

s.t. SatisfyDemand[p in PLANTS, r in RAMPS}:

```
sum{path in PATHS: Plant[path]=p and Ramp[path] = r}
    PathFlow[path] >= Demand[p,r];
```

Model

Define UseLane

For each pair of locations and mode between them write a constraint for each plant and ramp

s.t. DefineUseLane[p in PLANTS, r in RAMPS,
(f,t,m) in EDGES}:
sum{path in PATHS: Plant[path]=p and
Ramp[path] = r and
(f,t,m) in PATHEDGES[path]}
PathFlow[path] <= Demand[p,r]*UseLane[f,t,m];

Model

Large Model
  Lots of Variables: Many Paths
  Lots of Constraints: DefineUseLane

The LP relaxation is nearly always integral

New Rail Lanes

Reduced plant destinations

Results

- Cut vehicle transit time by 26% or 4 days
- $1 billion savings in vehicle inventory
- $125 million savings in inventory carrying costs
- Avoid bottlenecks
- Reduce assets in supply chain
- Improved inventory turns at dealer

Benefits

- Ford
- Dealers
- Rail Carriers
- Auto Haulers

Benefits - Ford

- On-time delivery
- Competitive edge
- Cost control

Benefits - Dealers

- Reduced inventories
- Increased customer satisfaction

Benefits - Rail Carriers

- Improved equipment utilization (reduced capital expenditures)
- Visibility and planning capabilities
- Synergies with existing UPS traffic
- Increased cooperation

Benefits - Auto Haulers

- Expanded dealer delivery hours
- Visibility and planning capability
- Improved asset utilization
- Increased cooperation