Using the RTC Simulation Model to Evaluate Effects of Operating Heterogeneity on Railway Capacity

Mark Dingler

September 12, 2008

The William W. Hay Railroad Engineering Seminar Series

ILLINOIS
RAILROAD ENGINEERING PROGRAM

Outline

- Background
- Methodology
- Freight Heterogeneity Study
- Passenger Heterogeneity Study
- Future Work

What is Railroad Capacity?

General Definition:

- *Capacity is a measure of the ability to move a specific amount of traffic over a defined rail line with a given set of resources with acceptable punctuality.* (e.g. number of tons moved, average train speed, on-time-performance, maximum number of trains per day, etc.)

Theoretical Capacity:

- *Maximum number of trains physically possible to move across a rail line under ideal conditions*

Practical Capacity:

- *Maximum number of trains possible accounting for actual conditions and achieving a reasonable level of reliability*

Factors Affecting Capacity

Infrastructure

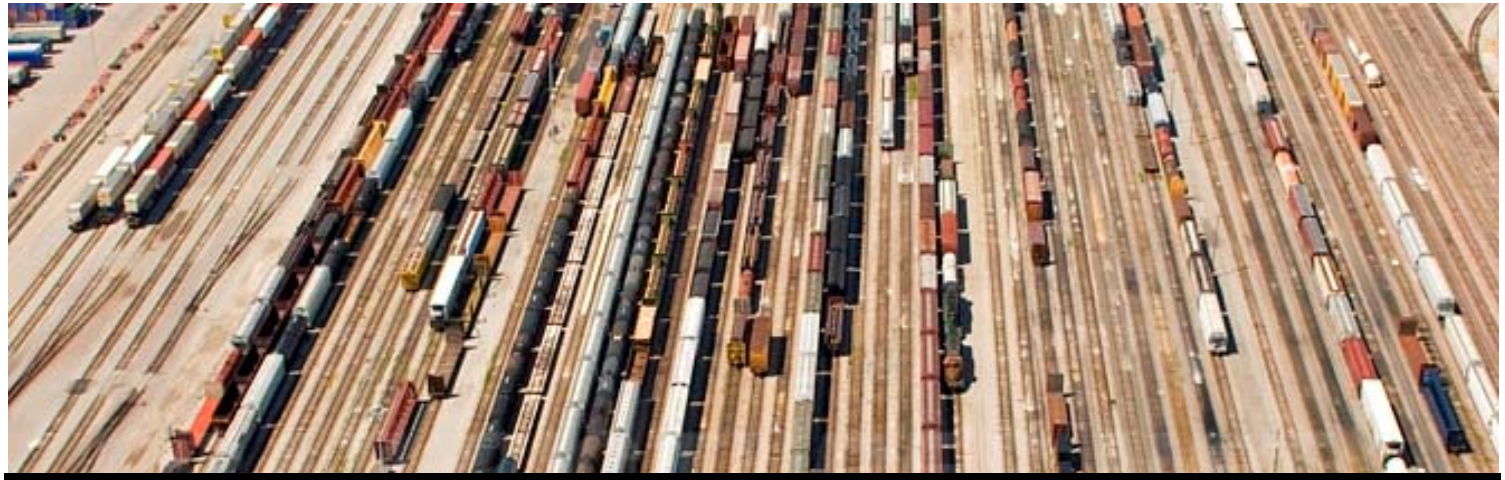
- Siding length and spacing
- Crossover spacing
- Number of tracks
- Signal and traffic control system
- Grade
- Curvature

Operations

- Average and variability in speed
- Schedule stability
- Terminal efficiency
- Heterogeneity in train type

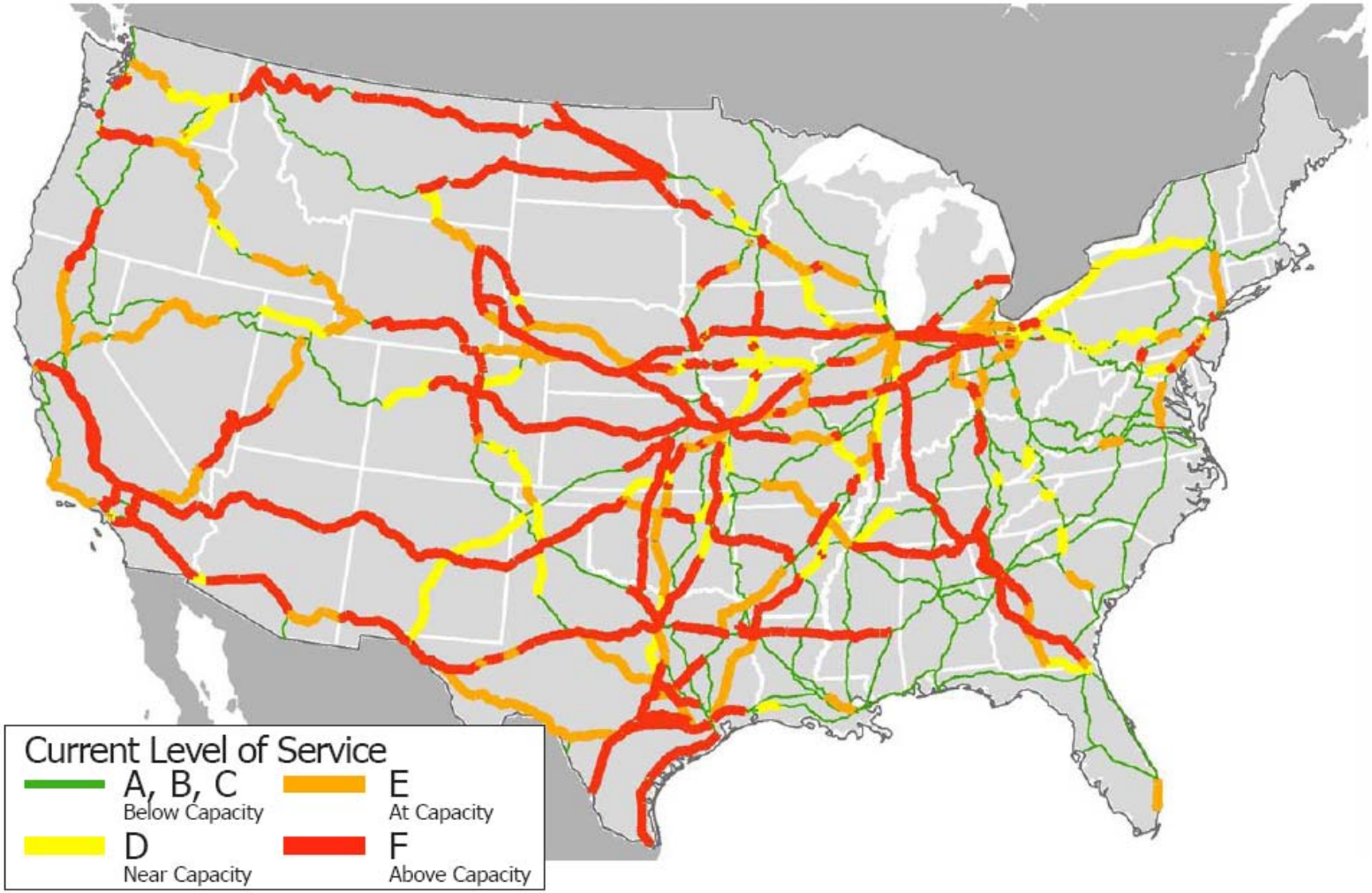
The North American railroad industry is facing capacity constraints

- Between 2000 and 2005 the US railroads revenue ton miles increased by over 13%
- AASHTO predicts the demand for freight rail services will increase 84% based on ton-miles by 2035
- In 2007 Amtrak's ridership had its fifth straight year of growth with an increase of 6.3%



The North American railroad industry is facing capacity problems

Future Volumes Compared to Future Capacity In 2035 without Improvements



Capital Expansion is Costly

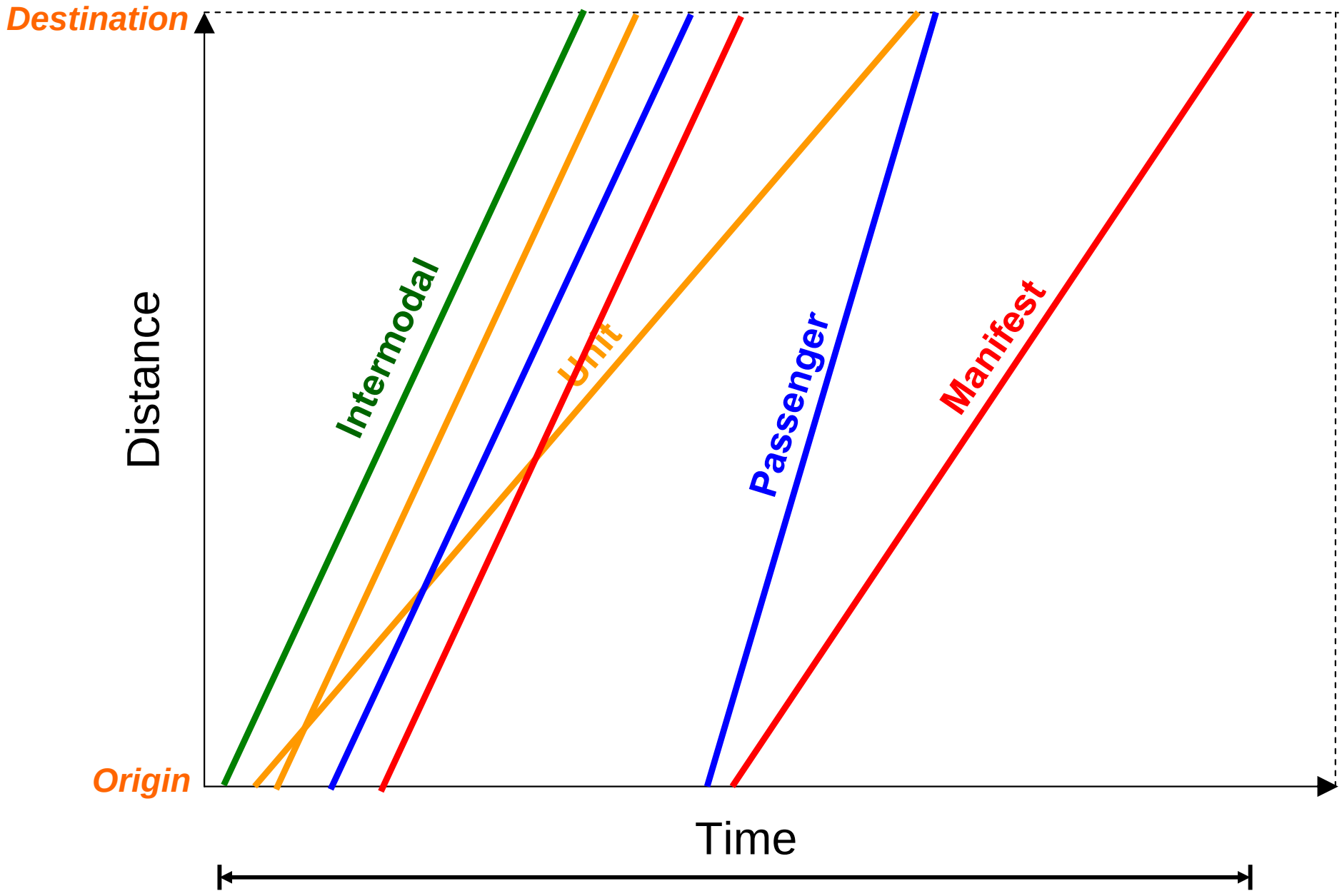
- An investment of $148 billion (in 2007 dollars) is required for infrastructure expansion over the next 28 years to meet the USDOT's forecasted demand
- Class I capital expenditures for infrastructure expansion totaled:
  - $1.1 billion in 2005
  - $1.4 billion in 2006
  - $1.9 billion in 2007 (estimate)

Understanding Operations is Necessary for Effective Capacity Planning

- Consideration of how operational practices affect demand on infrastructure is critical
- Heterogeneity in train and traffic characteristics is a key aspect of railway operations that affects capacity

- **What is train type heterogeneity?**
  - Different trains have substantially different operating characteristics including: speed, acceleration, braking distances and dispatching priorities

Impact of Heterogeneous Train Types on Capacity



Models Used in this Study

- **CN Parametric Model**
  - ***Parametric models*** are developed using simulation to identify critical parametric relationships and focus on the key elements of line capacity:
    - Fill the gap between simple theoretical models and detailed simulations
    - Quickly evaluate capacity characteristics of line
- **Rail Traffic Controller (RTC)**
  - ***Simulation models*** include detailed infrastructure configuration and mimics train dispatcher logic
    - Closest representation of actual operations
    - Sophisticated and computationally intensive

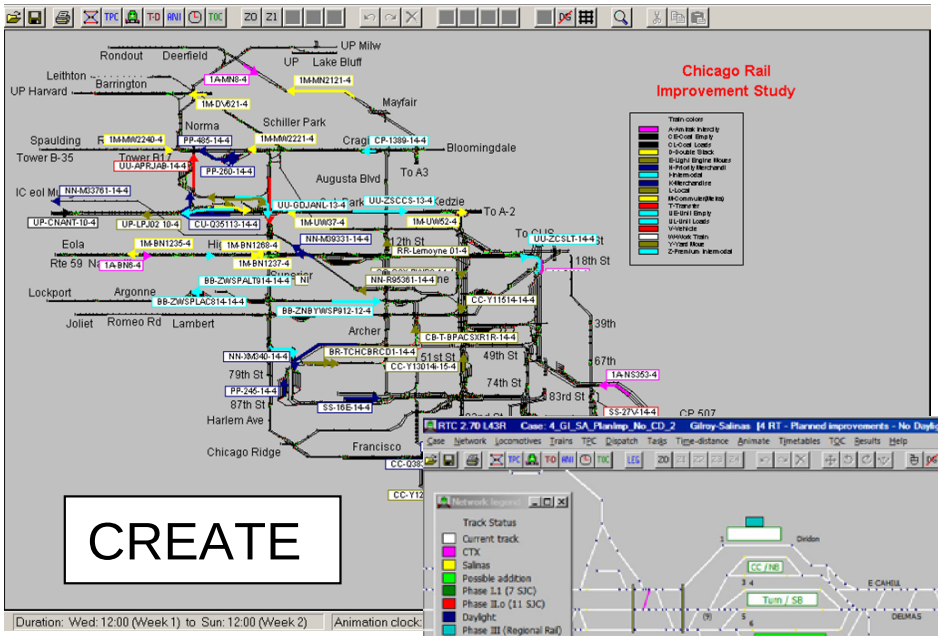
CN Parametric Model

- CN Parametric Model uses infrastructure and operating parameters to predict a delay-volume curve
  - Attributes include
    - Average speed
    - Speed ratio
    - Priority
    - Peaking
    - Siding spacing and uniformity
    - Percent double track
    - Signal spacing

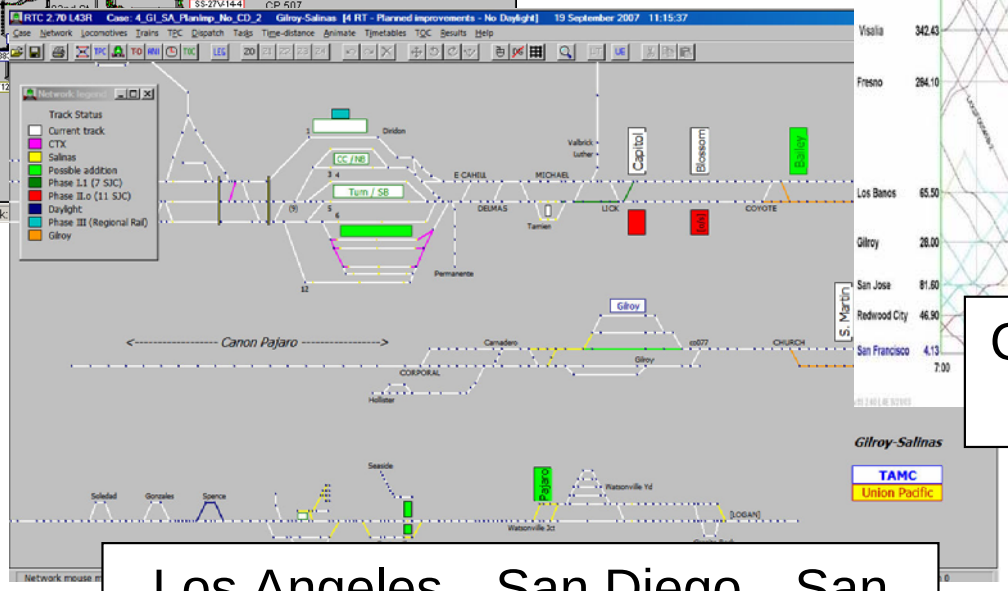
Rail Traffic Controller (RTC)

- Rail Traffic Controller (RTC) from Berkeley Simulation Software®
  - Dispatch simulation software
  - Allows modeling and simulation of multiple traffic scenarios
  - Variety of types of outputs available

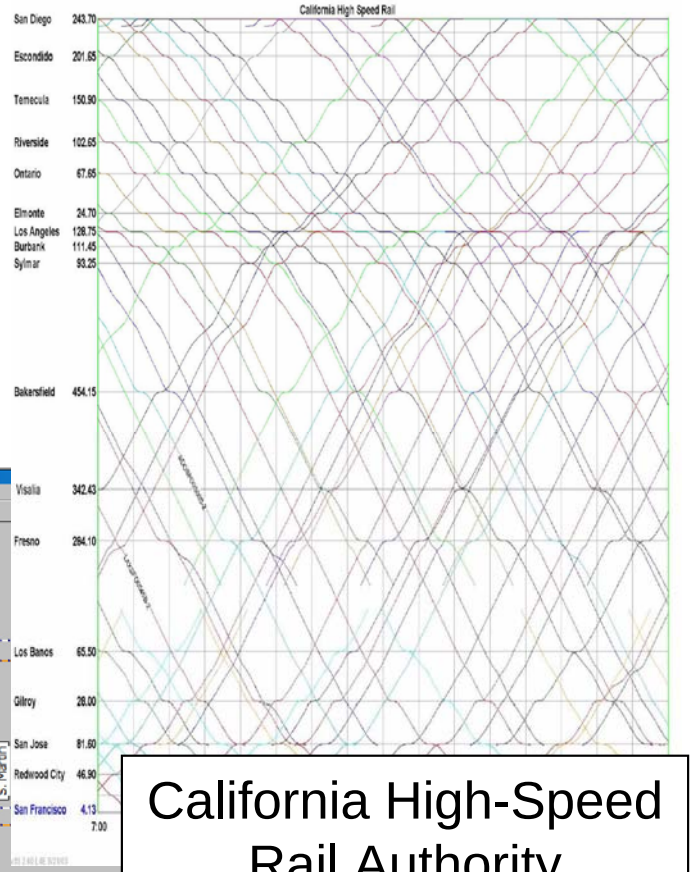
Industry-Standard Software



CREATE



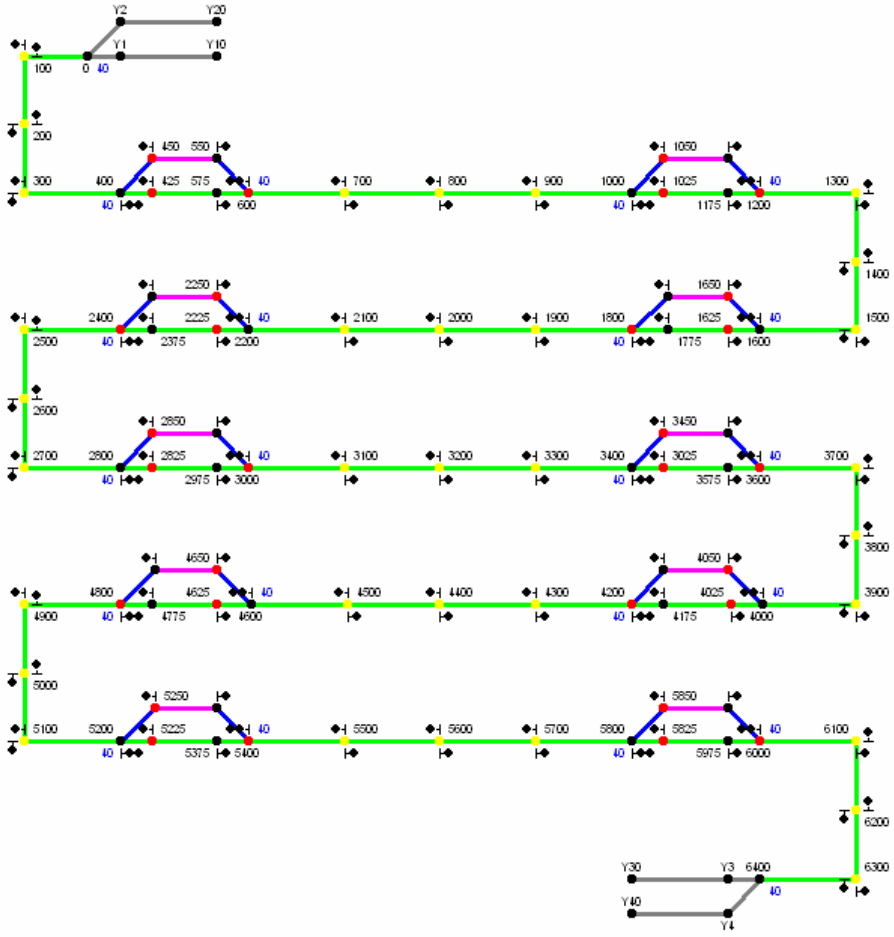
Los Angeles—San Diego—San Luis Obispo Rail Corridor Agency



California High-Speed Rail Authority

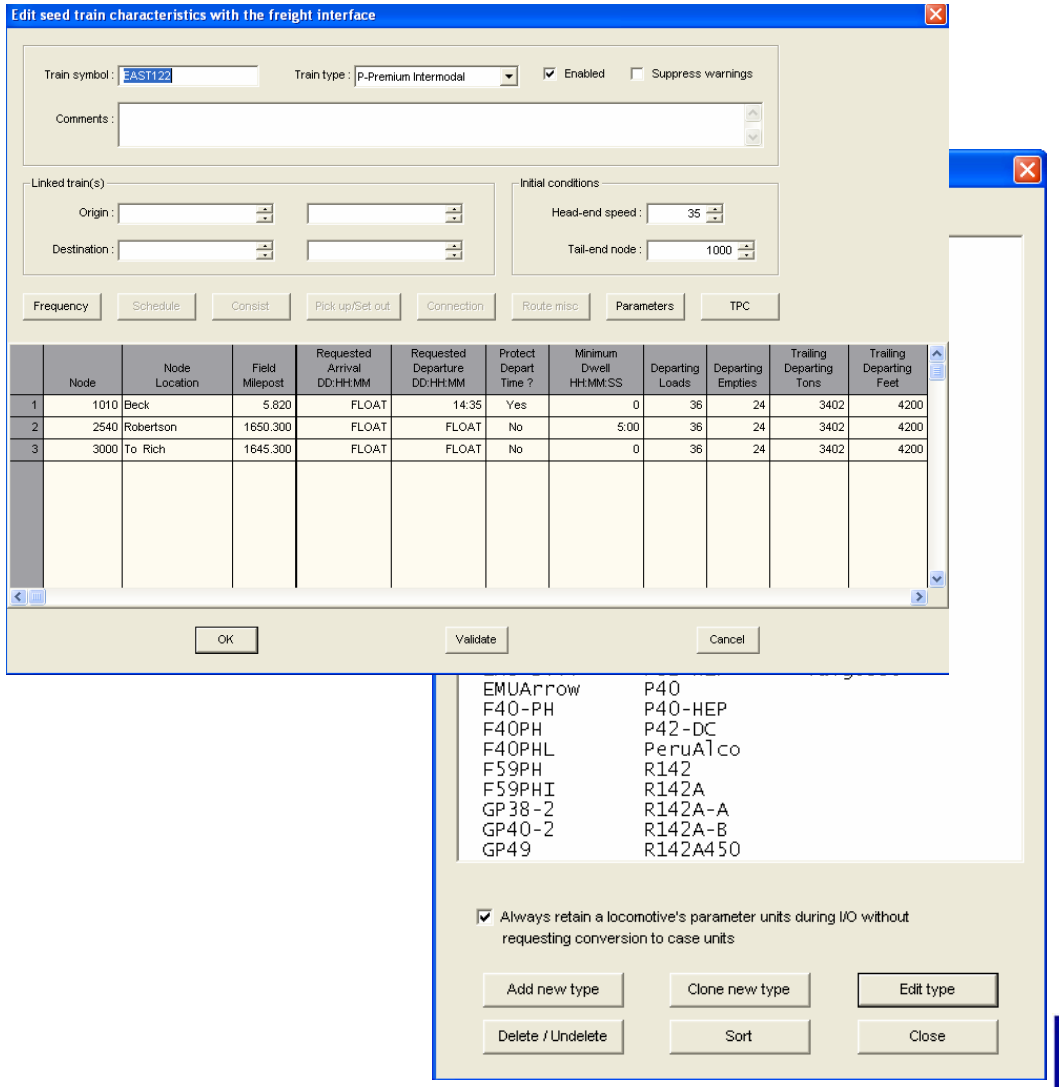
Network Inputs

- Track layout
  - Sidings
  - Turnouts
  - Crossovers
  - Interlockings
  - Switch types
- Signals
  - Absolute and permissive



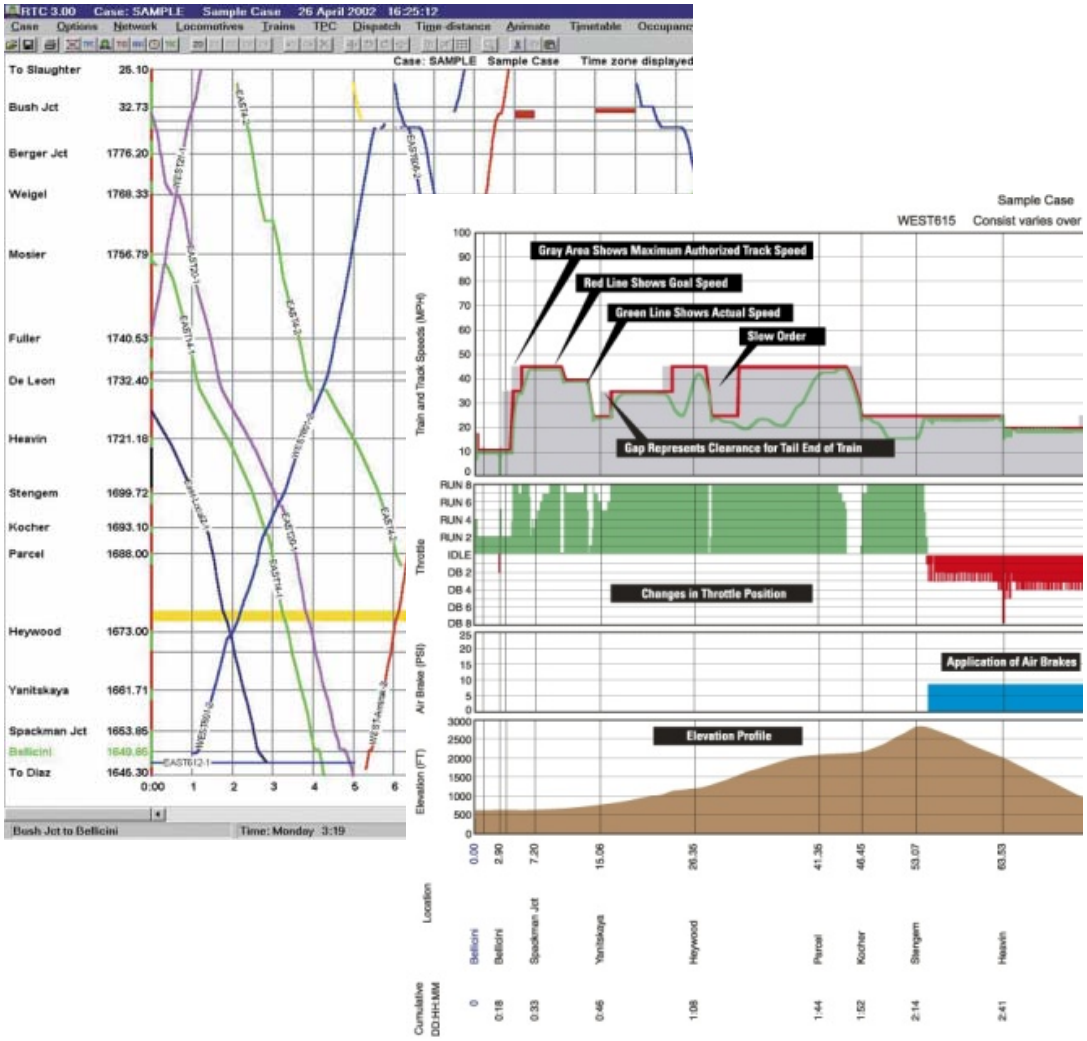
Train Inputs

- Locomotives
  - Type
  - Number
  - Position in train
- Consists
  - Loads
  - Empties
  - Tons
  - Feet
  - Special instructions
- Schedules
  - Departure
  - Arrival
  - Protected times



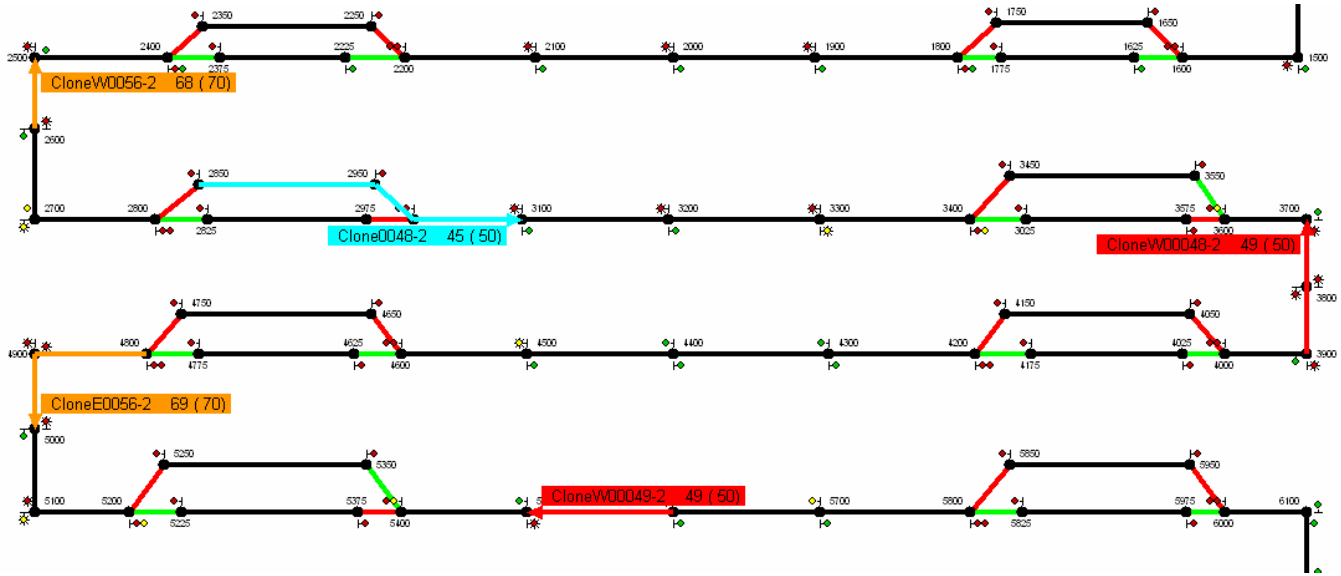
Outputs

- Graphical Outputs
  - Time-distance graphs
  - Timetables
  - Train Performance Calculator (TPC)
  - Animations
- Textual Outputs
  - Reports for each train
  - Detailed delay Information



Research Methodology

- Create generic route to represent a conventional subdivision
- Conduct scenarios with different train types and dispatching sequences
- Quantify the results to evaluate the impact of heterogeneity



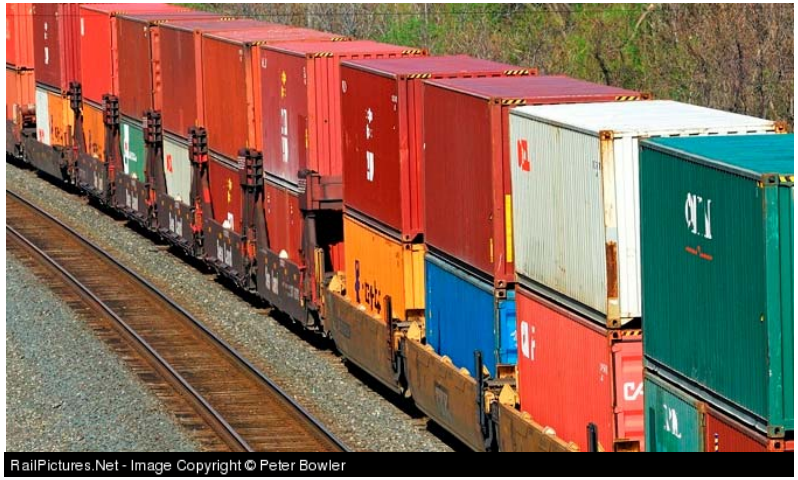
Representative Route

- Single Track
- 124 miles
- 10 miles between sidings
- 2.5 miles signal spacing
- 3-aspect signaling
- 0% grade and curvature

Trains Used in Analysis

Intermodal

- 75 cars
- 5,250’
- 6,750 tons
- 3 SD70 4,300 HP Locomotives
- 1.91 HP/Trailing Ton
- Max Speed: 70 mph



Unit Coal

- 90 cars
- 4,950’
- 12,870 tons
- 3 SD70 4,300 HP Locomotives
- 1.00 HP/Trailing Ton
- Max Speed: 50 mph

Trains Used in Analysis

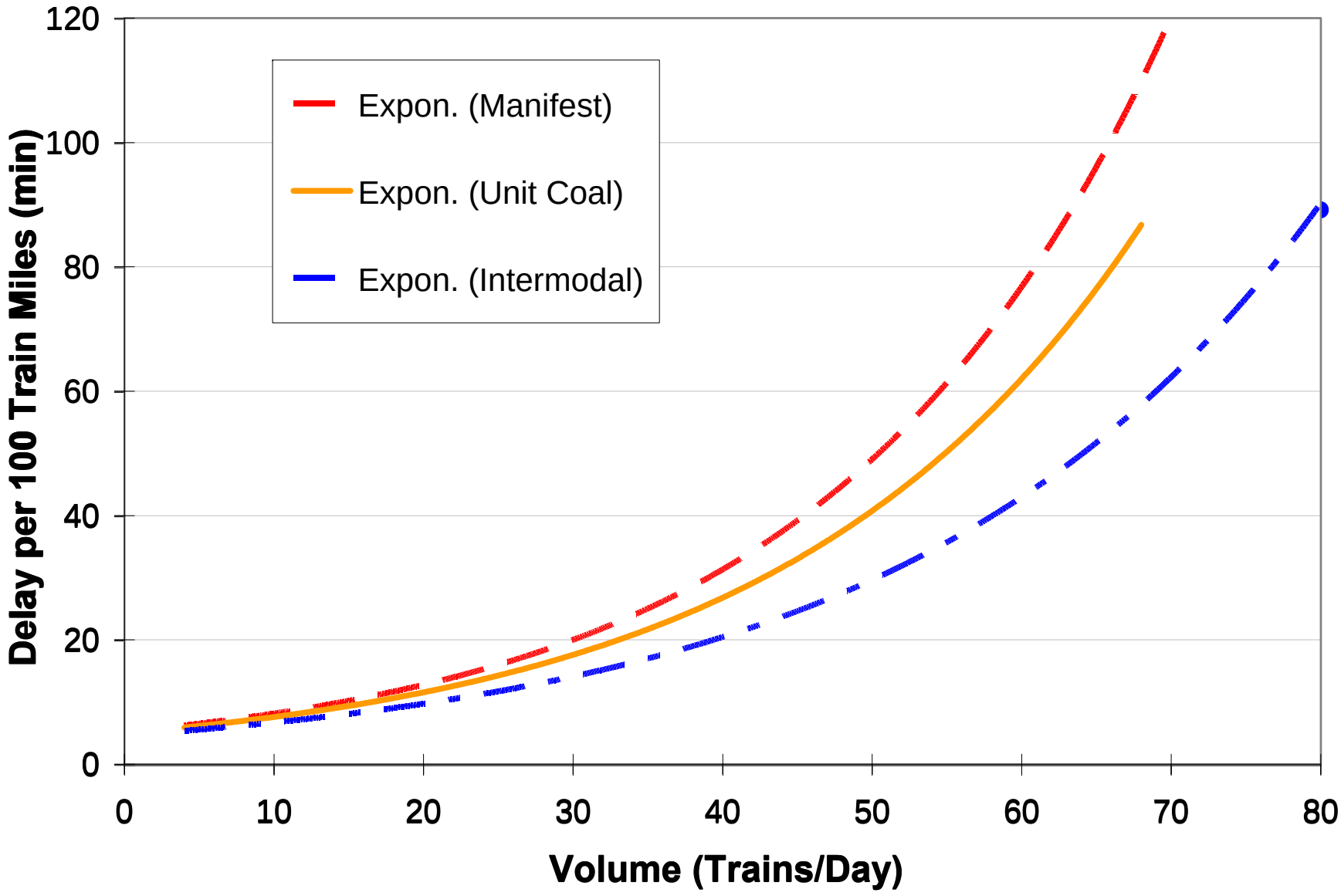
Manifest

- 70 cars
- 4,550’
- 7,700 tons
- 2 SD70 4,300 HP Locomotives
- 1.12 HP/Trailing Ton
- Max Speed: 60 mph

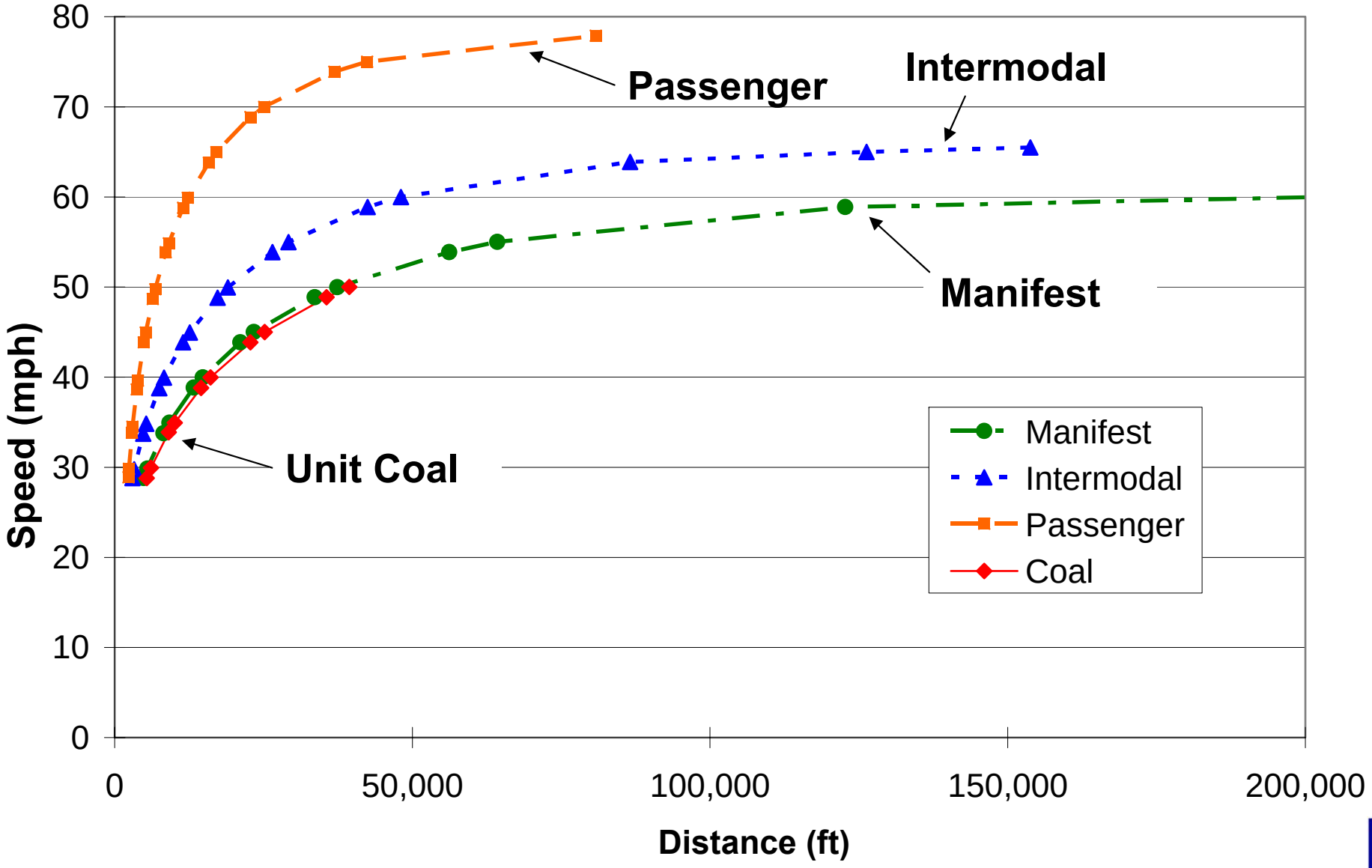
Passenger

- 20 coaches
- 1,500’
- 835 tons
- 1 P42-DC 4,250 HP Locomotive
- 5.09 HP/Trailing Ton
- Max Speed: 79 mph

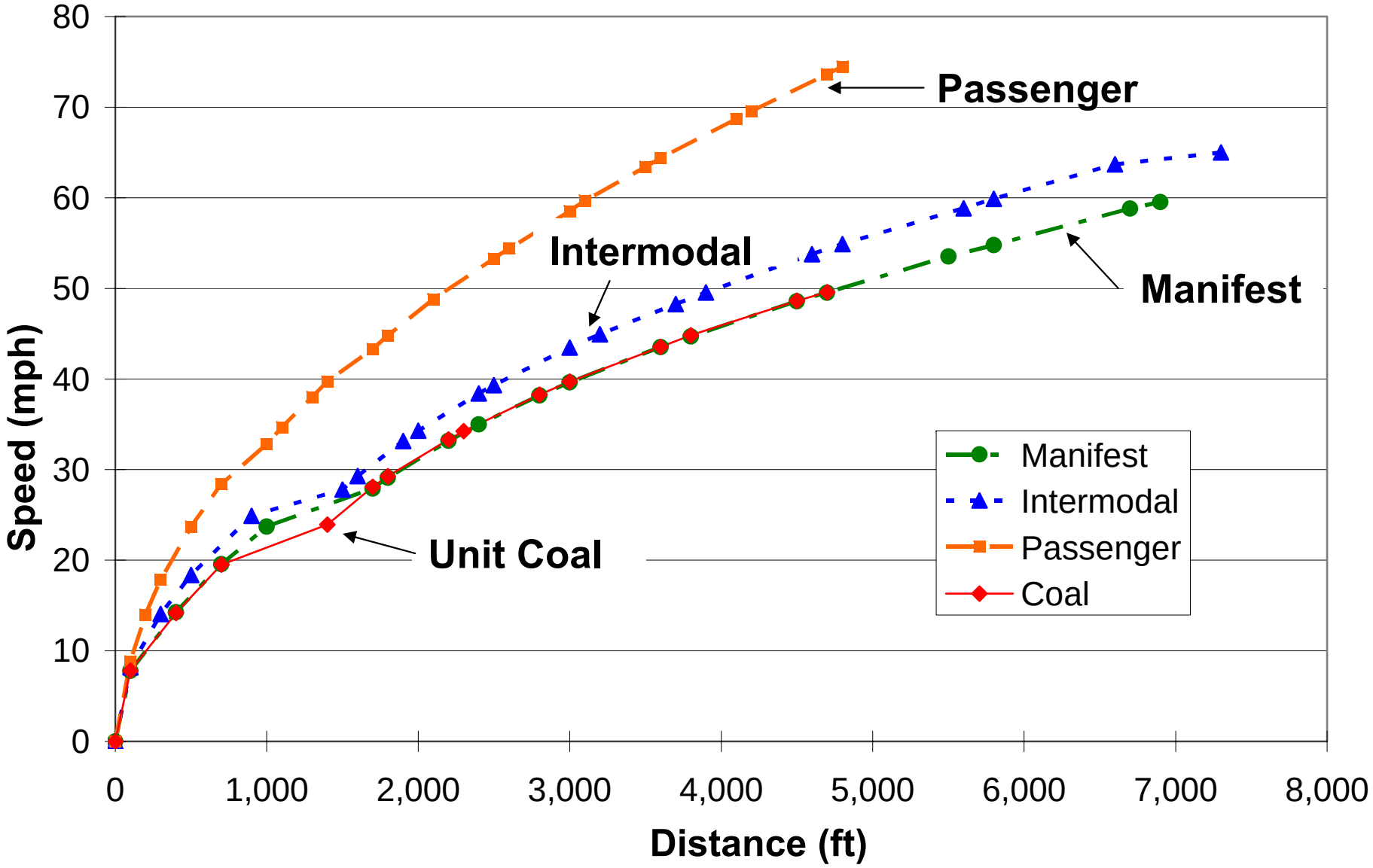
Delay-Volume Relationship



Acceleration Distances

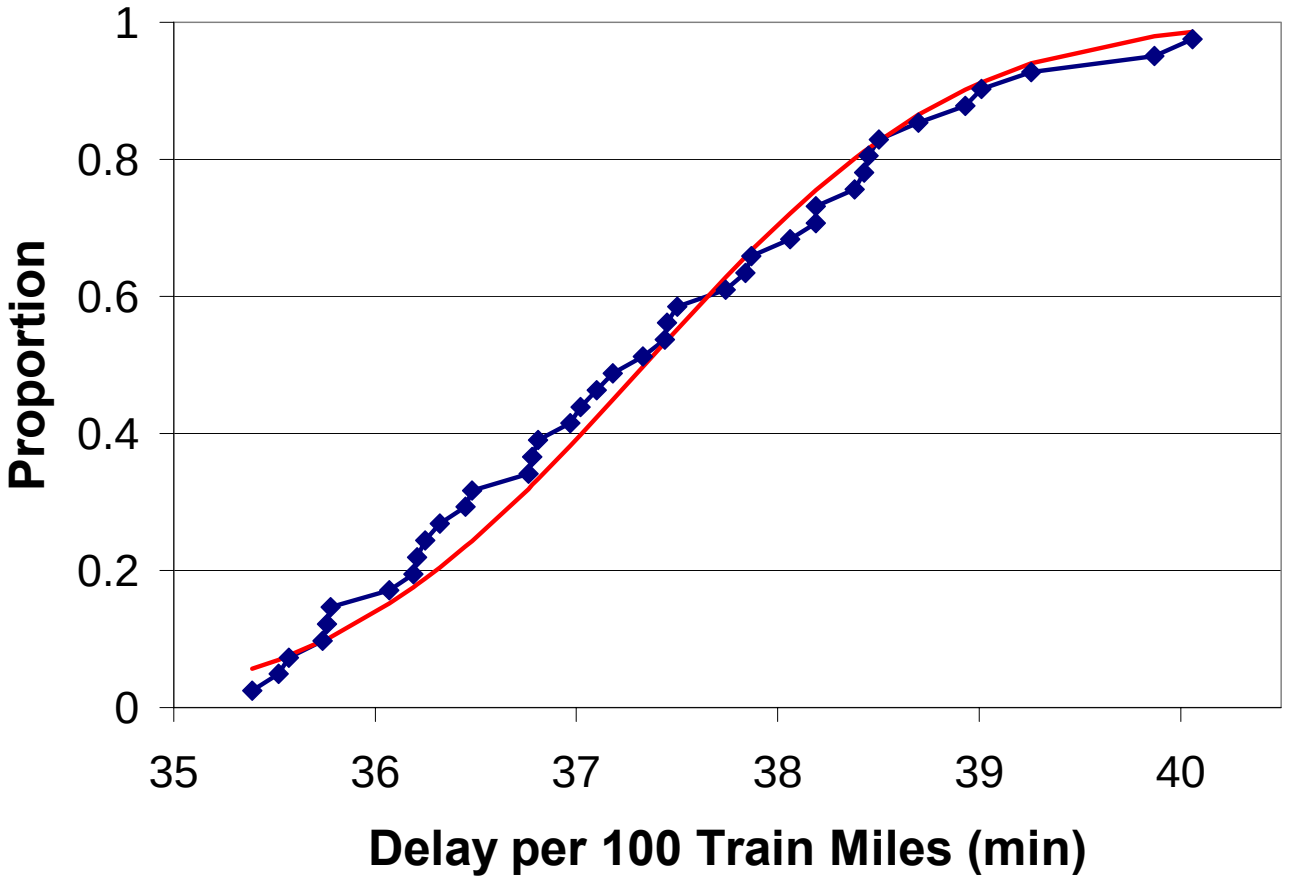


Braking Distances



Characteristics of Randomness

- Departure times evenly distributed randomly ± 5 minutes
- Resulting delays follow normal distribution
- Verified under Kolmogorov-Smirnov test

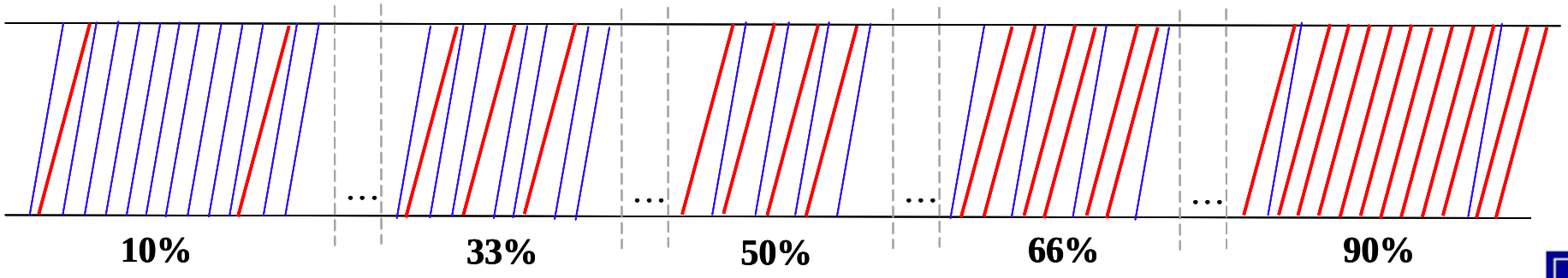


Freight Heterogeneity Study

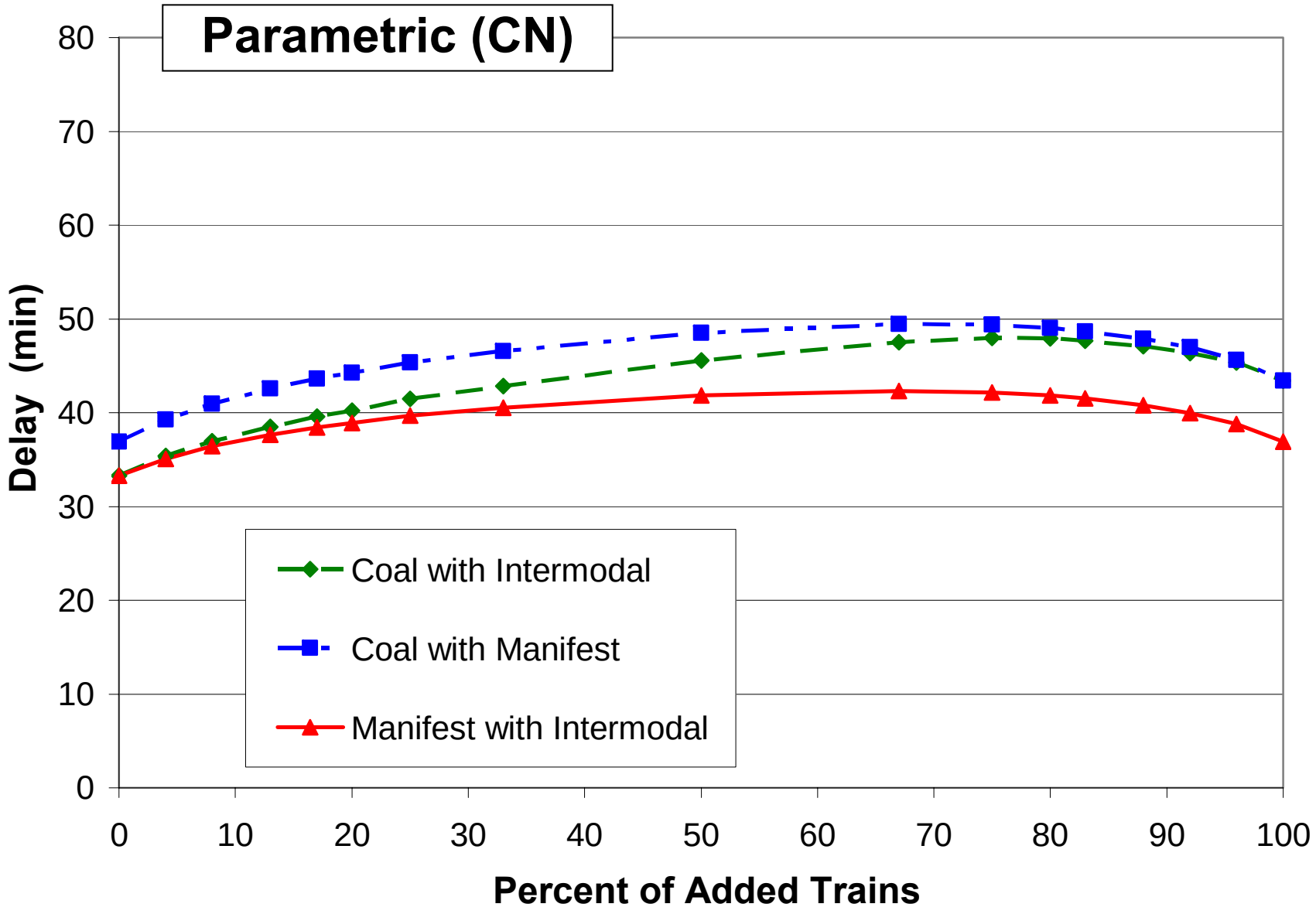
- 3 freight-train types
  - Intermodal
  - Manifest
  - Unit Coal
- Evenly spaced over 24 hours
- Identical schedule in each direction

Heterogeneity Scenarios

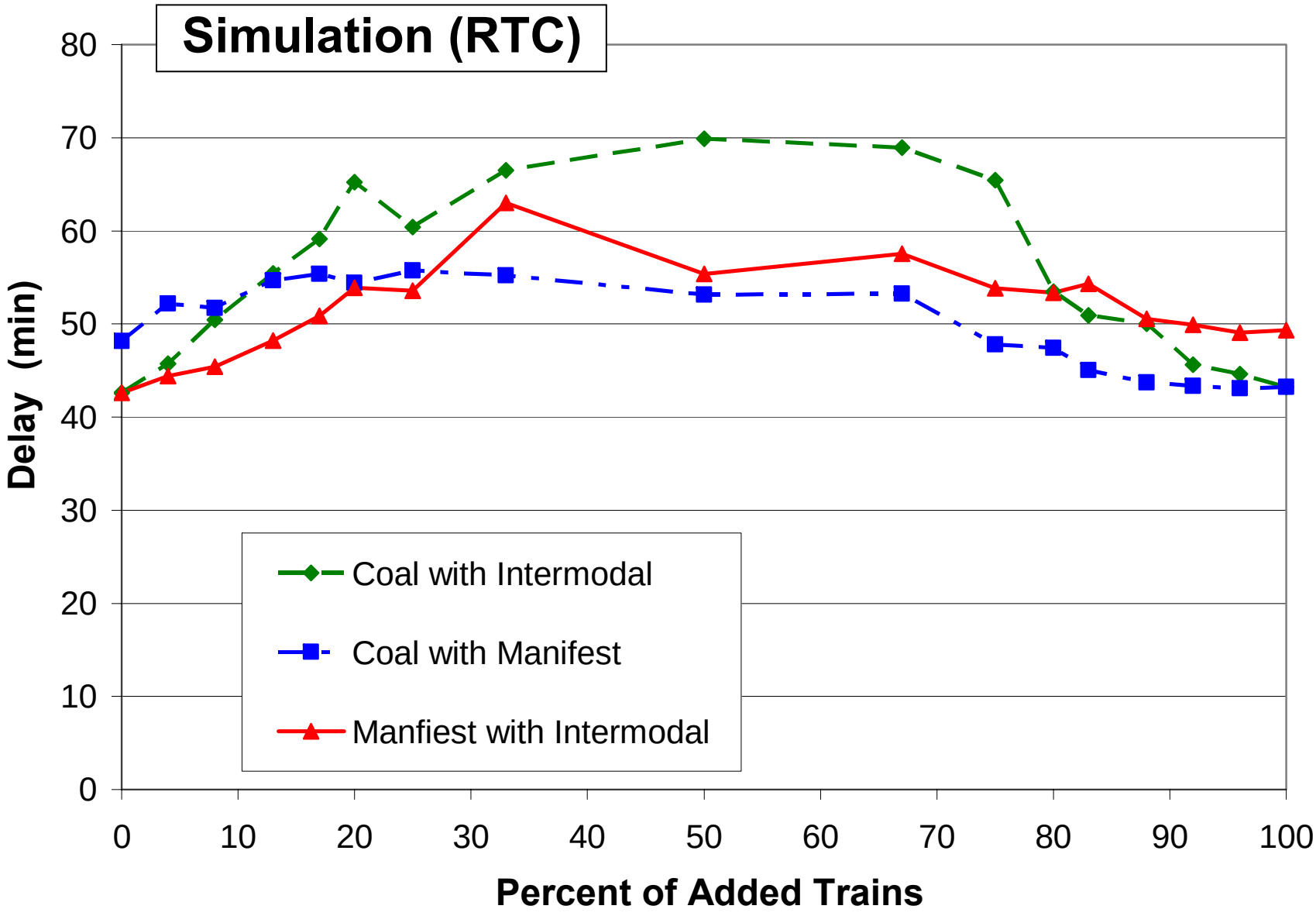
- Parameters Tested
  - Train Combination
    - Pairwise combinations of train types
  - Volume
    - 28, 34, 40 and 46 trains per day
  - Different levels of heterogeneity
    - Heterogeneity corresponds to ratio of each train type



CN Parametric Model Results



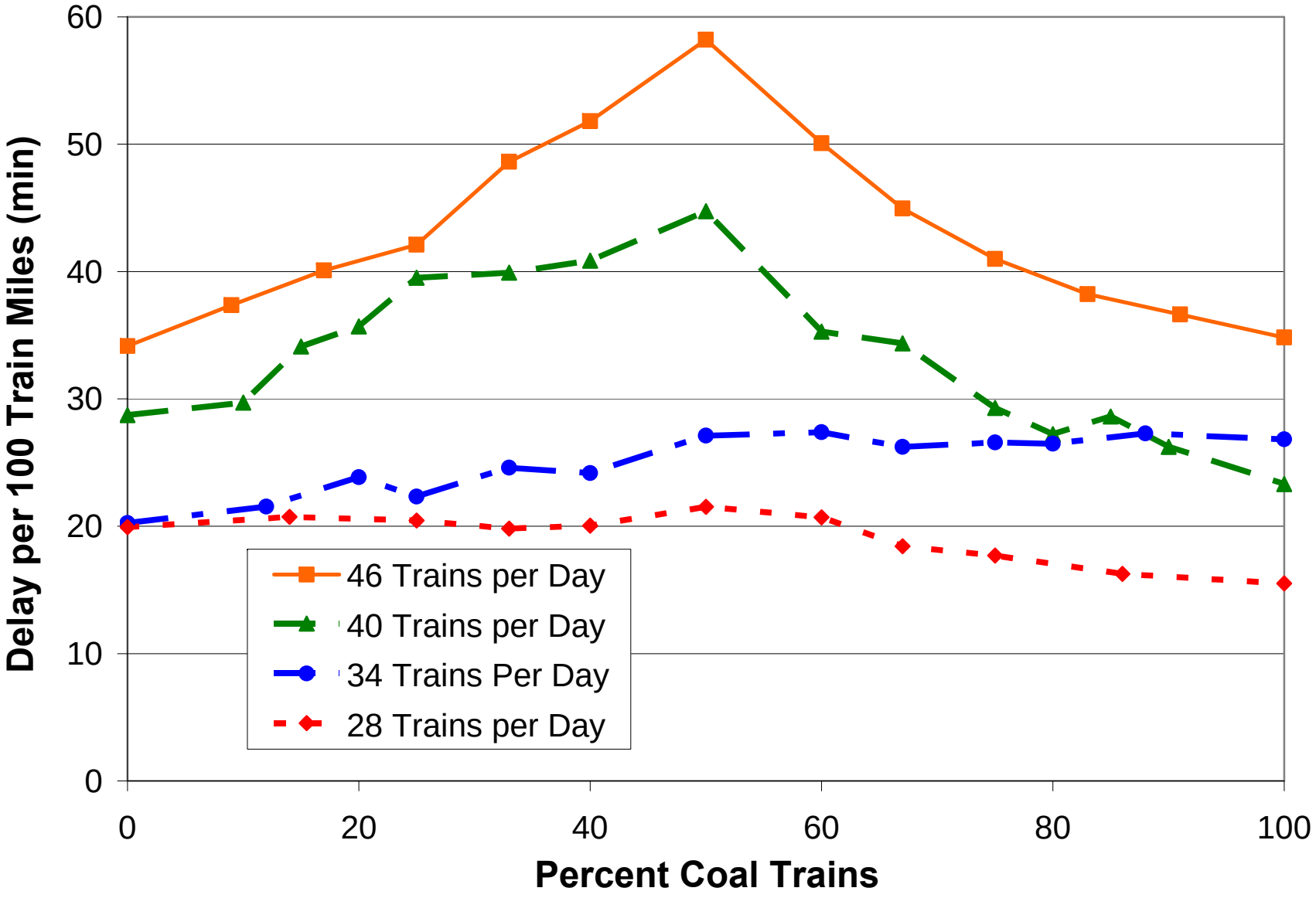
RTC Simulation Results



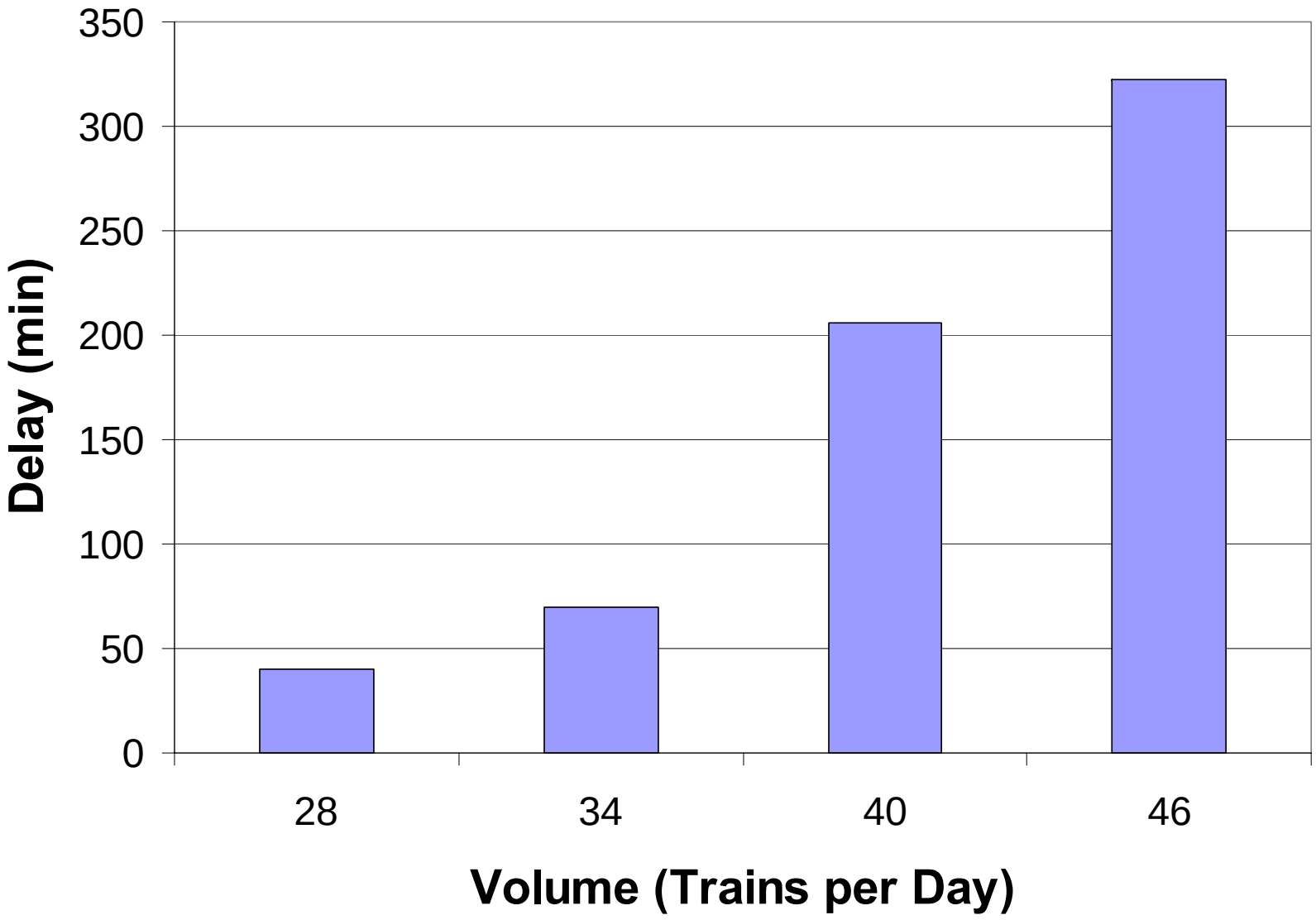
Use of Parametric Model for Heterogeneity Analysis

- Parametric model excels at providing a fast way to estimate the delay and the resulting capacity on a line with limited heterogeneity
  - Good for network-level analysis
  - Average speed calculated based on minimum run times of different train types
    - Does not account for meets or passes
    - Does not account for fine-grained characteristics of train performance
- Study objective is to assess effect of detailed train performance characteristics
  - Requires use of simulation model

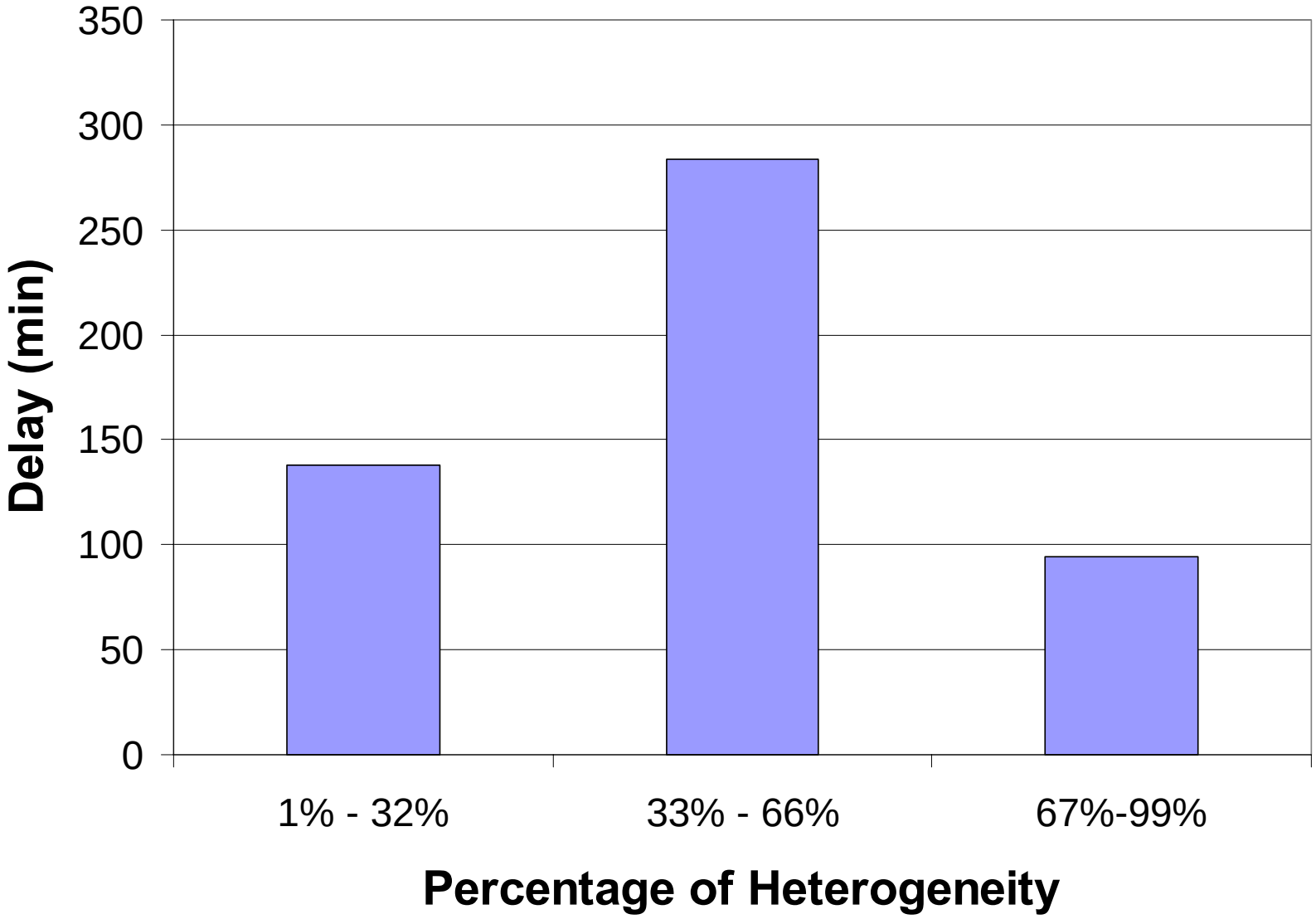
Effect of Heterogeneity and Density on Delay



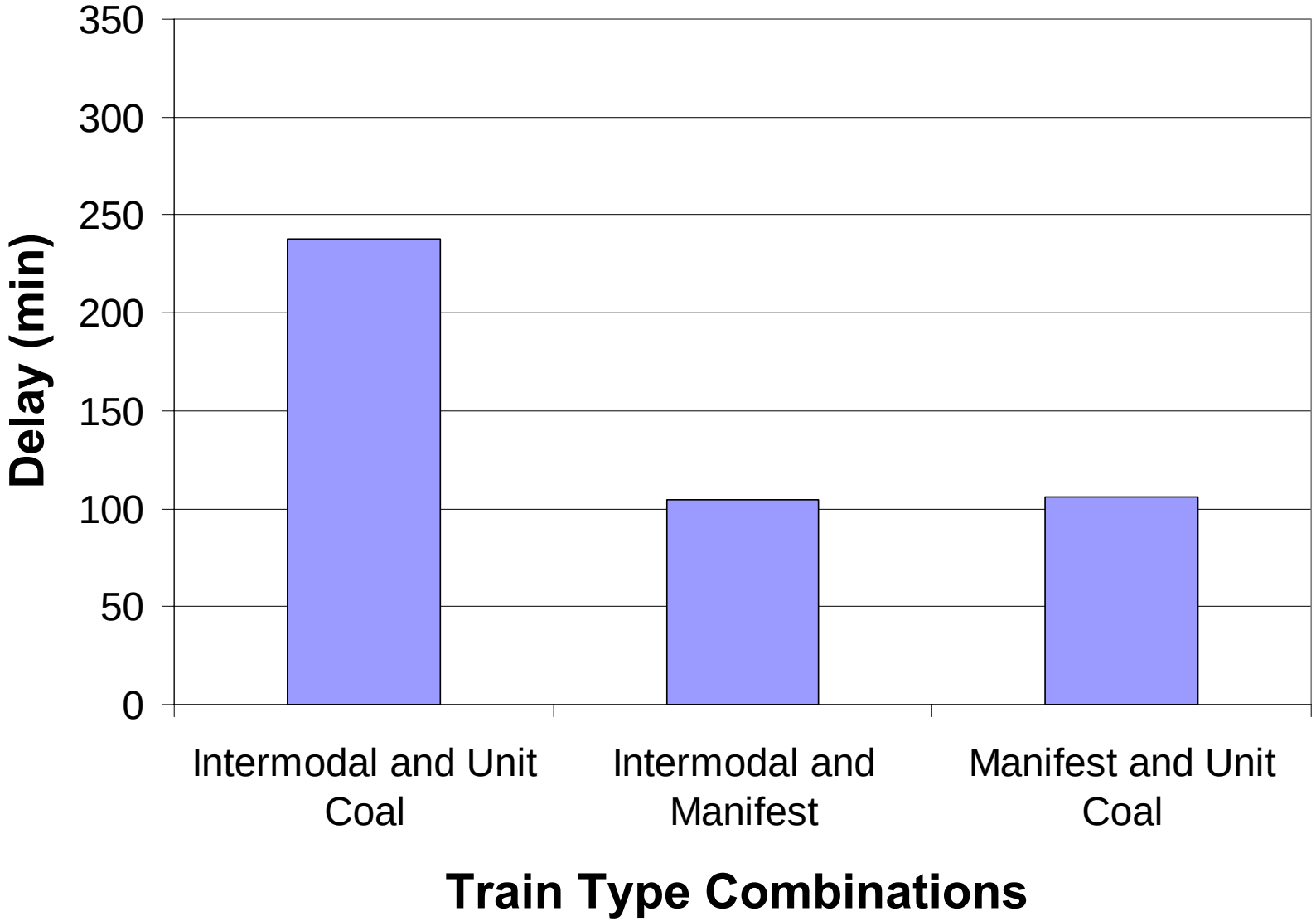
Increase in Delay due to Volume



Increase in Delay due to Percentage of Heterogeneity



Increase in Delay due to Train Type Combinations

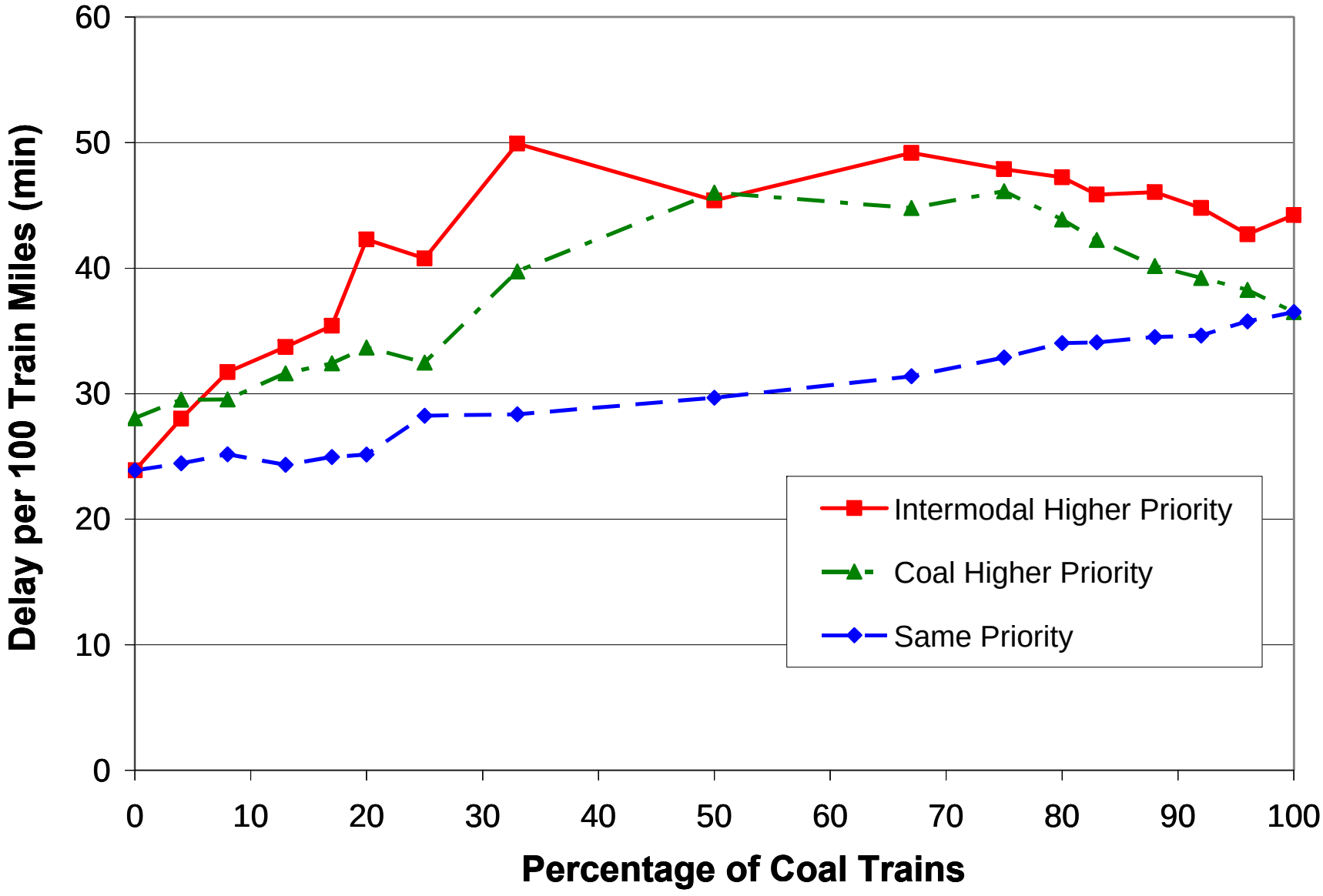


Specific Factors Affecting Heterogeneity

- Intermodal and Coal trains have highest delays, but why?
  - Priority?
  - Physical train characteristics (HPT, tonnage)?
  - Speed Difference?

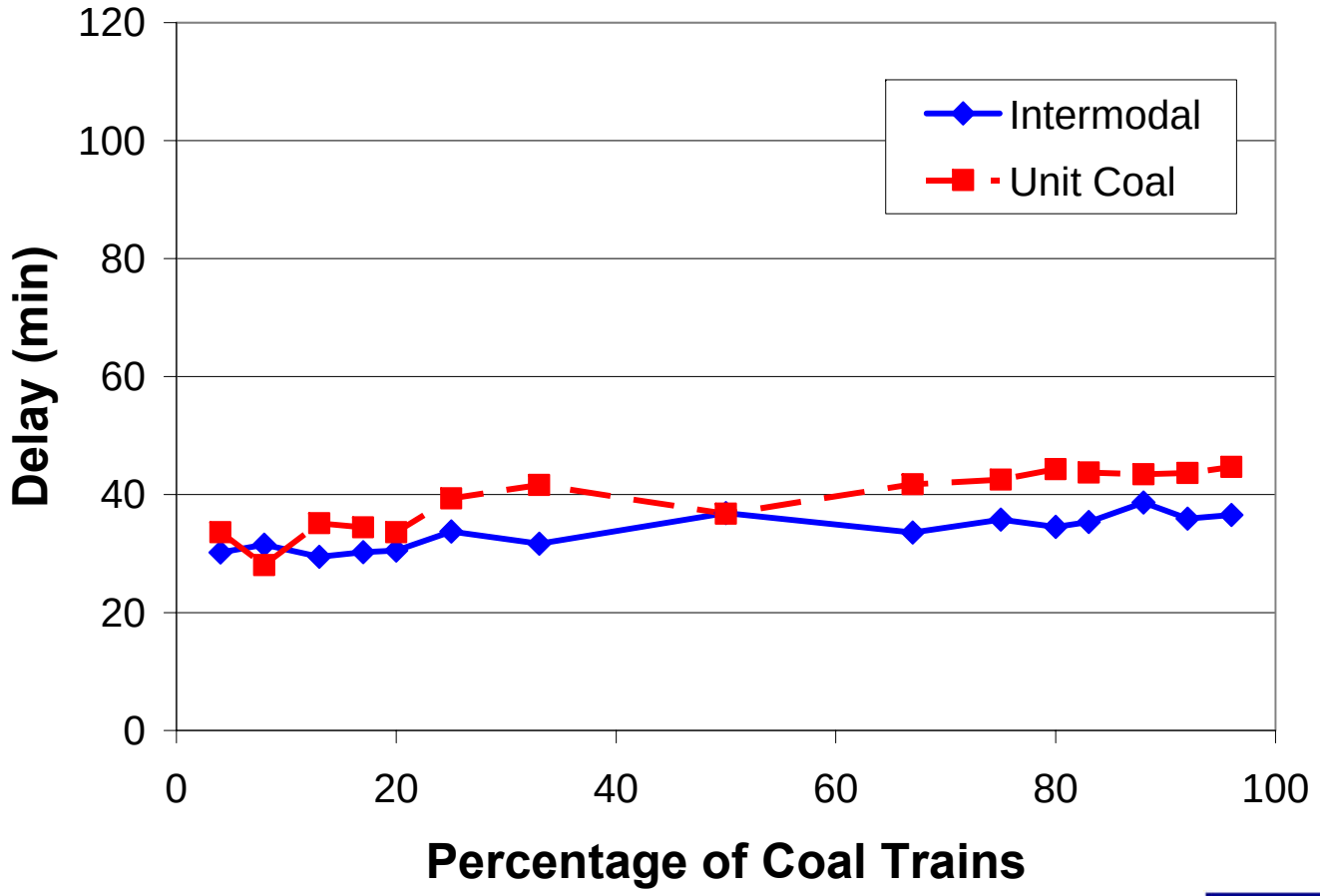
- Analyzed at mix of Intermodal and Unit-Coal at 46 trains per day

Train Characteristics vs. Priority



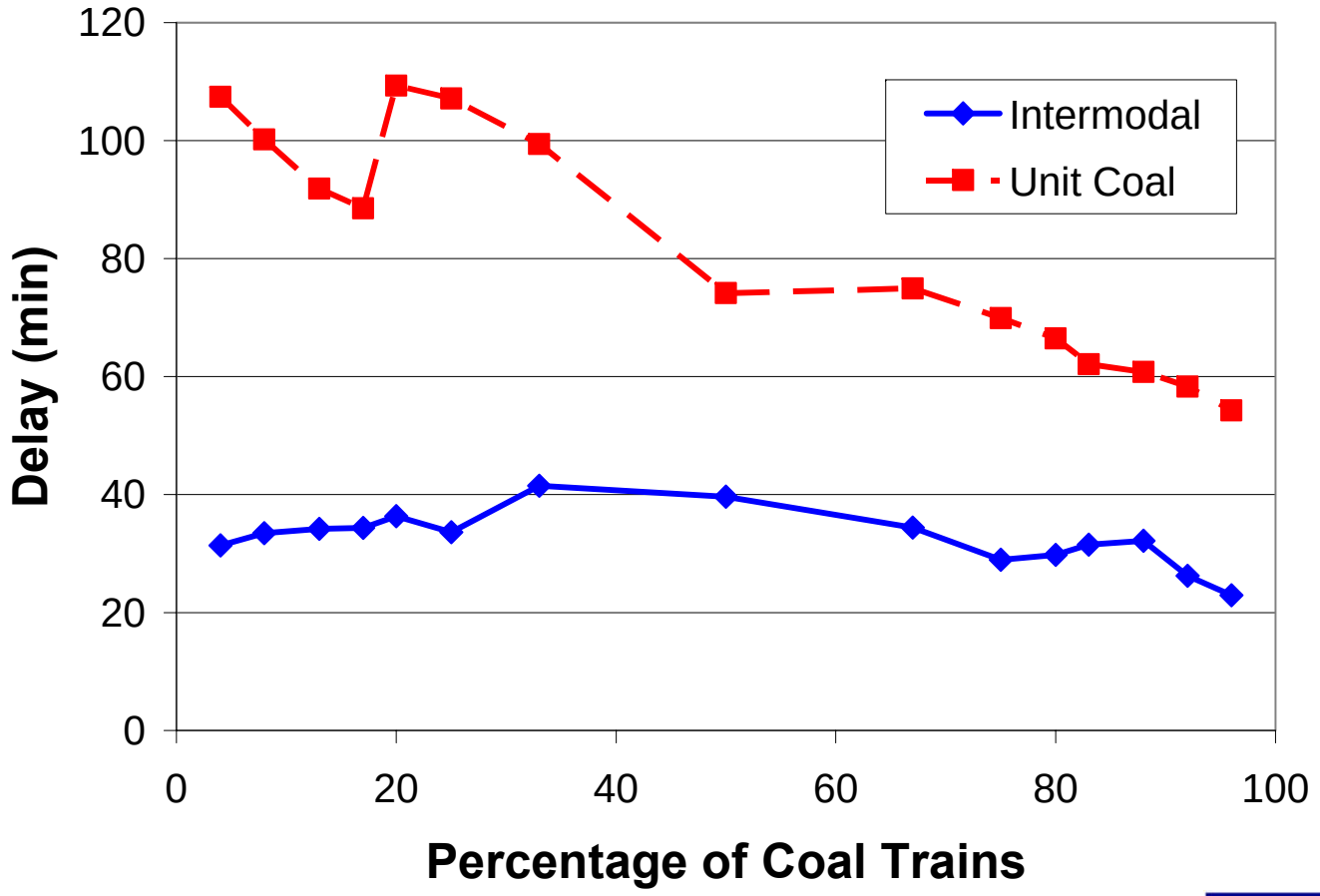
Delay of Specific Train Types When Priorities are the Same

- Minimal Difference in Delay
- Average Delay of 37 Minutes



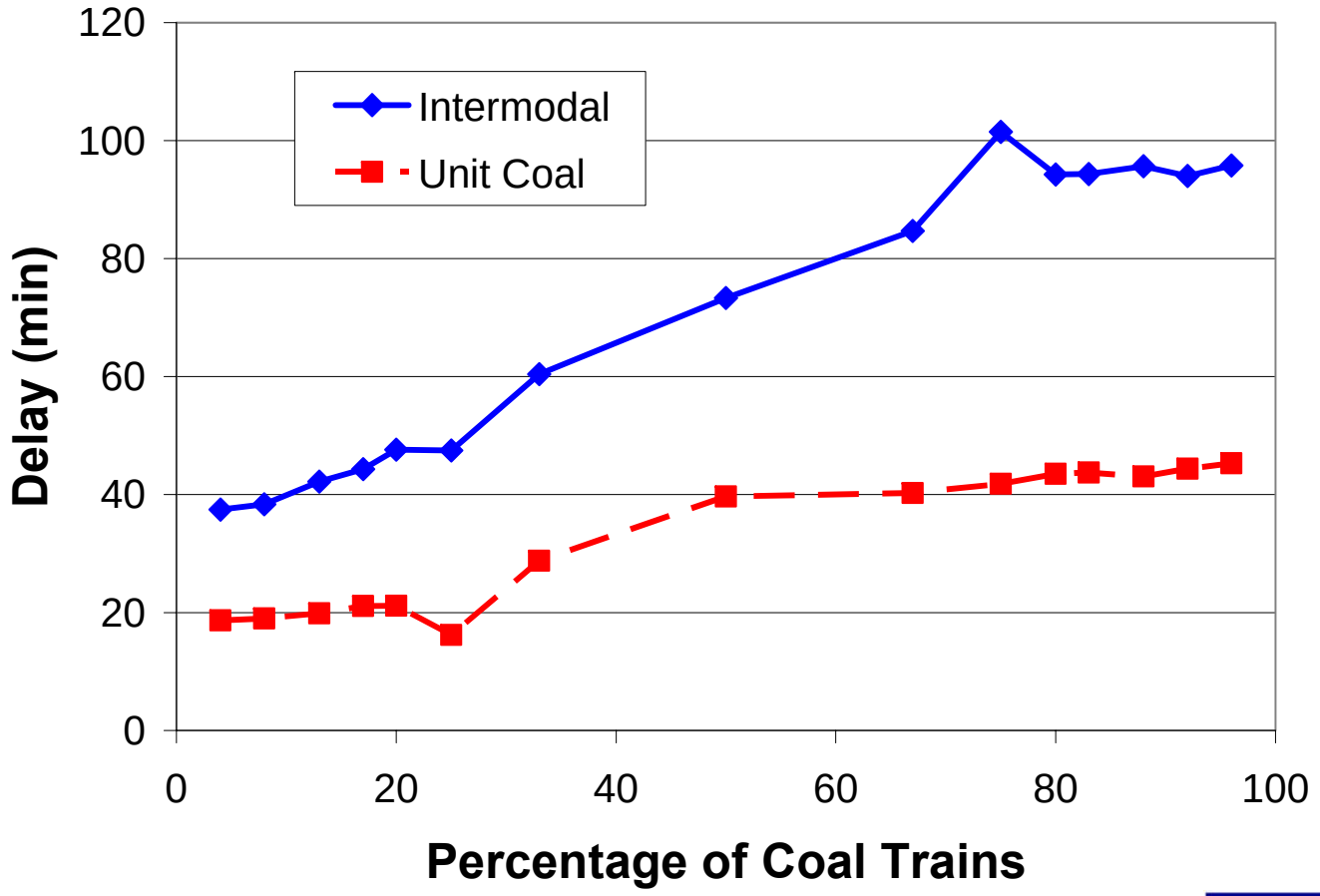
Delay of Specific Train Types When Intermodal Has Higher Priority

- 40-Minute Increase in Average Delay for Unit Coal
- 1-Minute Decrease in Average Delay for Intermodal
- Average Delay of 51 Minutes



Delay of Specific Train Types When Unit Coal Has Higher Priority

- 34-Minute Increase in Average Delay for Intermodal
- 6-Minute Decrease in Average Delay for Unit Coal
- Average Delay of 46 Minutes



Impacts due to Freight Heterogeneity

- Two ways to consider impacts:
  - **Train Starts**
    - Compare delays to delay-volume graph in homogeneous conditions
  - **Delay Cost**
    - Cost incurred by the railroad due to delay
- Results specific for this model but provides idea of magnitude

Train Starts Lost due to Heterogeneity

- From delay-volume curve at 46 intermodal trains per day the delay is 35 minutes
- A traffic mix of 50% intermodal and 50% unit coal increases delay 100%, up to 70 minutes.
- If the traffic was homogenous the lost capacity is:
  - 24 intermodal trains
  - 16 unit coal trains

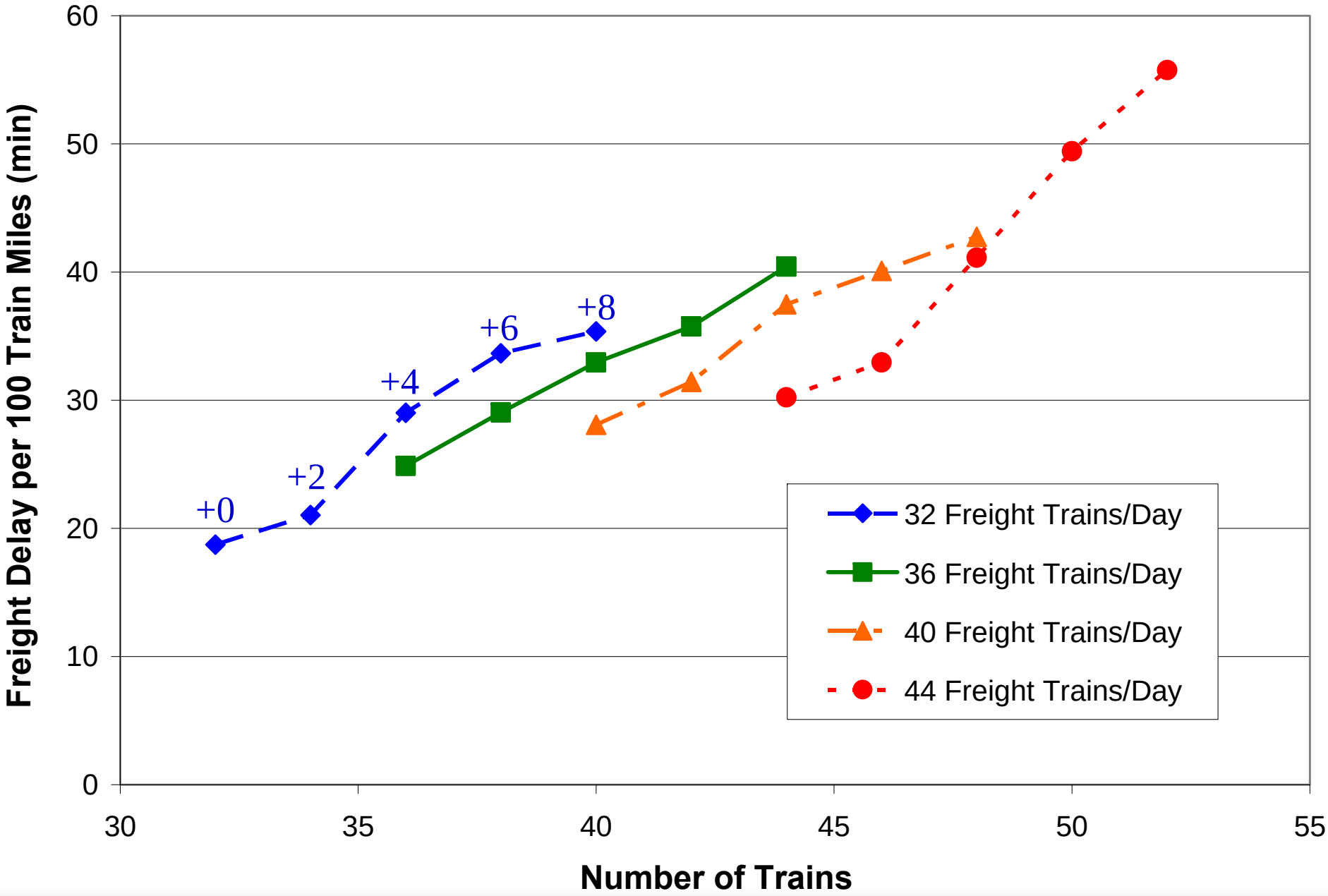
Delay Cost due to Heterogeneity

- Four components of cost
  - Unproductive locomotive cost
  - Idling fuel cost
  - Car/equipment cost
  - Crew cost
- Estimated at $261 per train-hour
- 46 Trains per day (50% Intermodal, 50% Unit Coal)
  Total annual cost = $1.8 million

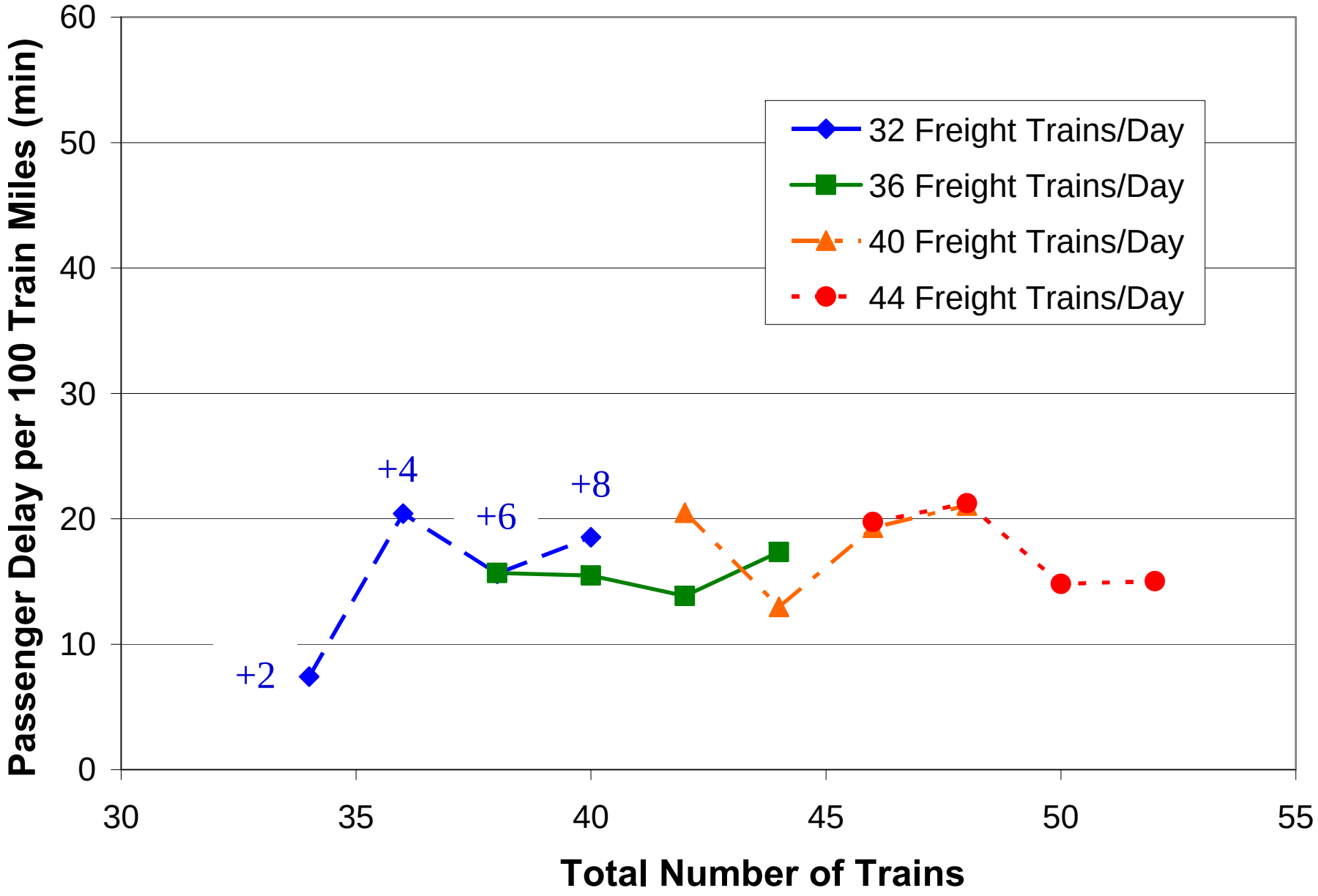
Passenger Heterogeneity Study

- Passenger trains added to base levels of freight
  - 80% manifest
  - 20% intermodal
- Pairs of passenger added
  - Evenly spaced
  - Up to 4 in each direction (8 total)

Delay to Freight Trains



Delay to Passenger Trains



Conclusion

- Costs of heterogeneity are significant
- Impacts of freight heterogeneity dependent on level of:
  - Heterogeneity
  - Volume of traffic
  - Priority
- Impact of passenger traffic causes greater impact then corresponding number of freight trains

Future Work

- Perform economic analysis of possible mitigation techniques
- Perform heterogeneity study with double track model
- Analyze impacts of commuter rail

Acknowledgments

- Support and assistance from Eric Wilson of Berkeley Simulation Software and Harald Krueger of CN
- Support from CN Graduate Research Fellowship in Railroad Engineering
- Dr. Chris Barkan and Dr. Yung-Cheng Lai

Rail Traffic Controller™

CN

ILLINOIS
RAILROAD ENGINEERING PROGRAM

Speed Ratio vs. Speed Difference

- Four scenarios simulated
  - Two with a *Speed Difference* of 10 mph
  - Two with the same *Speed Ratio* as the two with the same speed difference
- Compared correlation coefficients of the train delays

	Speed Ratio		Δ Speed
Intermodal and Unit Coal	0.899	0.900	0.814
Manifest and Unit Coal	0.214	0.514	0.289
Intermodal and Manifest	0.878	0.864	0.806
Intermodal and Intermodal	0.378	0.675	-0.200