

**Delayer Pays Principle:**  
**Examining Congestion Pricing with**  
**Compensation**

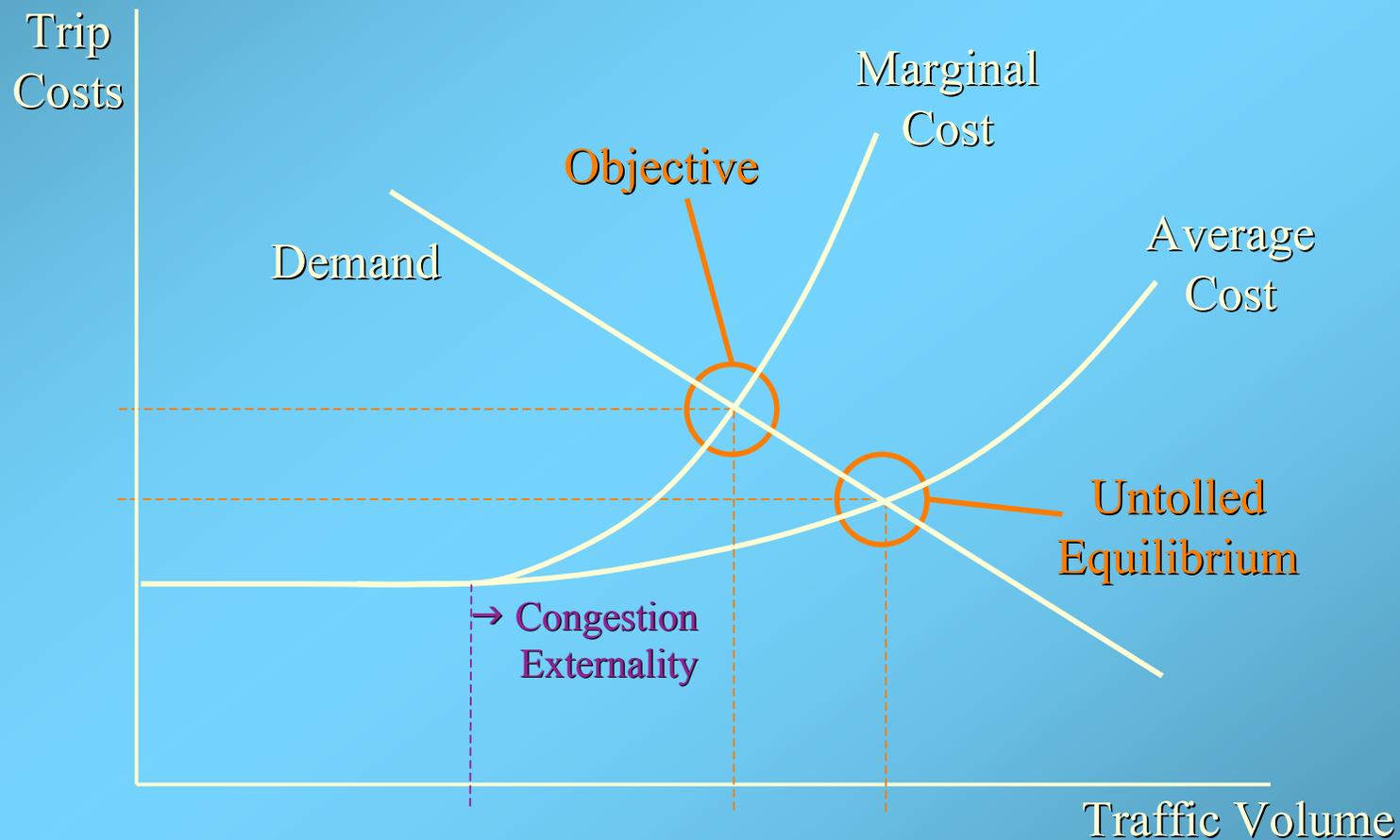
*By Peter Rafferty, P.E., SEH Inc. and*

*David Levinson, Ph.D., University of  
Minnesota*

# *Abstract*

Despite its virtues, congestion pricing has yet to be widely adopted. This project explores the issues of equity and use of toll revenue and several possible alternatives. The equity and efficiency problems of conventional (uncompensated) congestion pricing are outlined. Then, several alternatives are discussed and developed. A new compensation mechanism is developed, called the "delayer pays" principle. This principle ensures that those who are undelayed but delay others pay a toll to compensate those who are delayed. We evaluate the effectiveness of this idea by simulating alternative tolling schemes and evaluating the results across several measures, including delay, social cost, consumer surplus, and equity. Different tolling schemes can satisfy widely varying policy objectives, thus this principle is applicable in diverse situations. Such a system is viable and can eliminate some common hurdles of congestion pricing – while remaining revenue neutral.

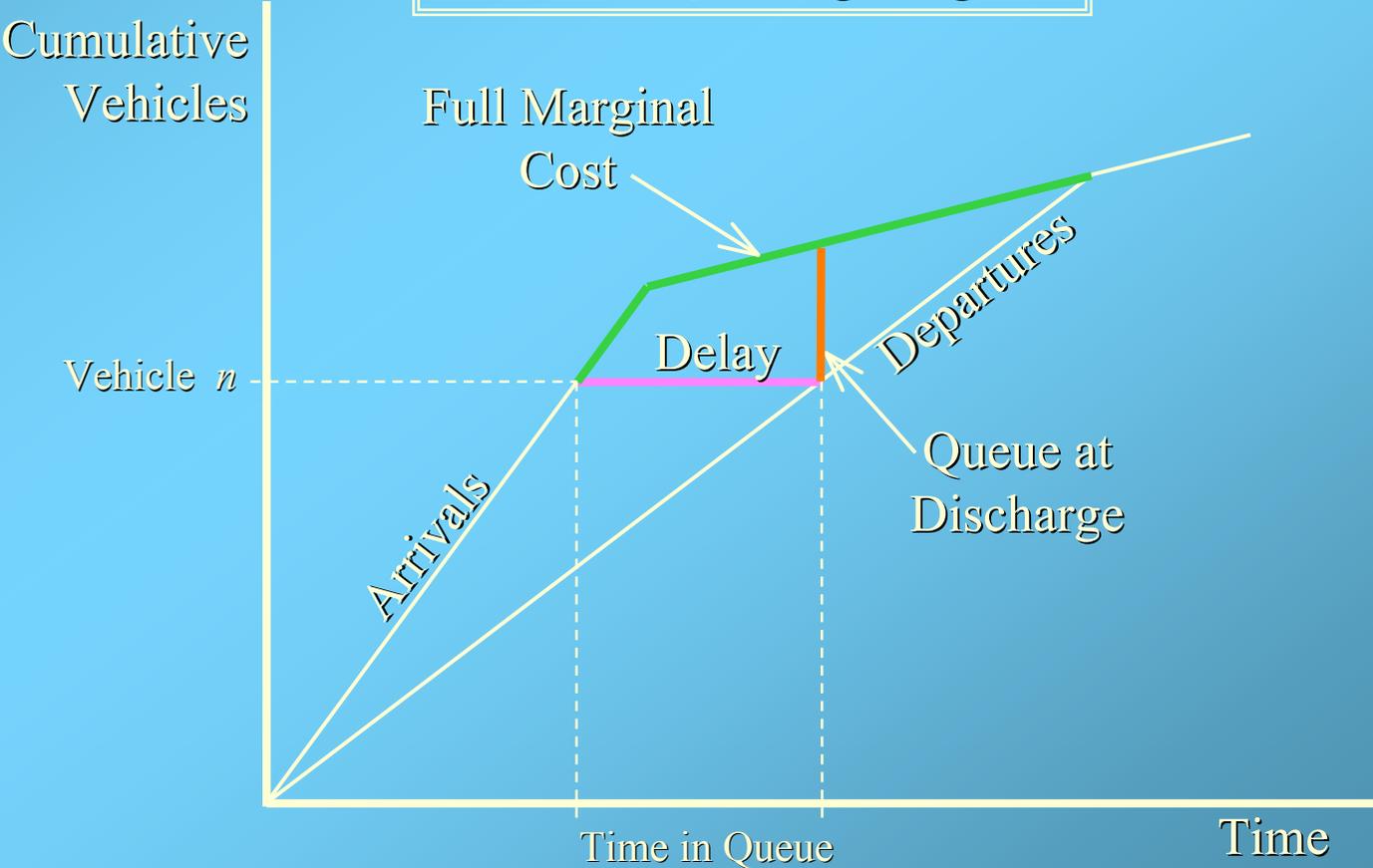
# Congestion Pricing Brings About Efficient Equilibrium



# *Critical to Identify the Full Marginal Costs*

- Average Cost: Time delayed, or spent in queue – caused by vehicles arriving before vehicle  $n$ .
- Incomplete Marginal Cost: Queue at discharge, sometimes estimated by time delayed.
- Full Marginal Cost: Incremental delay caused to every vehicle arriving after vehicle  $n$ . Estimated by considering total cost savings in vehicle's absence.
- Positive Toll: Each delayer pays a toll proportional to their full marginal cost.
- Compensation: Motorists are compensated for the delay they experience. The delayers pay the delayed, though indirectly. The transaction agent estimates the positive toll and compensation, and the user sees only the net toll.

# Standard Queuing Diagram



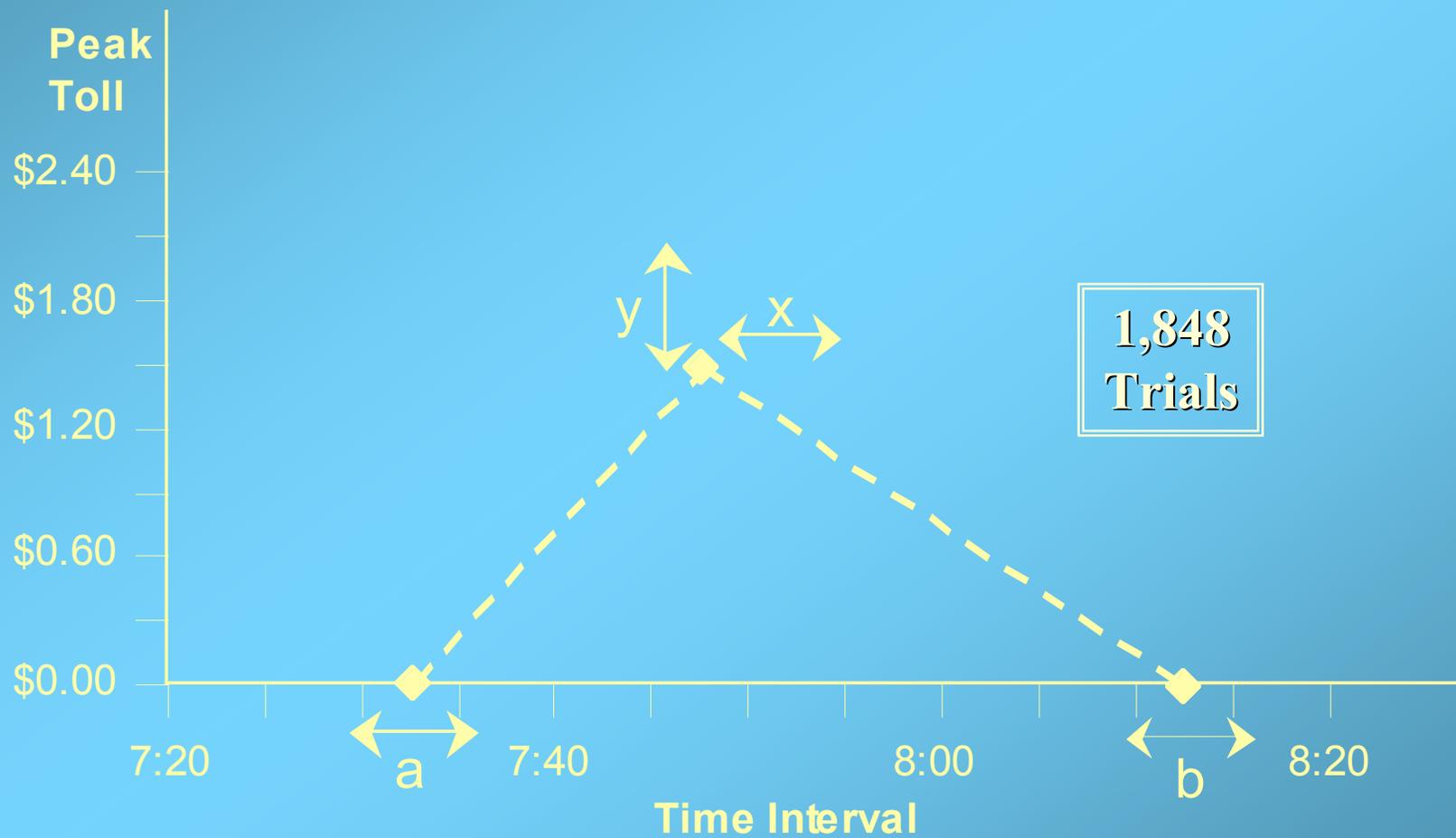
# *Seven Policy Objectives*

-  **Total Delay:** Reduce relative to untolled condition
-  **Schedule Delay:** Reduce relative to untolled condition
-  **Total Toll:** Minimize, but must remain positive
-  **User Cost:** Reduce relative to untolled condition
-  **Social Cost:** Reduce relative to untolled condition, sum of Total Delay and Schedule Delay
-  **Equity:** Improve relative to untolled condition, estimated with the Gini coefficient
-  **Consumer Surplus:** Improve relative to untolled condition, estimated with the LogSum value

# Experimental Model

- Electronic tolling, necessary to minimize transaction costs
  - Drivers seek to maximize utility by minimizing travel costs
  - User/Travel costs include:
    - Schedule Delay – arriving early or late
    - Congestion Delay – travel time
    - Tolls
  - Tolls consist of three components:
    - Positive Toll – long-range marginal cost, the delay caused *to* others
    - Negative Toll – short-range marginal cost, delay caused *by* others
    - Base Toll - to ensure drivers cannot profit, also to cover administrative and operation costs
  - Toll is posted prior to decision point
- ## Bottleneck Model
- 8:00 AM desired passage time
  - One-hour analysis period
  - Five-minute intervals
  - Drivers choose from twelve periods
  - Assuming no change of route or mode
  - Values of time vary per activity
  - Utility function has a random component
  - Demand for each interval derived from logit probability
  - For each positive tolling scheme, equilibrium is reached through an iterative approach

# *Positive Toll Alternatives*



# Iterative Process for each Trial

## Specification:

- Demand Flow
- Bottleneck Capacity
- Desired Passage Time
- Unit Costs, Values of Time
- Tolls (positive and compensation)

Initialization

Determine Trip  
Cost for Each  
Interval ( $C_i$ )

Calculate  
Demand for Each  
Interval ( $V_i$ )

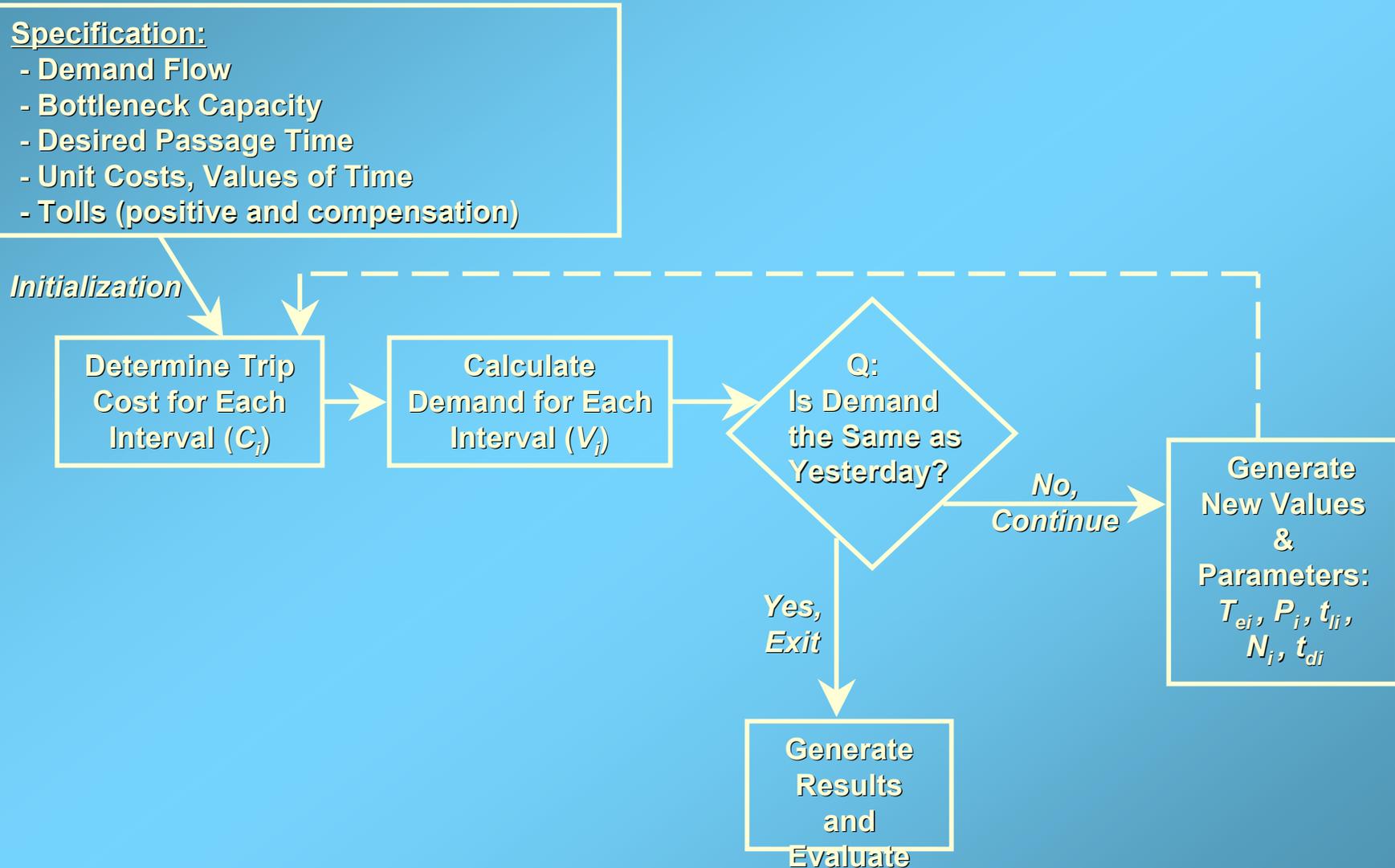
Q:  
Is Demand  
the Same as  
Yesterday?

No,  
Continue

Generate  
New Values  
&  
Parameters:  
 $T_{ei}, P_i, t_{li},$   
 $N_i, t_{di}$

Yes,  
Exit

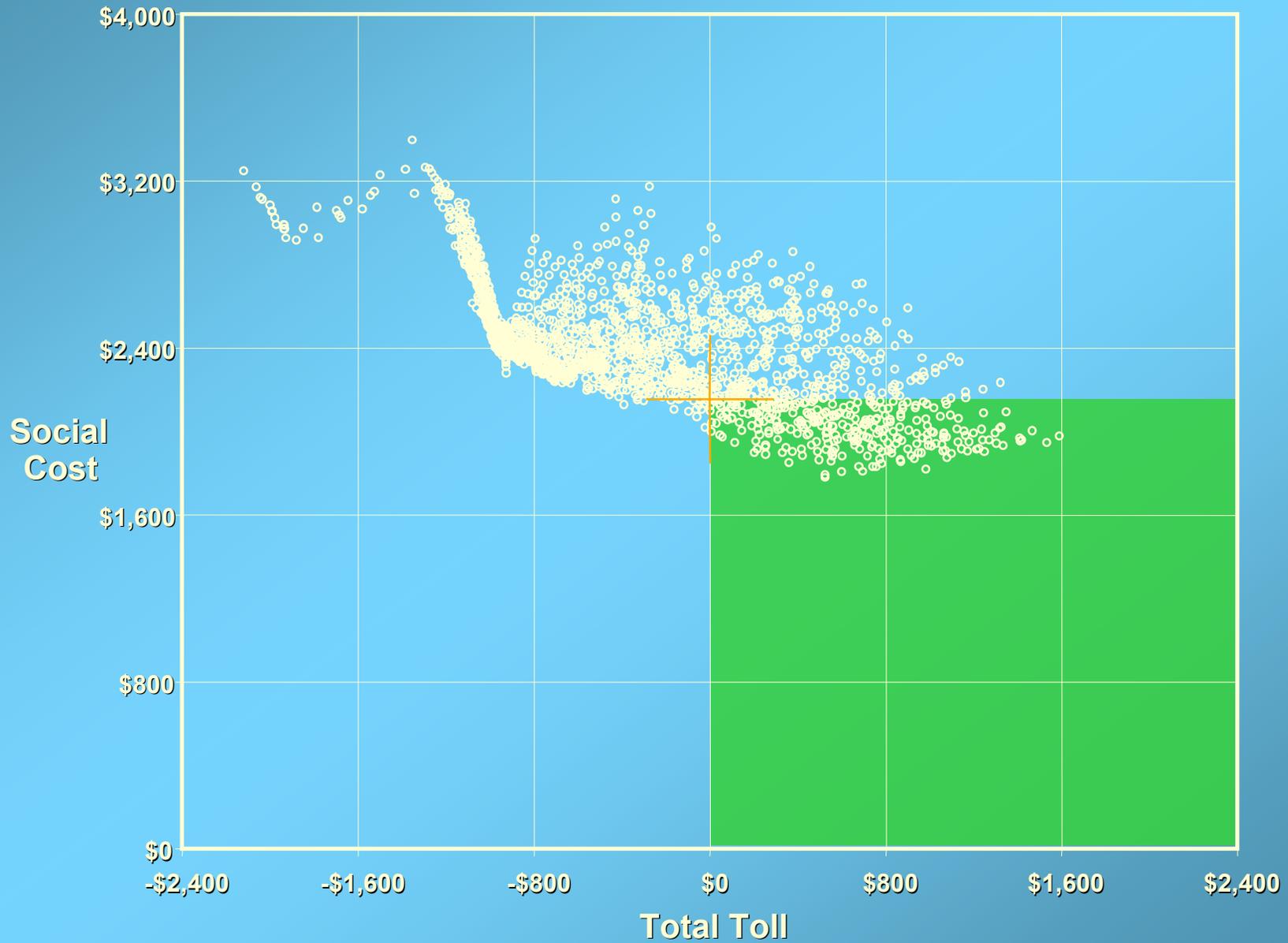
Generate  
Results  
and  
Evaluate



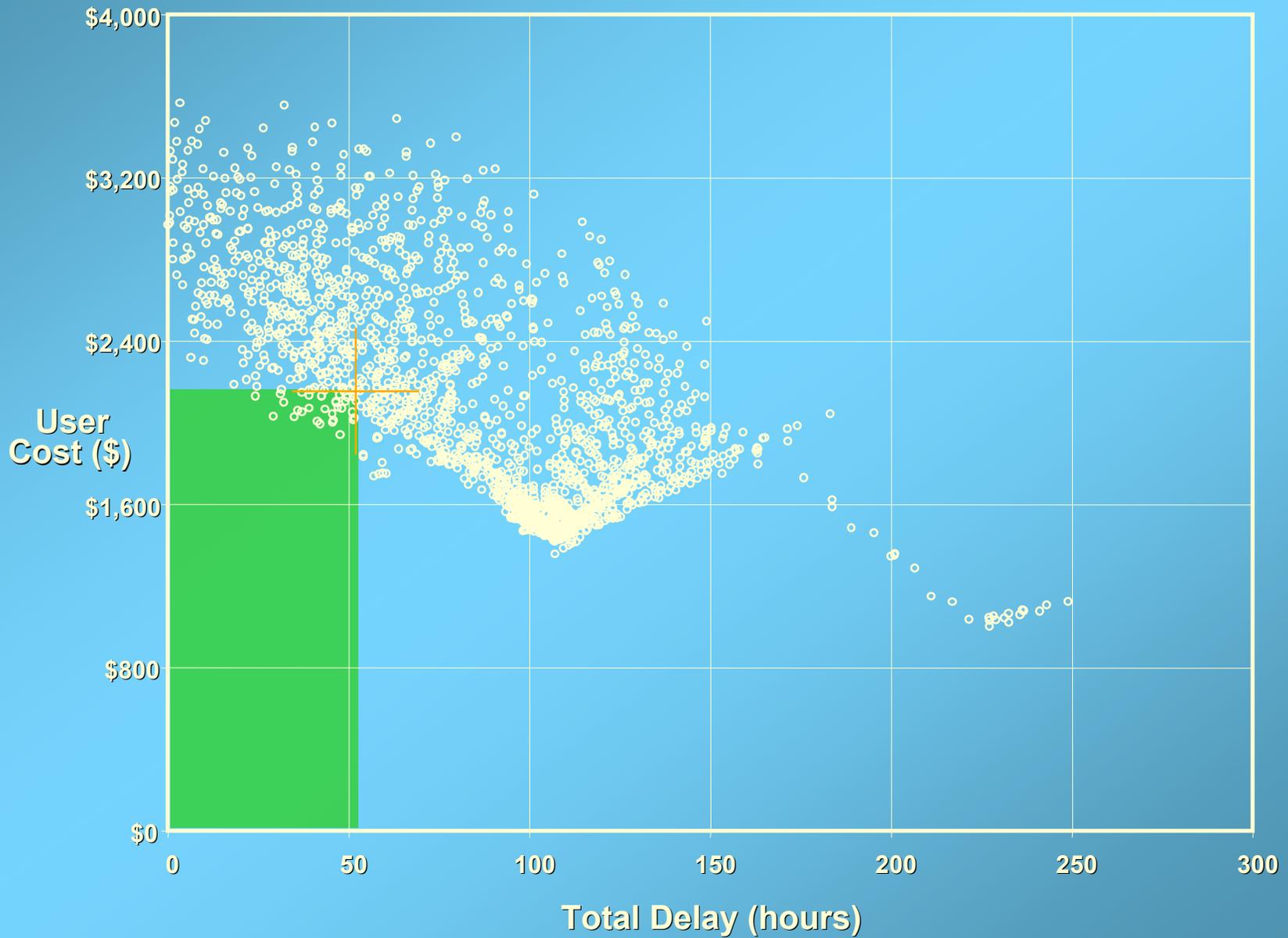
# Results

- Each trial is compared against the untolled condition with the seven policy objectives
- For example, these 3 graphs show the untolled condition and all trials in a pair wise comparison of policy objectives
- The shaded area shows a region of improvement or feasibility
- All pair wise comparisons are included in the binder below

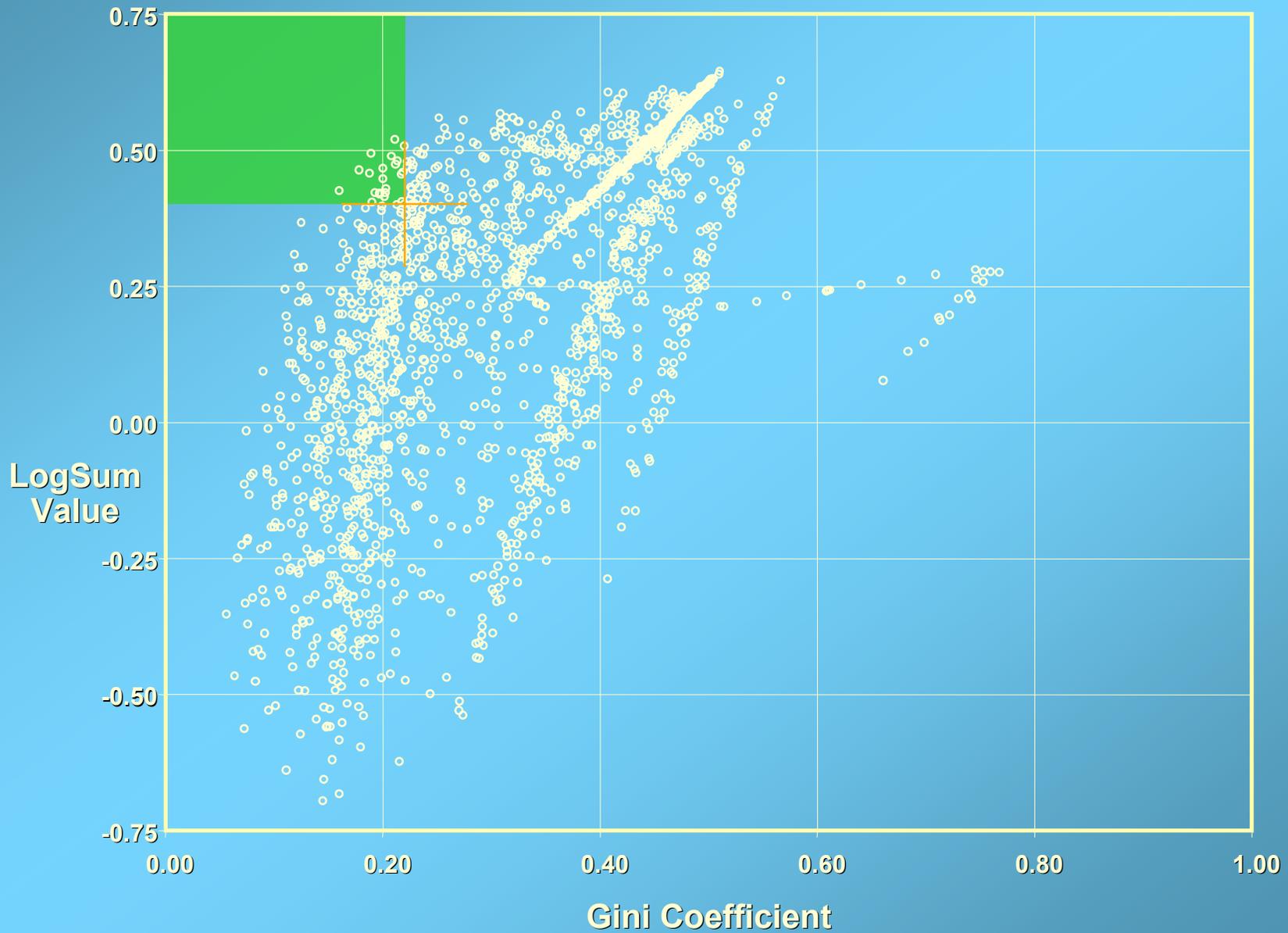
# *Social Cost vs. Total Toll*



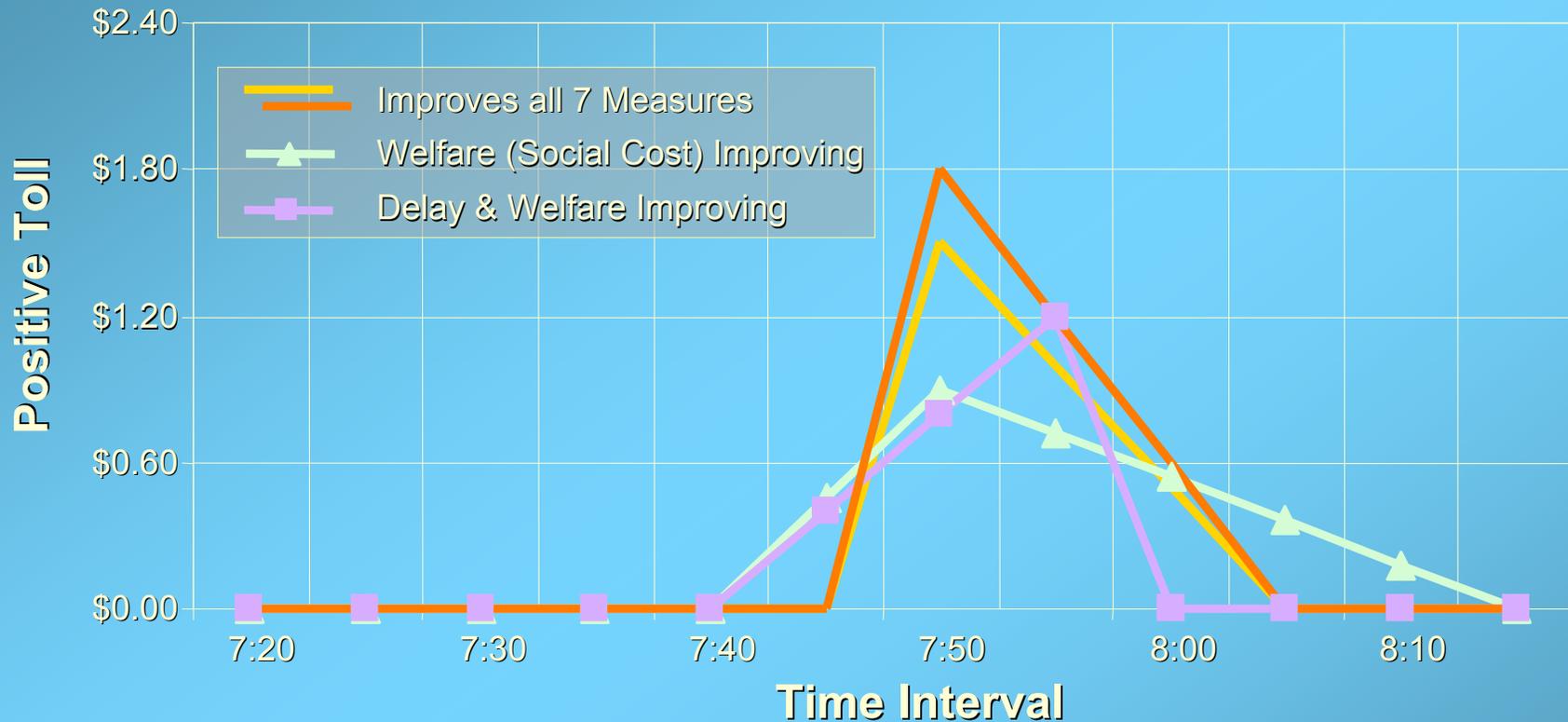
# *User Cost vs. Delay*



# Consumer Surplus vs. Equity



# Examples of Tolls Satisfying Varying Policy Objectives



- Two schemes improve all seven measures
- The welfare-improving scheme minimizes social cost while ensuring user cost and the total toll are not worsened
- The last minimizes delay and social cost while ensuring all other measures (except schedule delay) are not worsened

## *Conclusions*

- Congestion pricing generates alternative financing while offering demand management
- The Delayer Pays principle – with compensation – can lead to efficient outcomes
- Remedying the congestion externality is tenable without making other measures worse for drivers
- Diverse policy objectives can be met simultaneously, including delay, welfare, and equity
- The next steps – expanded modeling and relaxed assumptions – should yield more positive results