

Hybrid Simulation Techniques for the Analysis of Landside and Terminal Capacity Issues

J. Sam Lott

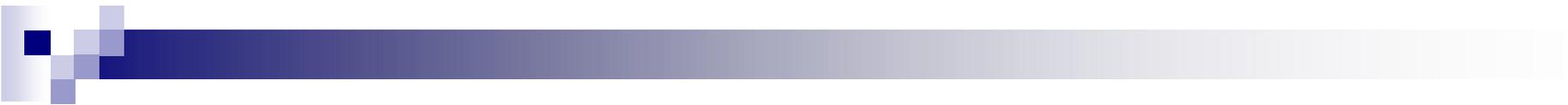
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FAA/NASA/Industry
Airport Planning



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- n Developmental Stages
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- n Examples from Hybrid Applications
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- n Airport Capacity Analysis Implications

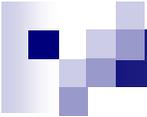
Philosophy of Modeling Approach

Hybrid Simulation Techniques

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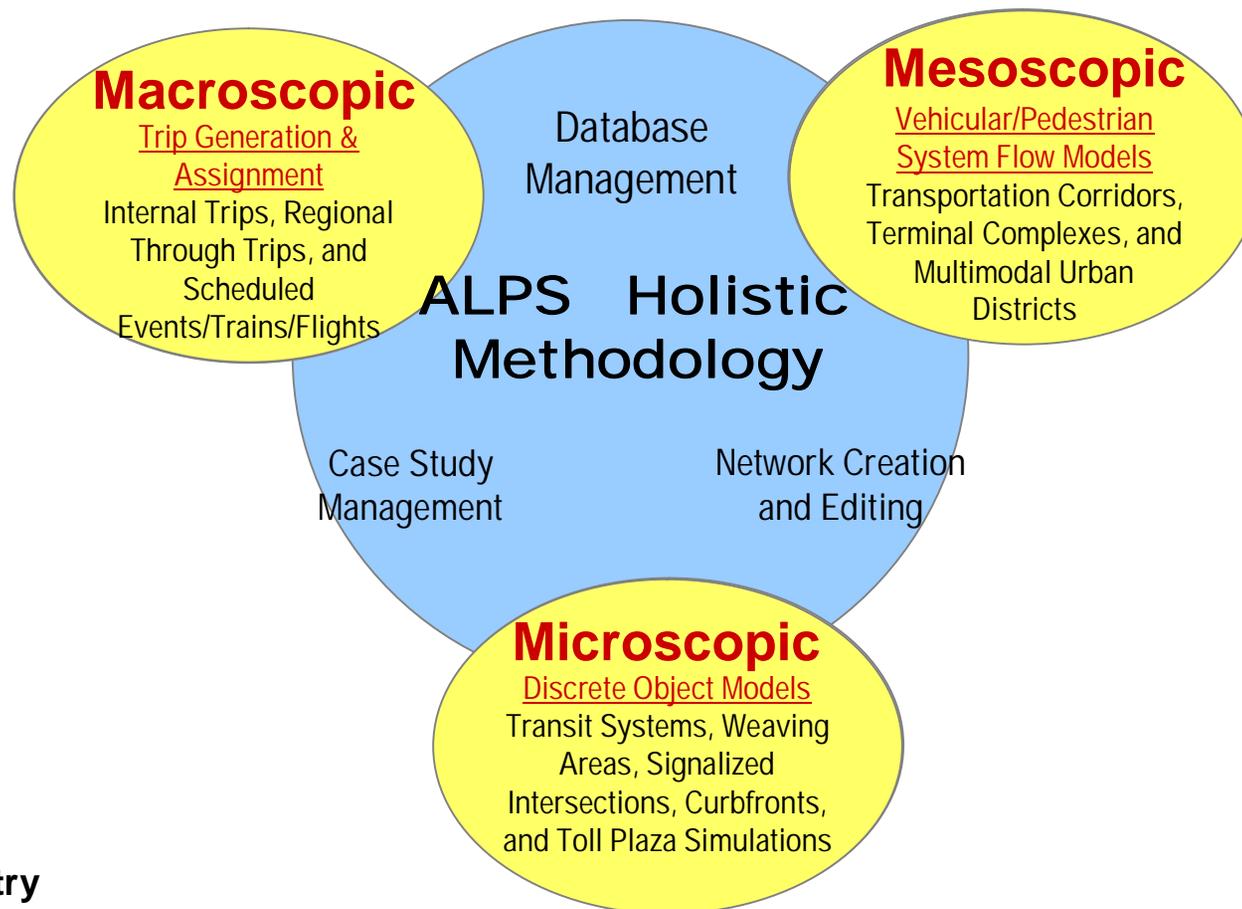
Philosophy of Modeling Approach

Holistic (ho lis'tik), *adj.*

- 1. Emphasizing the importance of the whole and the interdependence of its parts;*
- 2. Concerned with wholes rather than analysis or separation into parts.*

The American
Standard Dictionary

Philosophy of Modeling Approach

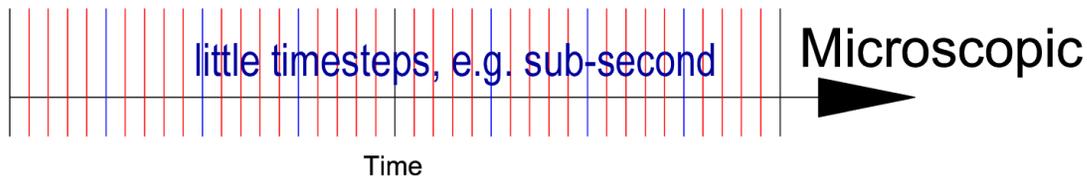


Philosophy of Modeling Approach

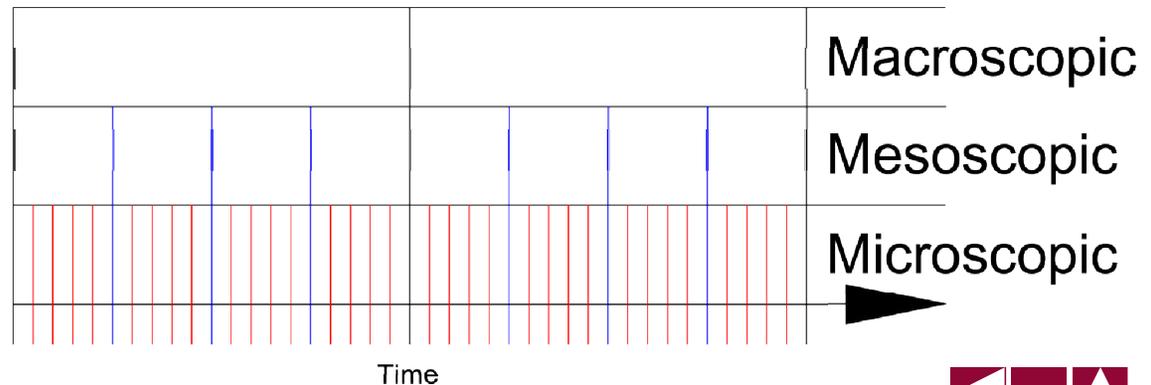


Assumptions binding Macro- and Micro-levels of detail

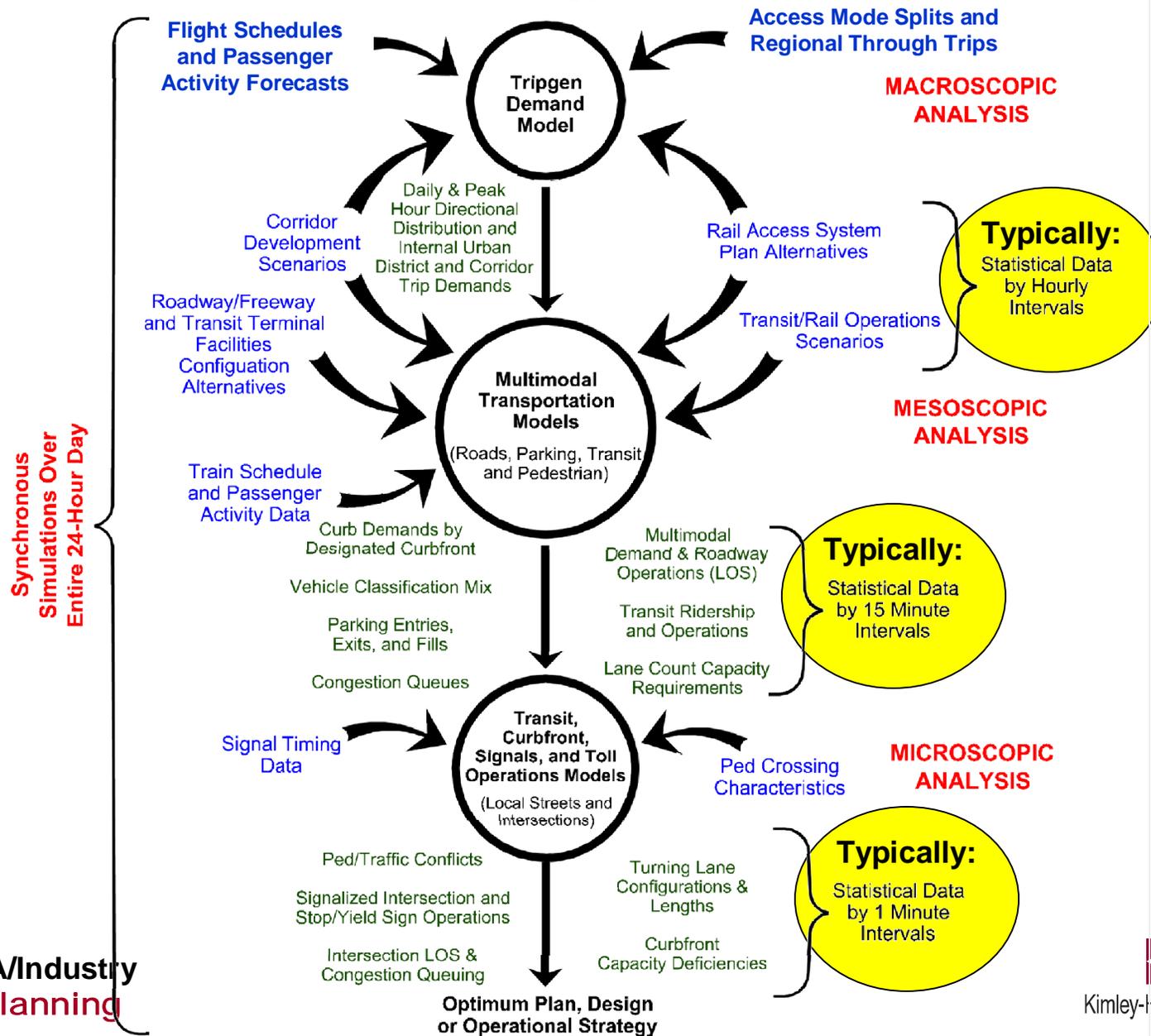
Traditional Simulation Techniques



Holistic Simulation Techniques



Holistic Methodology of ALPS2000



Developmental Stages

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ALPS™ – The Advanced Landside Performance Simulation

- n There are three basic modes of travel:
 - .. Land
 - .. Sea
 - .. Air
- n ALPS has developed with for the purpose of analyzing all aspects of ***Land*** transportation



ALPS Developmental Stages

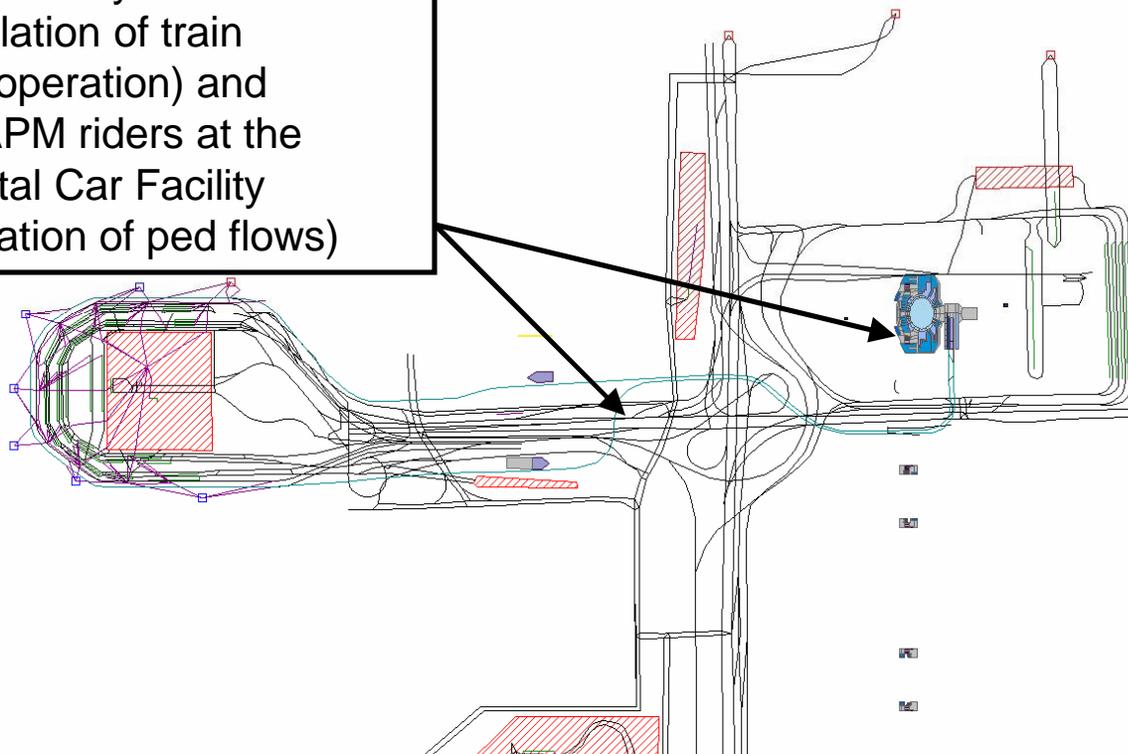
- n **Dynamic Analysis (1980s)** – *Operational performance over a complete 24 hour day with capacity constrained interaction between independent segments*
- n **Integrated Analysis (1990s)** – *Multiple simulations operating Independently in a common environment and in full coordination with a common database of trip activity*
- n **Synchronous Simulations (2000s)**– *Multiple simulations operating synchronously in time and exchanging data “on-the-fly”*

Sample of Synchronous Simulation

MIC/MIA Connector and ConRAC Facility (2001)

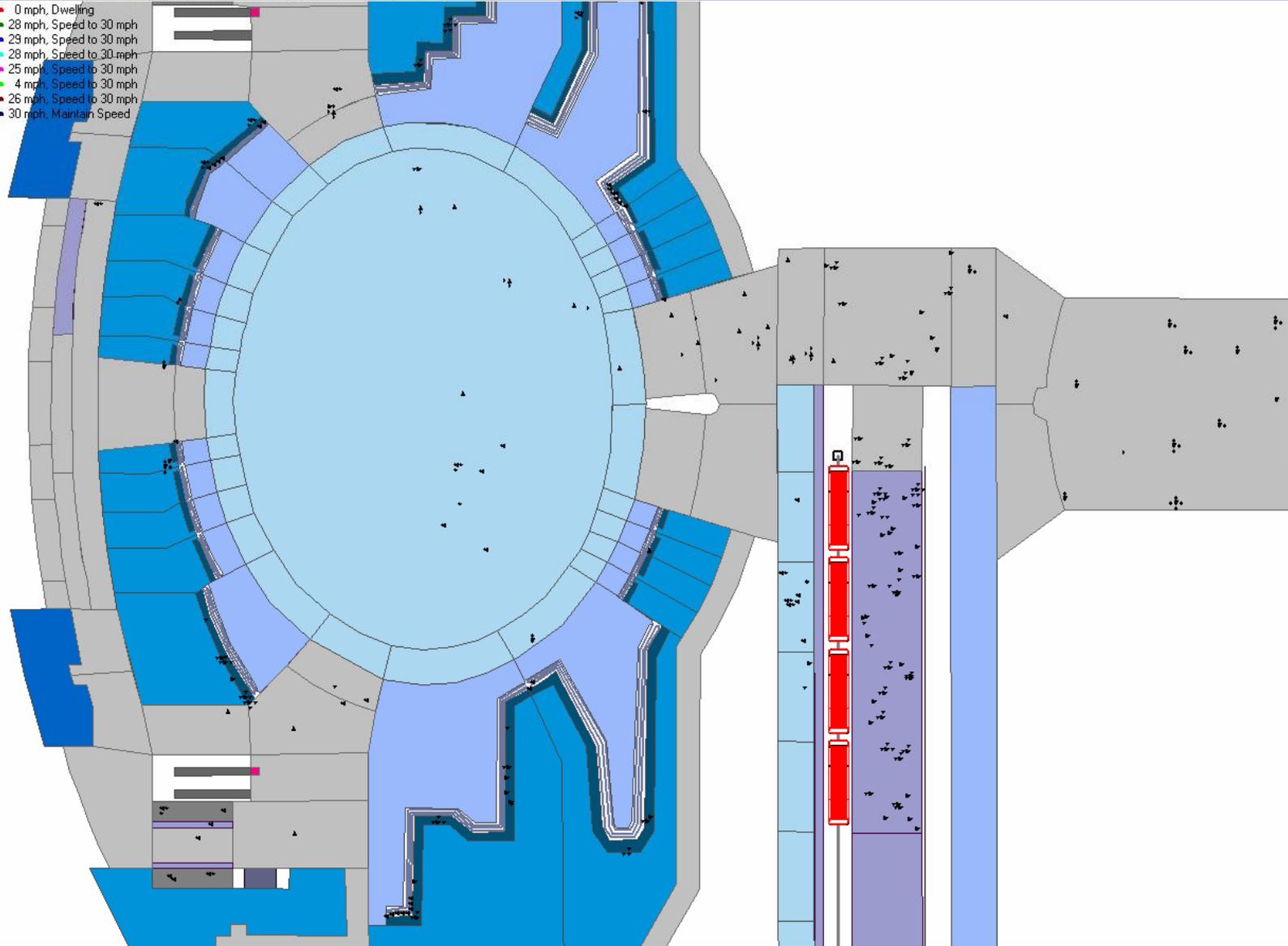


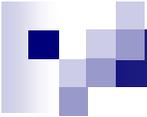
Synchronous simulations of MIC/MIA APM transit connector system (microscopic simulation of train performance and operation) and pedestrians and APM riders at the Consolidated Rental Car Facility mesoscopic simulation of ped flows)





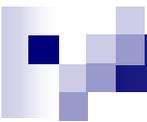
- 0 mph, Dwelling
- 28 mph, Speed to 30 mph
- 29 mph, Speed to 30 mph
- 28 mph, Speed to 30 mph
- 25 mph, Speed to 30 mph
- 4 mph, Speed to 30 mph
- 26 mph, Speed to 30 mph
- 30 mph, Maintain Speed





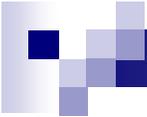
Macroscopic Model Characteristics

- n ***All trips assigned over entire route per time increment***
- n Results assembled in aggregate terms — e.g., total daily O/D trips, peak hour link demands, density, average velocity, volume vs. capacity relationships, travel time
- n Broad classifications of flows — e.g., originating passengers, employees, home-to-work trips
- n Abstract or Schematic representation of systems and facilities
- n ***Larger simulated time increments, with analysis of modeling results typically in 15 minute to 1 hour intervals***
- n No distinguishing of individual object location or specific “operational” performance of facility/system elements
- n ***Typically deterministic, although some stochastic techniques applied***



Mesoscopic Model Characteristics

- n Results are a calculation of continuous, aggregate flows throughout the simulation period – e.g., density, average velocity, volume vs. capacity relationships, travel time
- n ***Overall, the progressive movement of individual simulated objects is continuously calculated as to general location, but not necessarily precise location***
- n ***Moderate length simulated time increments, with analysis of modeling results typically in 1 to 15 minute intervals***
- n Detailed processing of individual elements is common
- n ***Blend of stochastic and deterministic calculations, and oriented toward statistical analyses – variations applied in random number seed***



Microscopic Model Characteristics

- n *Calculation of time-space movement and behavior of each simulated object with a fairly precise location*
- n *Small simulated time increments, with analysis of modeling results typically in 0.01 to 1 second intervals*
- n *Behavior of simulated objects modeled in relation/reaction to other simulated objects within the modeled environment*
- n Highly sensitive to process rates, and random choice or sequence
- n Blend of stochastic and deterministic calculations, and oriented toward statistical analyses – variations applied in random number seed

Definition of Hybrid Modeling

Hybrid Simulation Techniques

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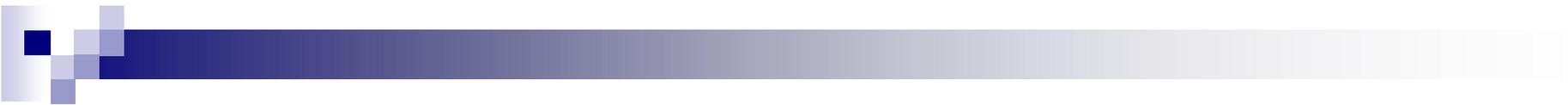
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Hybrid Modeling

Definition: An analysis technique which embeds a higher level of processing fidelity and accuracy within a generally lower level processing simulation model. ***Higher processing level embedded at limited locations and/or segment types only where significant analytical benefits result.***

Objective: Faster, more efficient simulation processing of land-based systems/facilities



Hybrid Modeling Characteristics

- n Network structures consist of:
 - Link/node networks
 - Spatial area sequence networks
 - Process points/systems sequence networks
- n Lower level processing over most of the model's network structure
- n Higher level processing embedded within a portion of the model's network structure

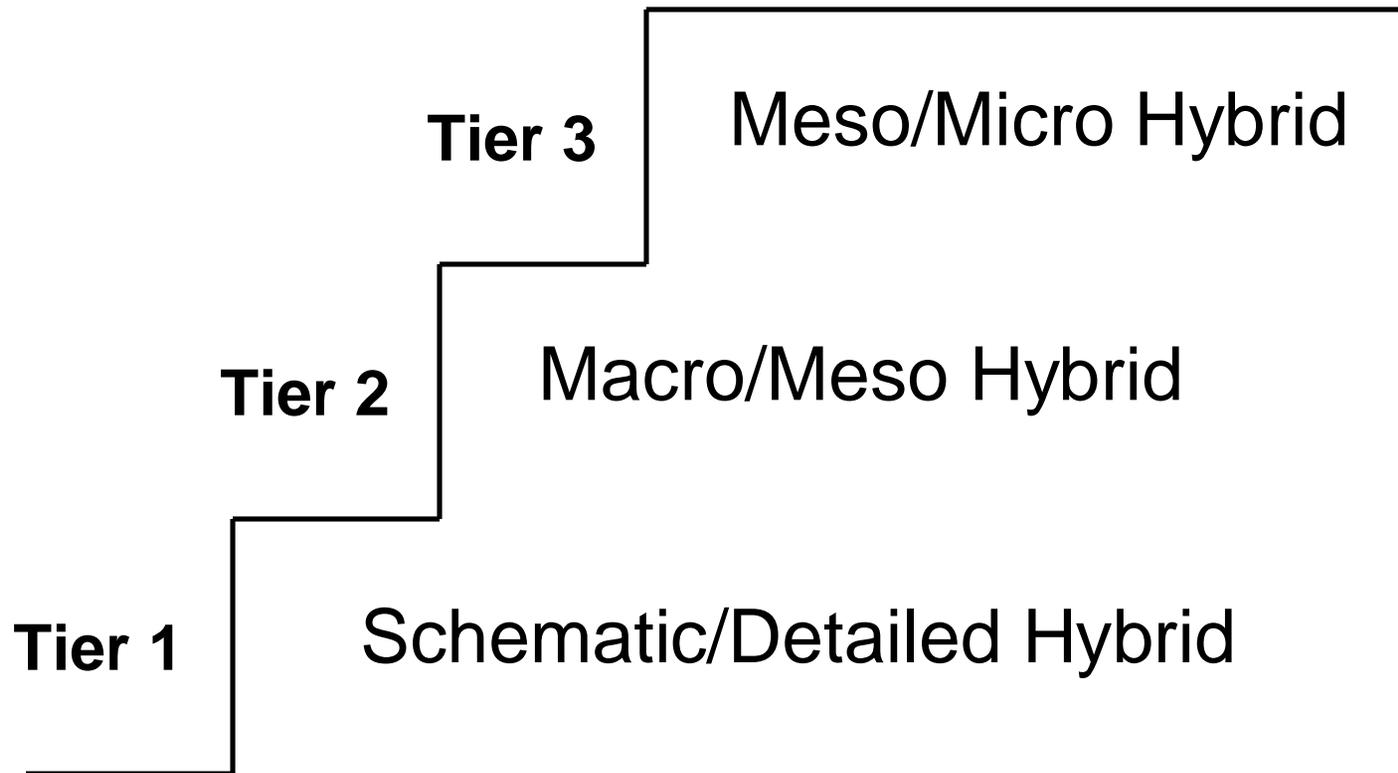


Tiers of Hybrid Model Complexity

- n Different combinations of different processing levels form hybrid models
- n Levels of complexity could be described as “tiers” of complexity
- n Examples that follow are three typical hybrid combinations, but the total number of possible combinations are very large

Tiers of Hybrid Model Complexity

Examples that follow are typical hybrid combinations



Comparison of Processing Speed Between Different Types of Operational Analysis Models

Case Study: 24 hour congested flow operations analysis of a 20 mile Freeway corridor with 750,000 vehicle trips

Model Type	Hybrid Macroscopic/ Mesoscopic Flow Model	Mesosopic Flow Model	Hybrid Mesoscopic/ Microscopic Model	Microscopic Model
Execution Time – 20 mile freeway corridor with 750,000 vehicle trips processed throughout a 24 hour simulation day	1 second ¹	5 minutes ¹	15 minutes ¹	24 hours ²

1. ALPS2000 benchmark runs
2. Based on project experience with VISSIM for a similar scale of analysis (approximate 20 mile freeway corridor)

NOTE: Comparisons are for a specific model and combination of hybrid features, and different combinations will produce different results. The comparative processing times range from 100x to 100,000x faster.

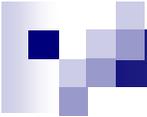
Examples from Hybrid Applications

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Tier 1 Schematic/Detailed Hybrid Applications

The examples that follow show how portions of the models were built using very schematic representation and portions were built using very detailed representation. The results was a very efficient model to create and exercise, providing the detailed result where needed.



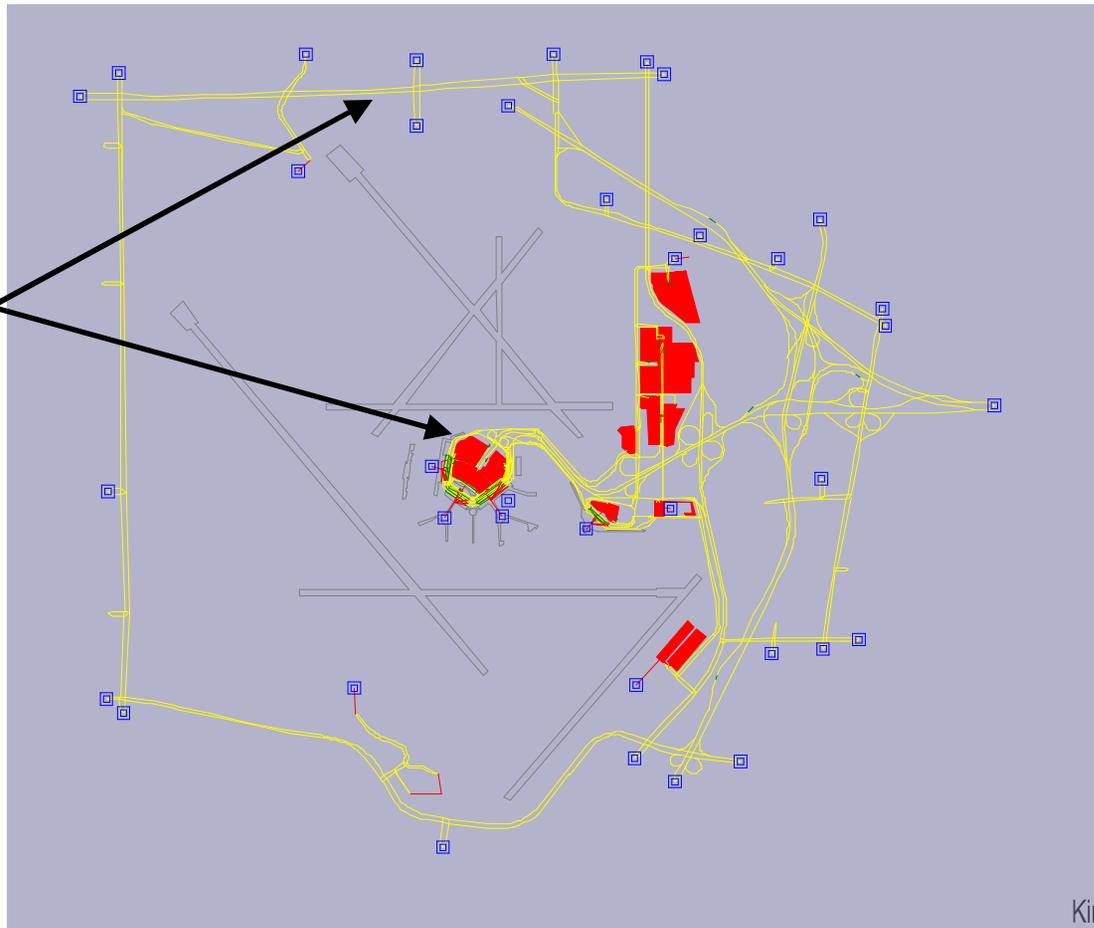
Tier 1 Schematic/Detailed Hybrid Applications

- n Chicago O'Hare International Airport (2000)
- n Houston Bush Intercontinental Airport
Master Plan (2005)
- n Hartsfield-Jackson Atlanta International
Airport (2004)

Tier 1 Schematic/Detailed Hybrid Applications

Examples – Chicago O’Hare International Airport (2000)

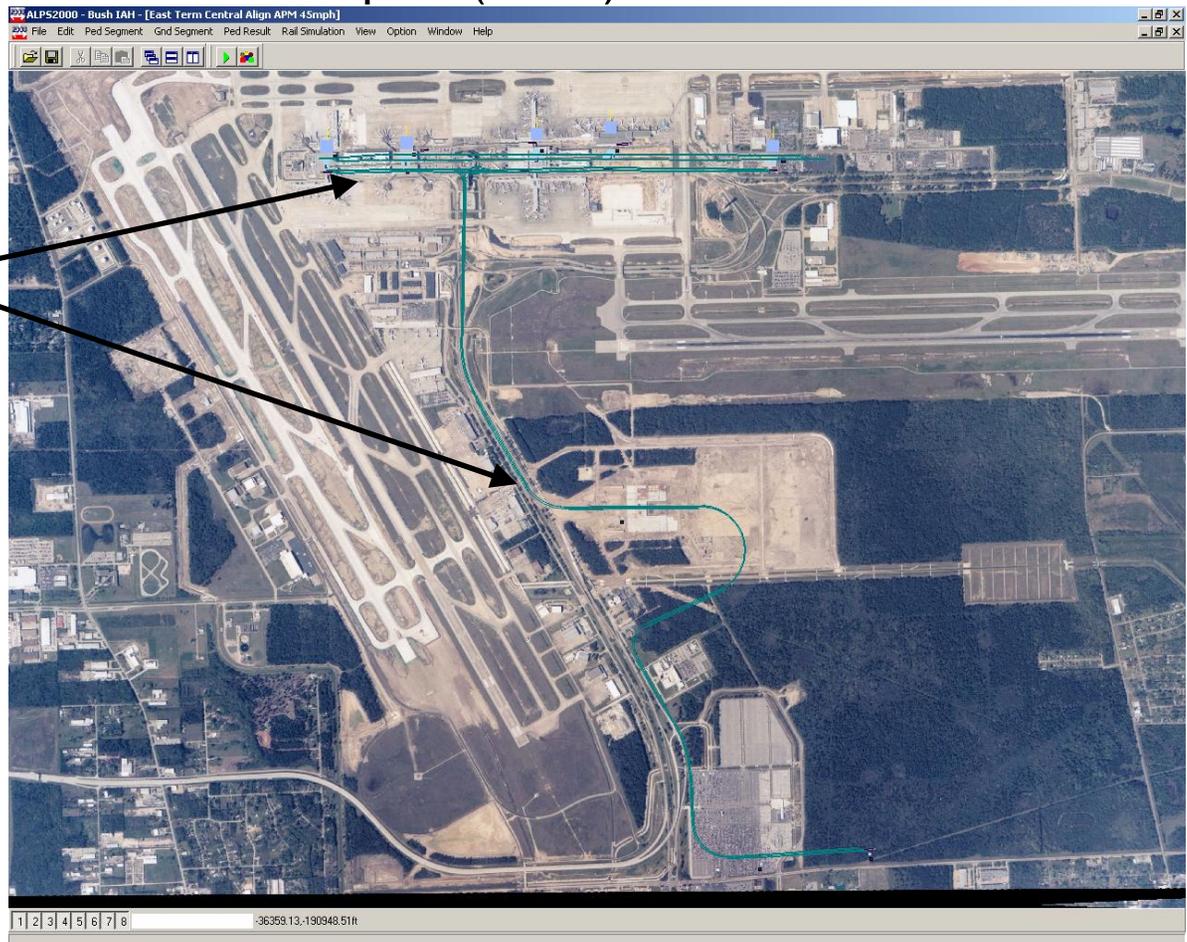
The further from the terminal the model reached, the less detail was included.



Tier 1 Schematic/Detailed Hybrid Applications

Examples – Bush IAH Intercontinental Airport (2005)

The model of the alternative transit systems to connect remote landside with the terminal was combined with a pedestrian model of transit ridership.

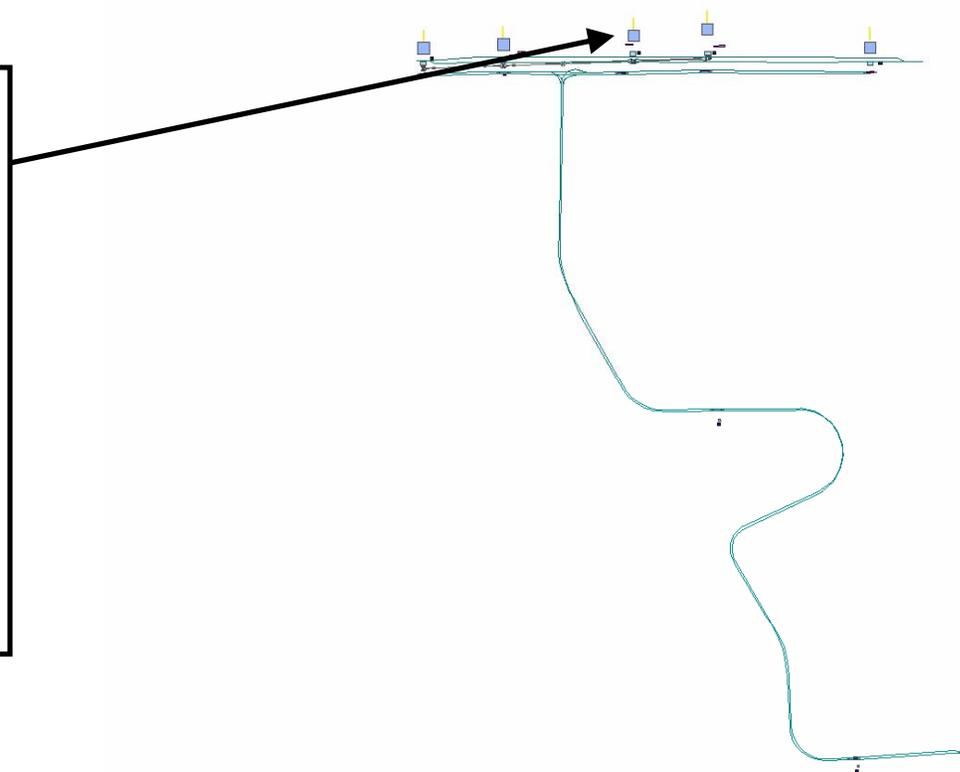


Tier 1 Schematic/Detailed Hybrid Applications

Examples – Bush IAH Intercontinental Airport (2005)



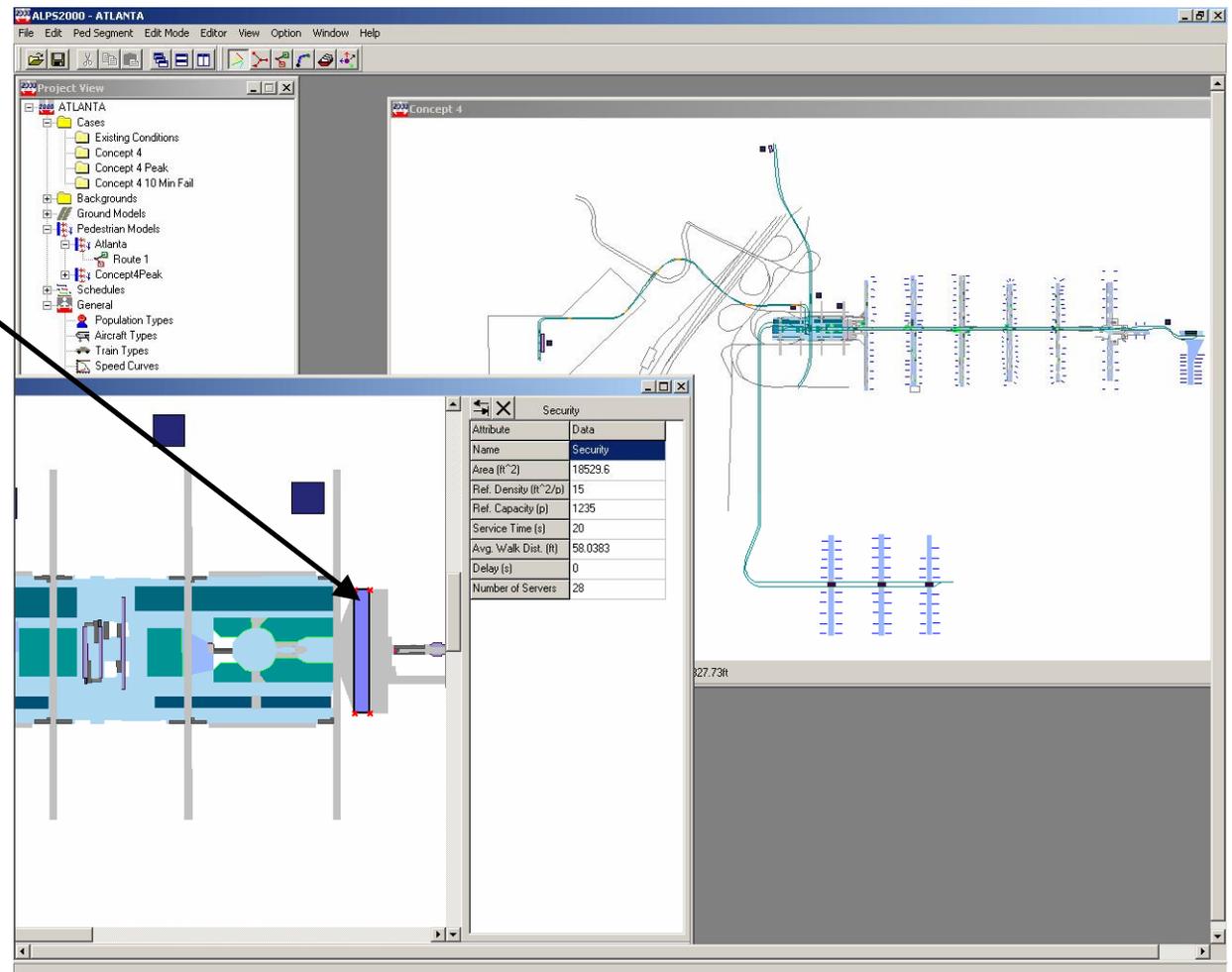
The pedestrian flow model of transit ridership used extremely schematic representation of the terminals (basically one segment and one gate) to serve all flights. Ped movements to/through transit stations to reach all remote stations were modeled in greater detail.

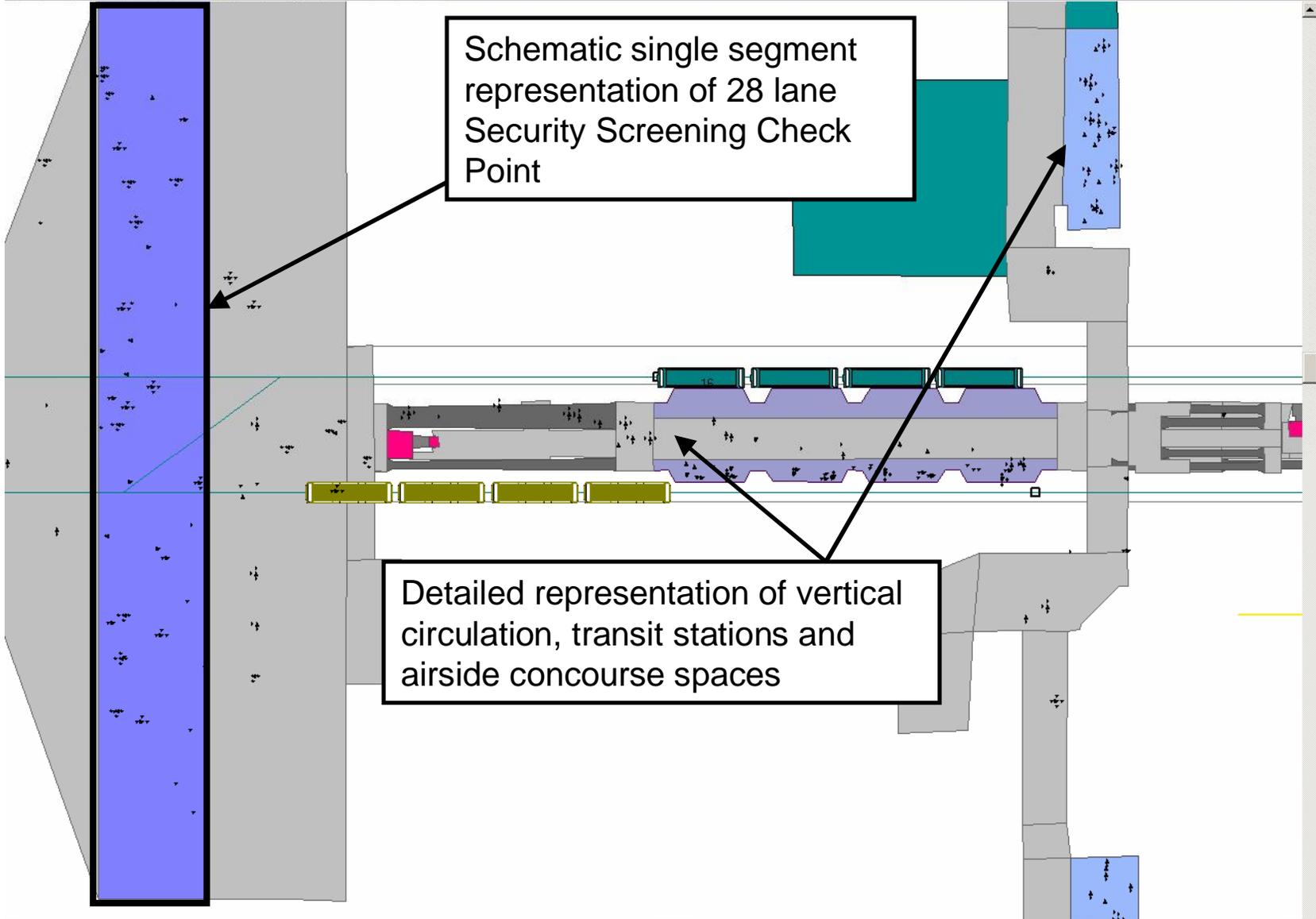


Tier 1 Schematic/Detailed Hybrid Applications

Video Examples – Hartsfield-Jackson Atlanta International Airport (2004)

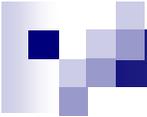
The model of four transit systems included a very schematic representation of the terminal functions, with much more detailed representation of the transit stations and airside concourses. The highlighted segment as a single schematic element that modeled the 28 lane Security Screening Check Point





Schematic single segment representation of 28 lane Security Screening Check Point

Detailed representation of vertical circulation, transit stations and airside concourse spaces



Tier 2 Macroscopic/Mesososcopic Hybrid Applications

The examples that follow show how a macroscopic model with demand assignments made within each 15 minute interval was leveraged through an embedded mesoscopic processing of operational congestion queues. The analysis tracked the buildup and dissipation of individual vehicles at locations where demands exceeded capacities.



Tier 2 Macroscopic/Mesososcopic Hybrid Applications

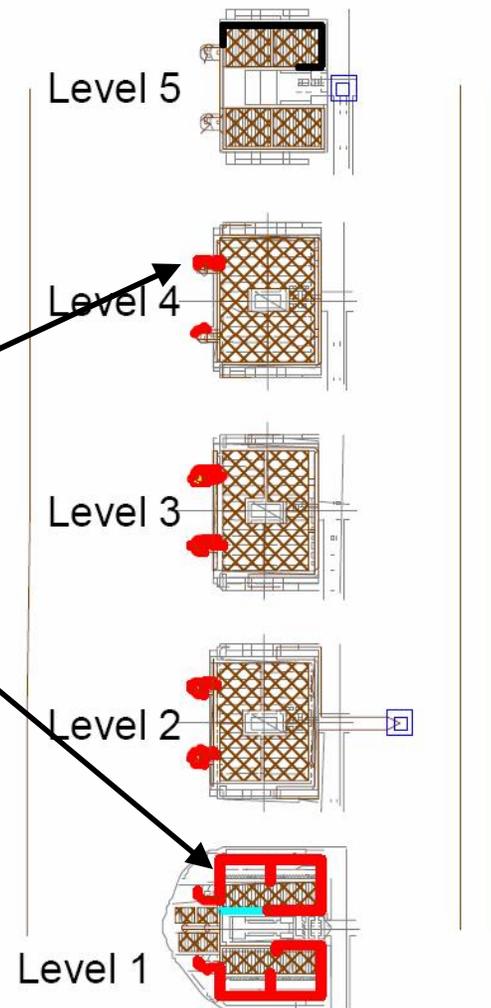
- n Miami Intermodal Center (MIC)
Consolidated Rental Car Facility (2000)
- n US 290 Freeway Corridor (Houston -
2005)

Tier 2 Macroscopic/ Mesoscopic Hybrid Applications

Video Examples – MIC ConRAC Facility (2000)

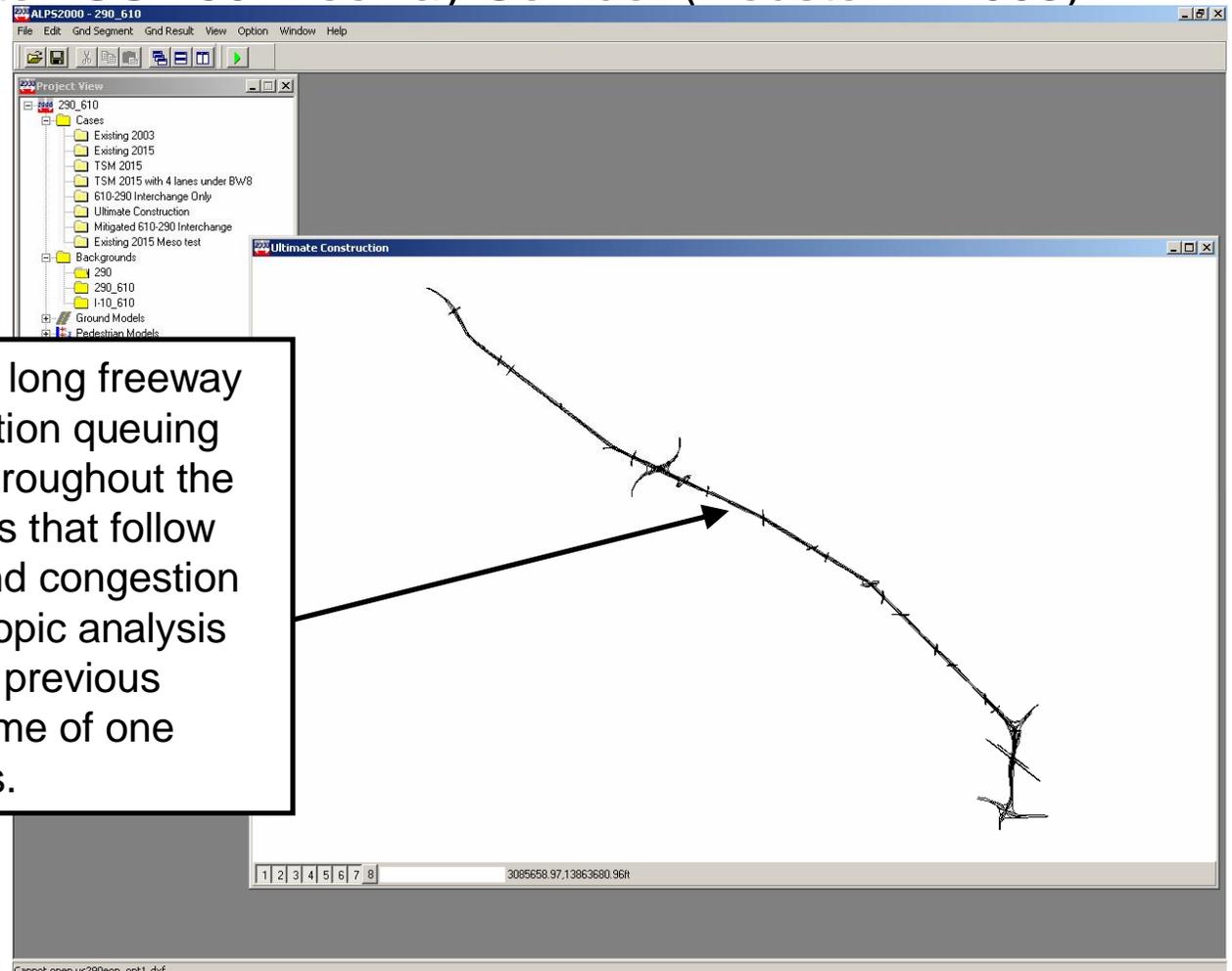
The model represented a multilevel facility with vehicles being moved from multiple levels down to the lowest level for fueling and cleaning. The model was able to show the period of the day that the congestion queues (indicated in red) of shuttled vehicles would stack all the way up the spiral ramps, and then dissipate over successive time intervals.

At 10:00 am

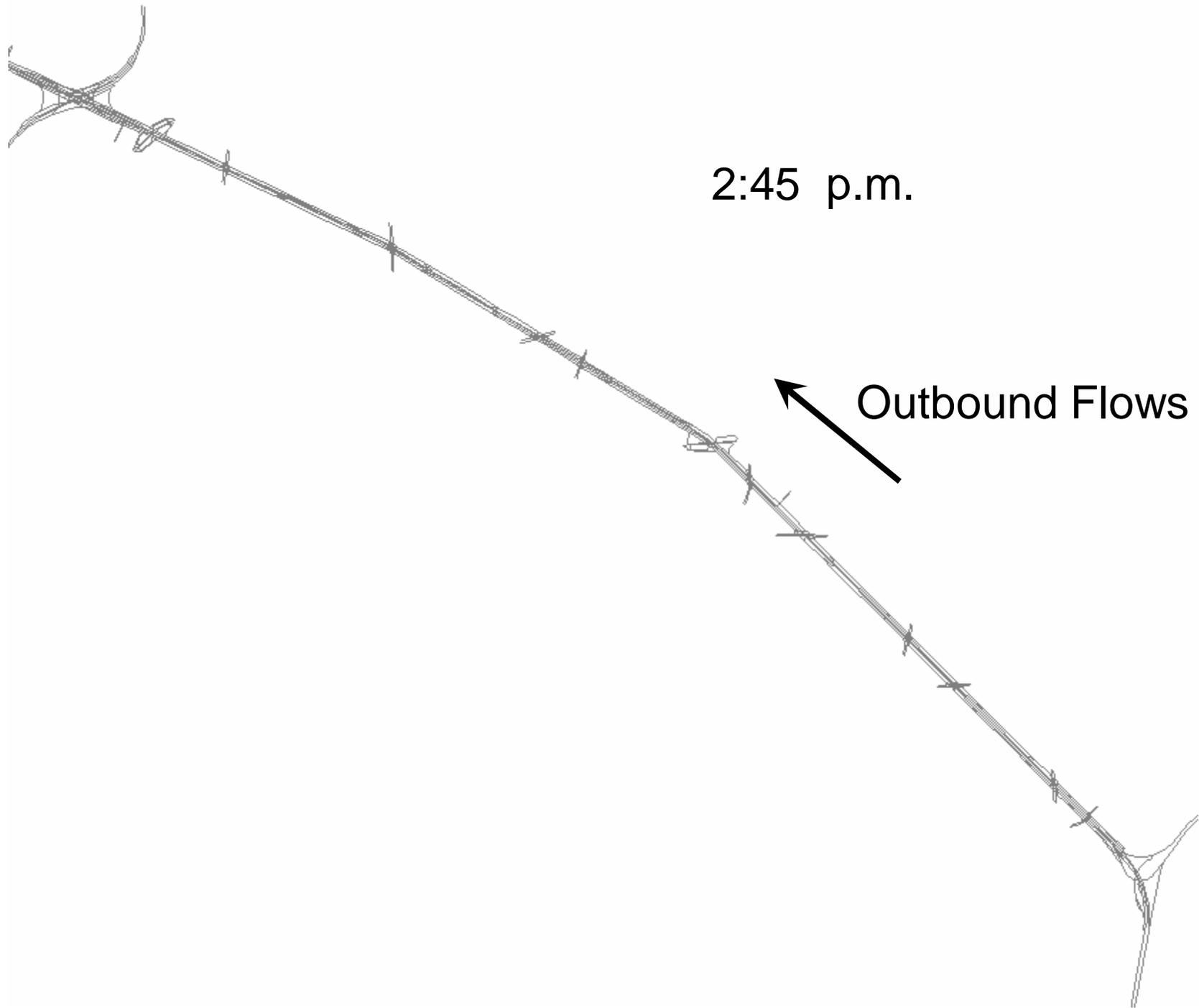


Tier 2 Macroscopic/Mesososcopic Hybrid Applications

Video Examples – Houston US 290 Freeway Corridor (Houston – 2005)

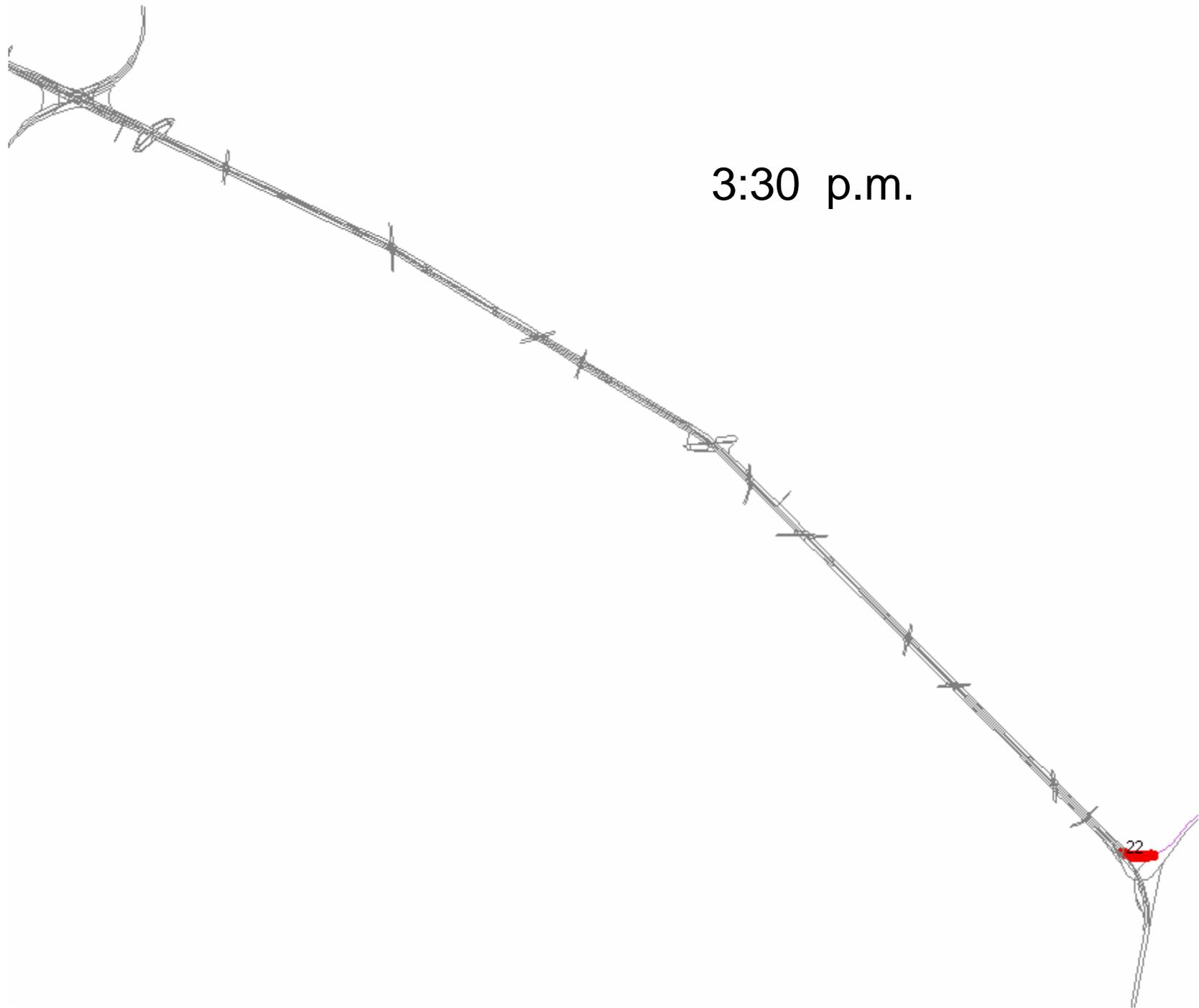


The model was of a 20 mile long freeway corridor, with heavy congestion queuing that builds and dissipates throughout the day. The sequence of slides that follow show the afternoon outbound congestion that the embedded mesoscopic analysis was able to represent. The previous indication of a processing time of one second was for this analysis.



2:45 p.m.

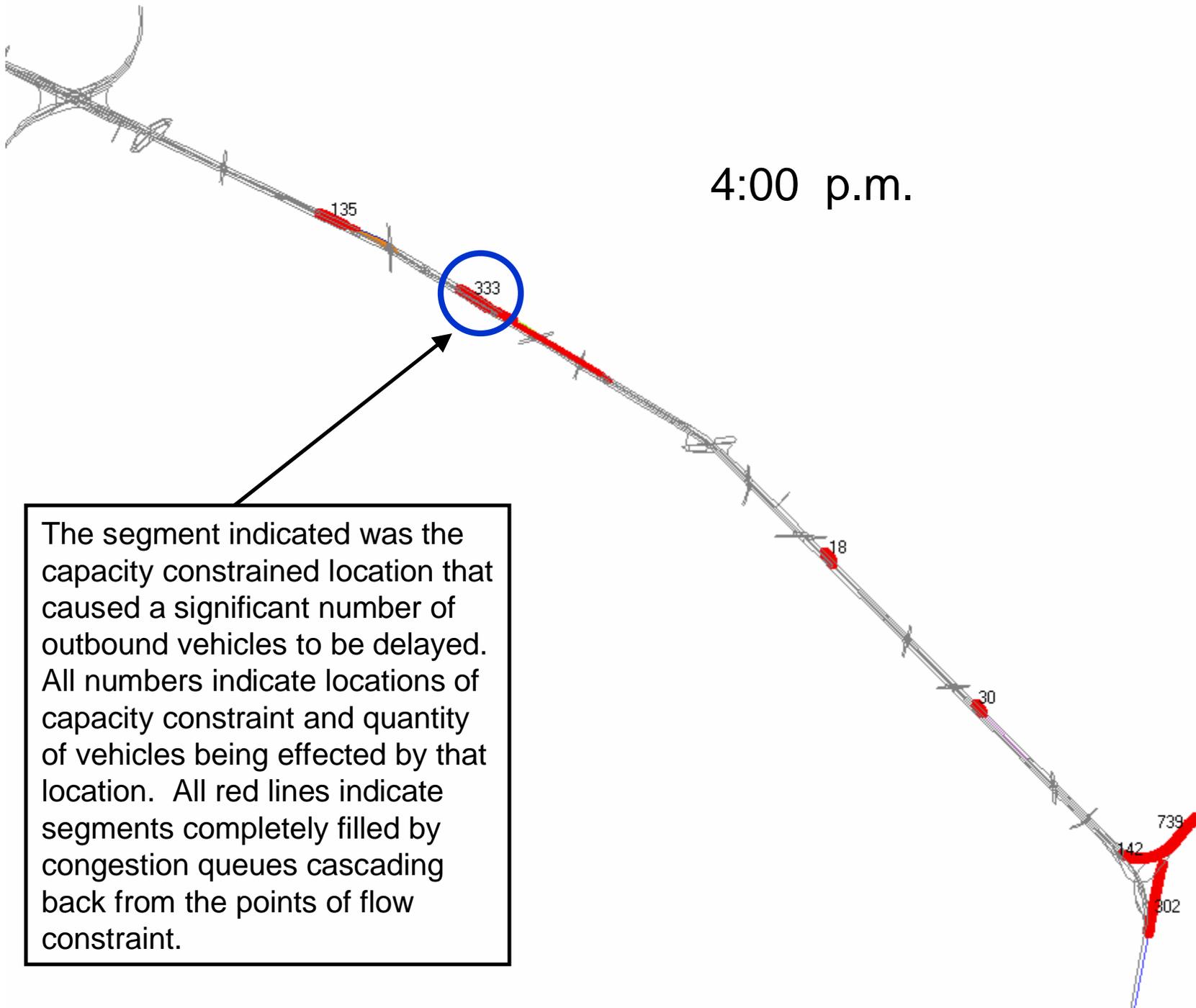
Outbound Flows



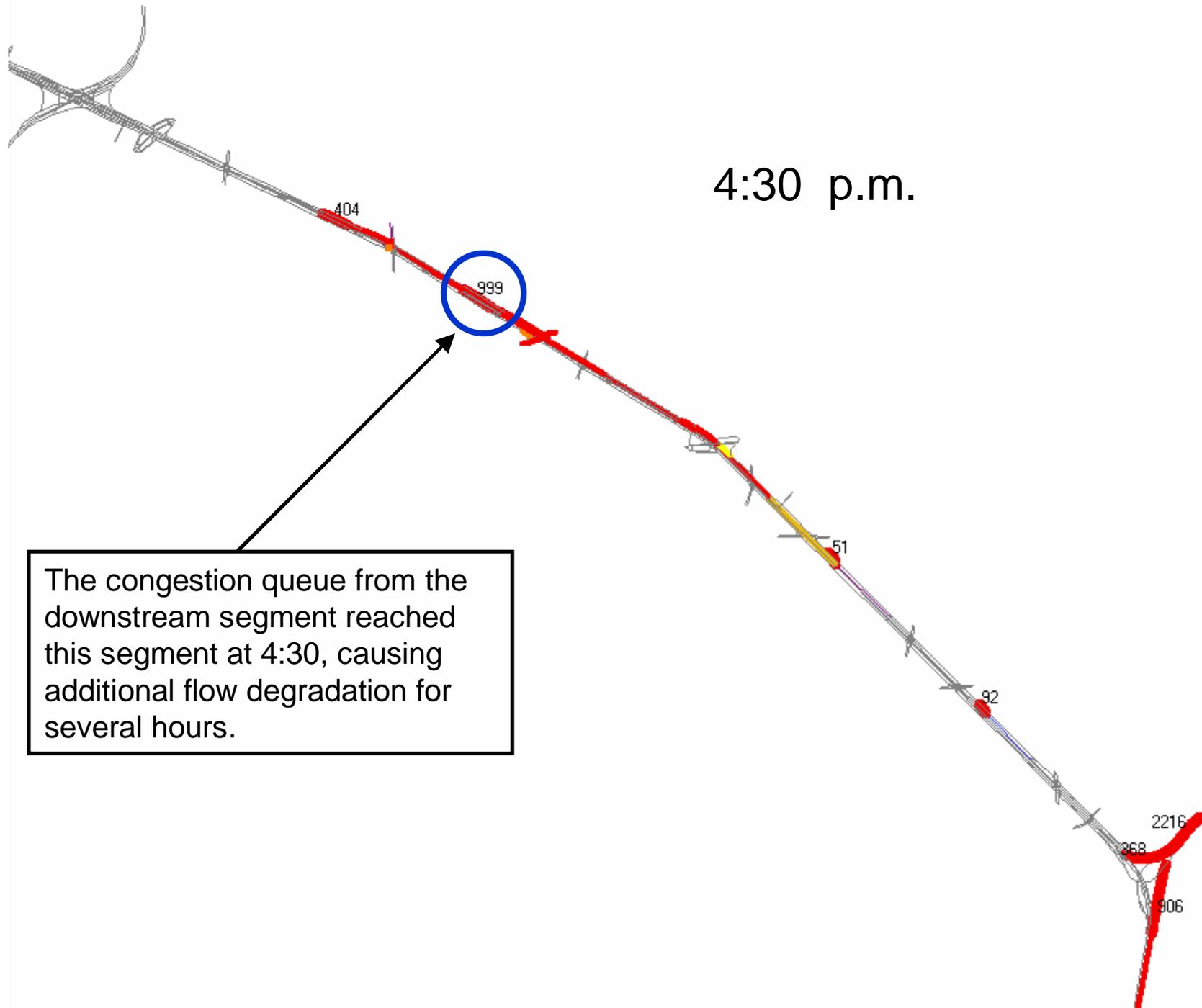
3:30 p.m.

22

4:00 p.m.

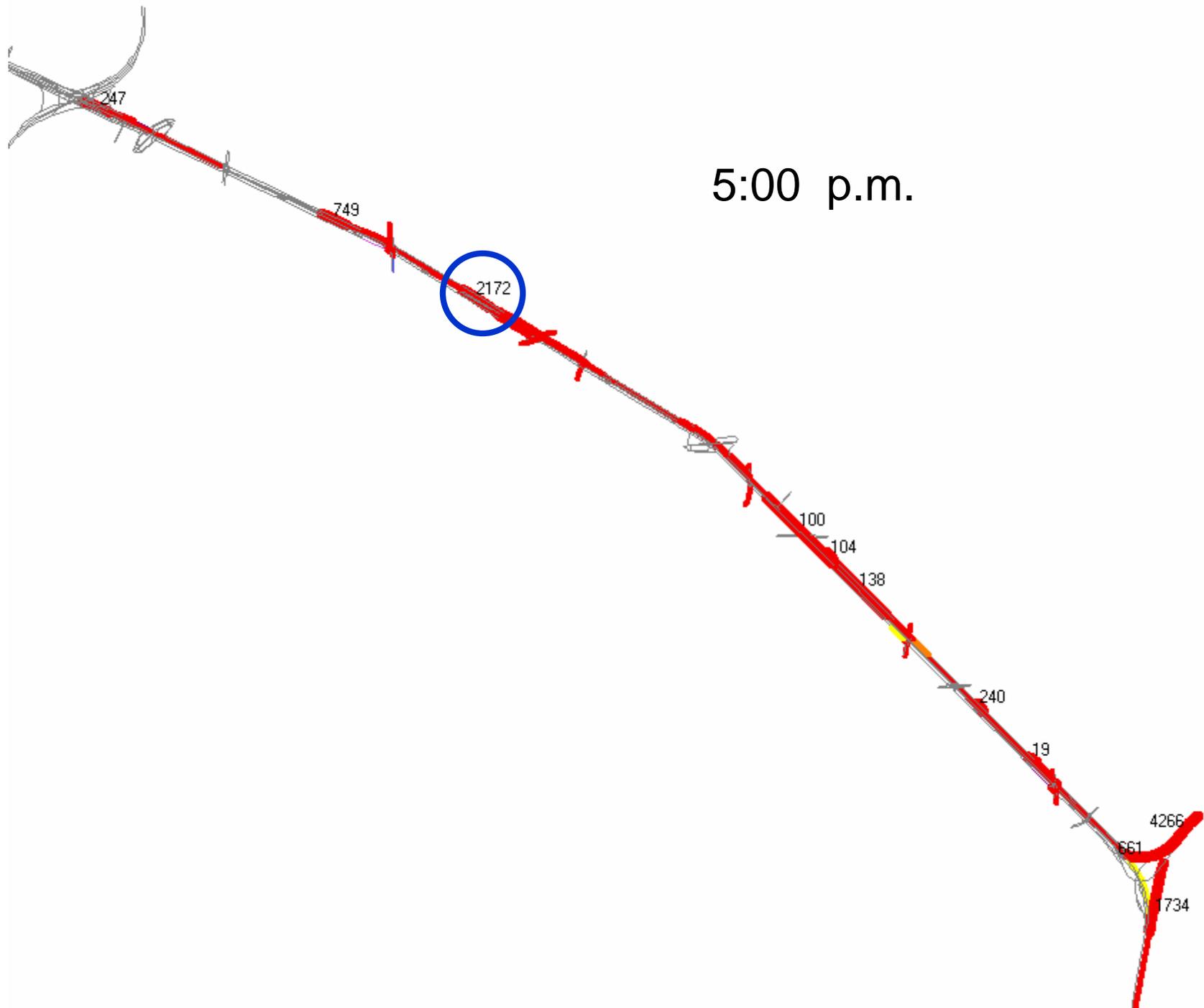


The segment indicated was the capacity constrained location that caused a significant number of outbound vehicles to be delayed. All numbers indicate locations of capacity constraint and quantity of vehicles being effected by that location. All red lines indicate segments completely filled by congestion queues cascading back from the points of flow constraint.

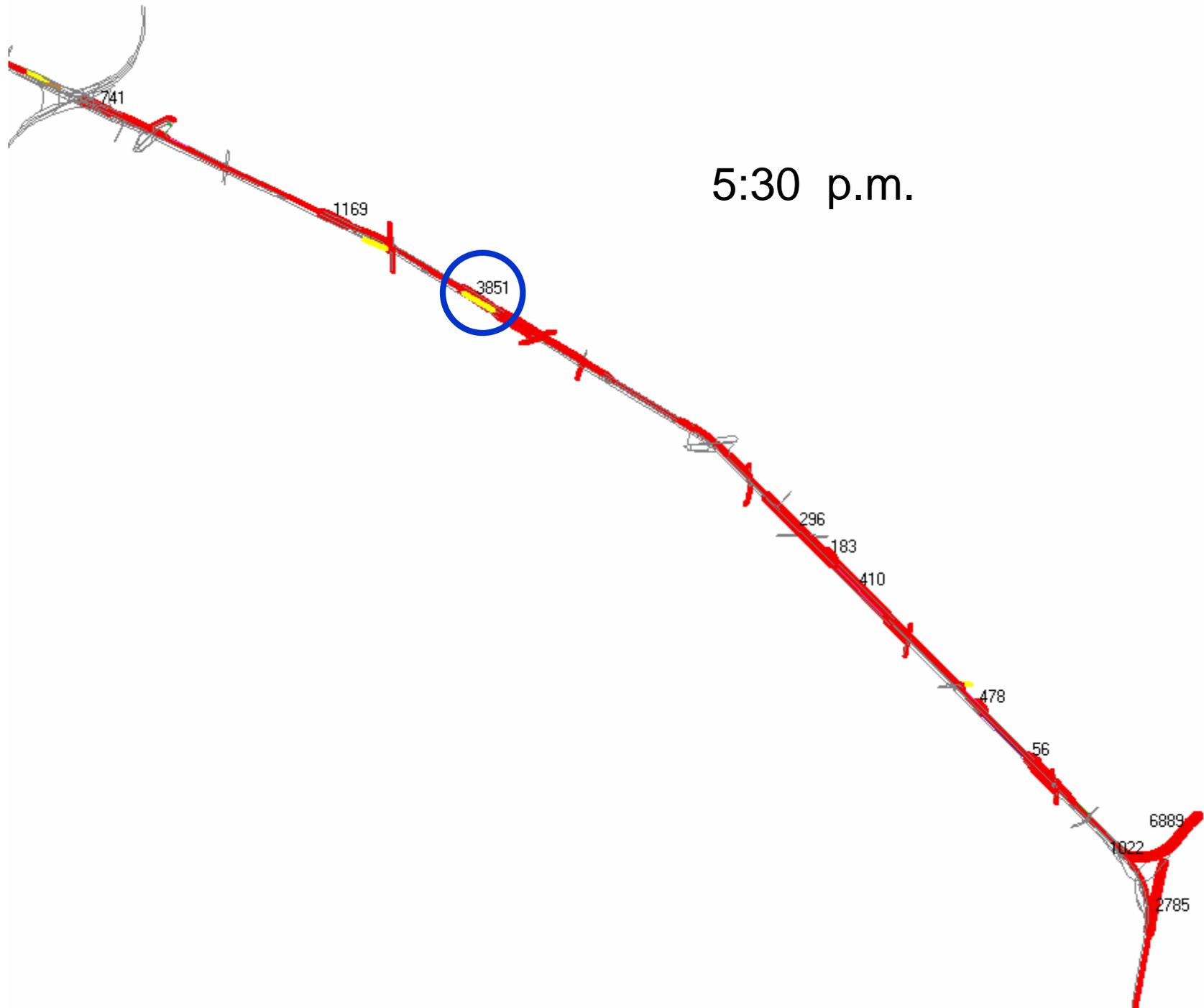


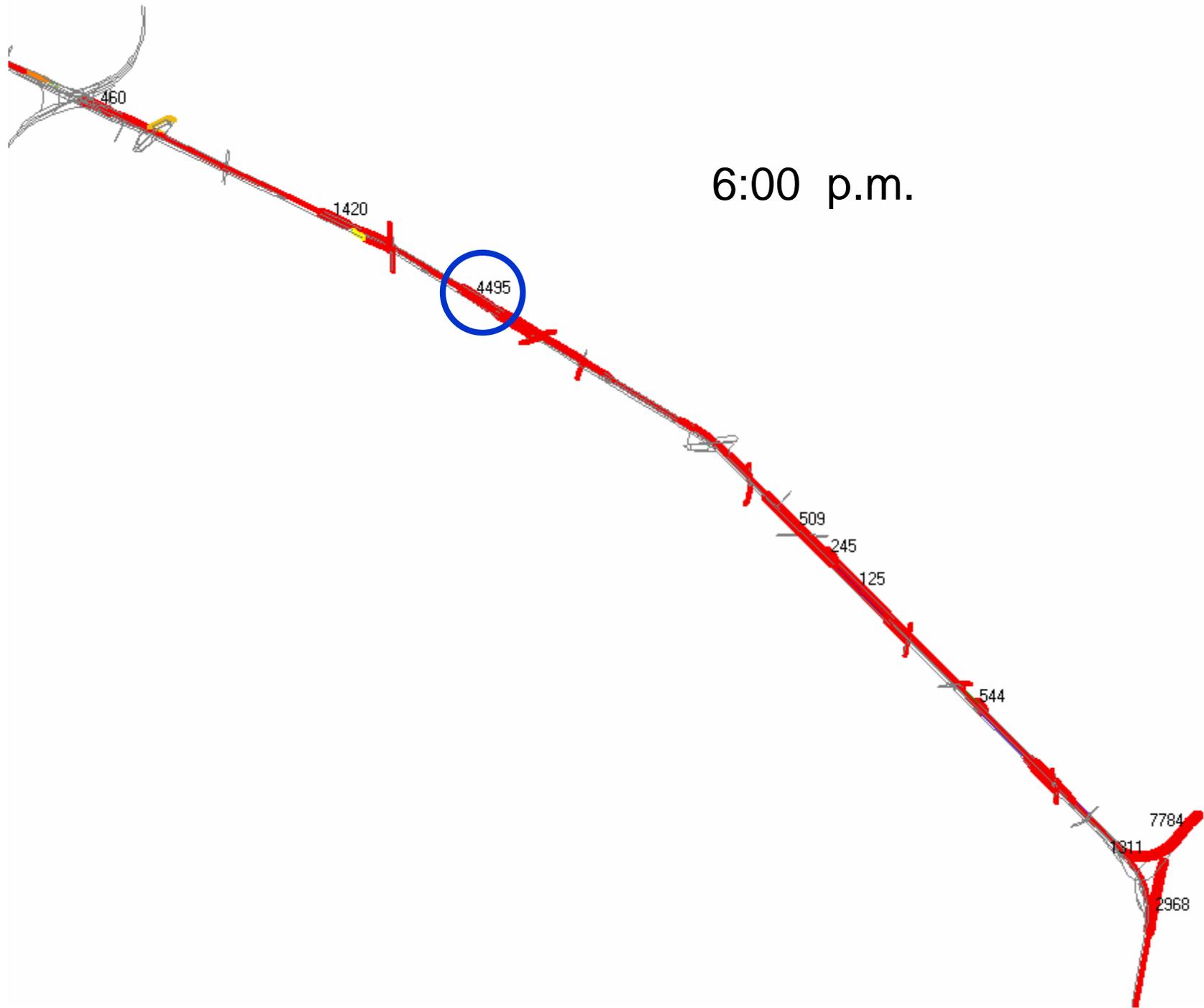
4:30 p.m.

The congestion queue from the downstream segment reached this segment at 4:30, causing additional flow degradation for several hours.



5:00 p.m.



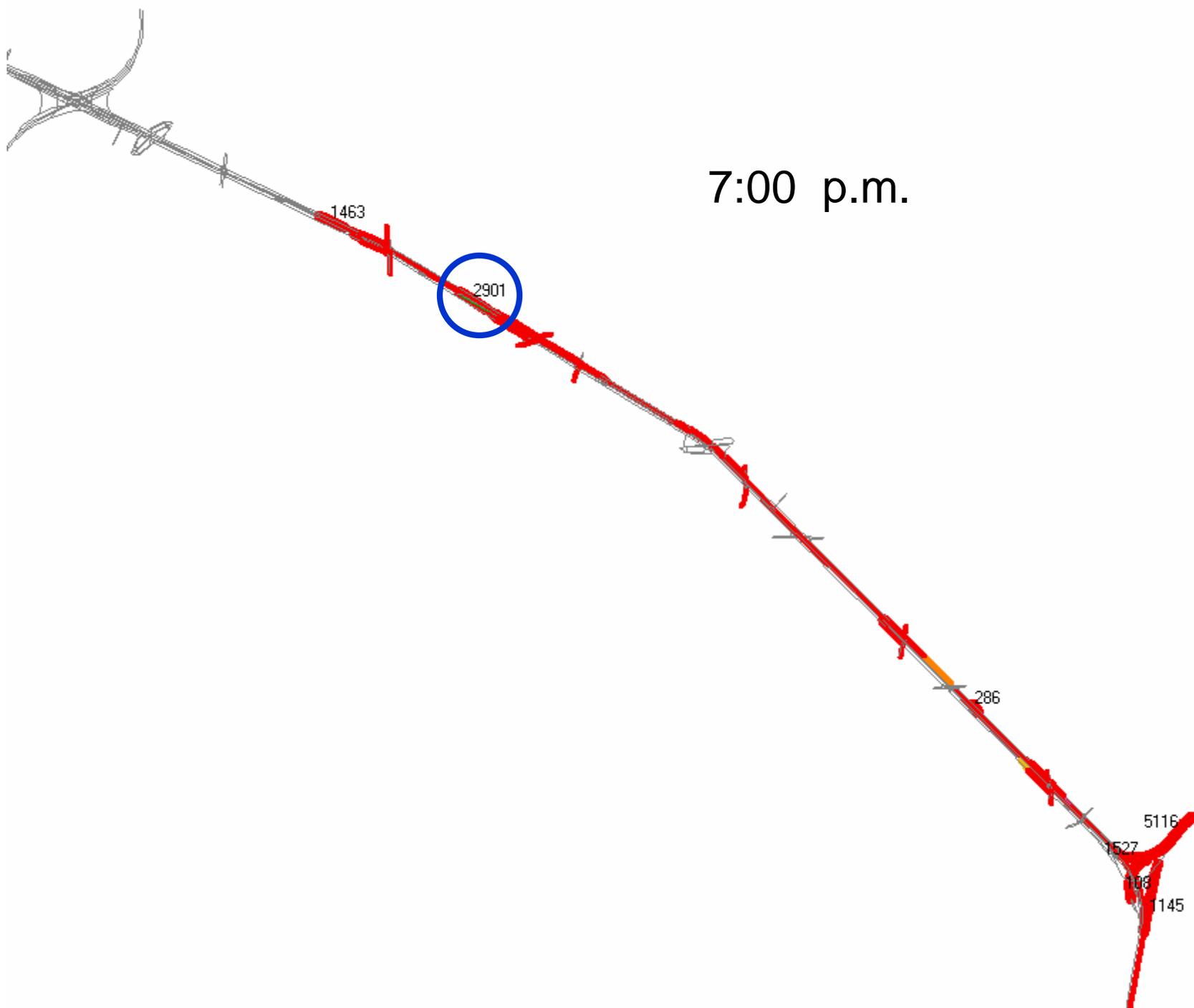


6:00 p.m.

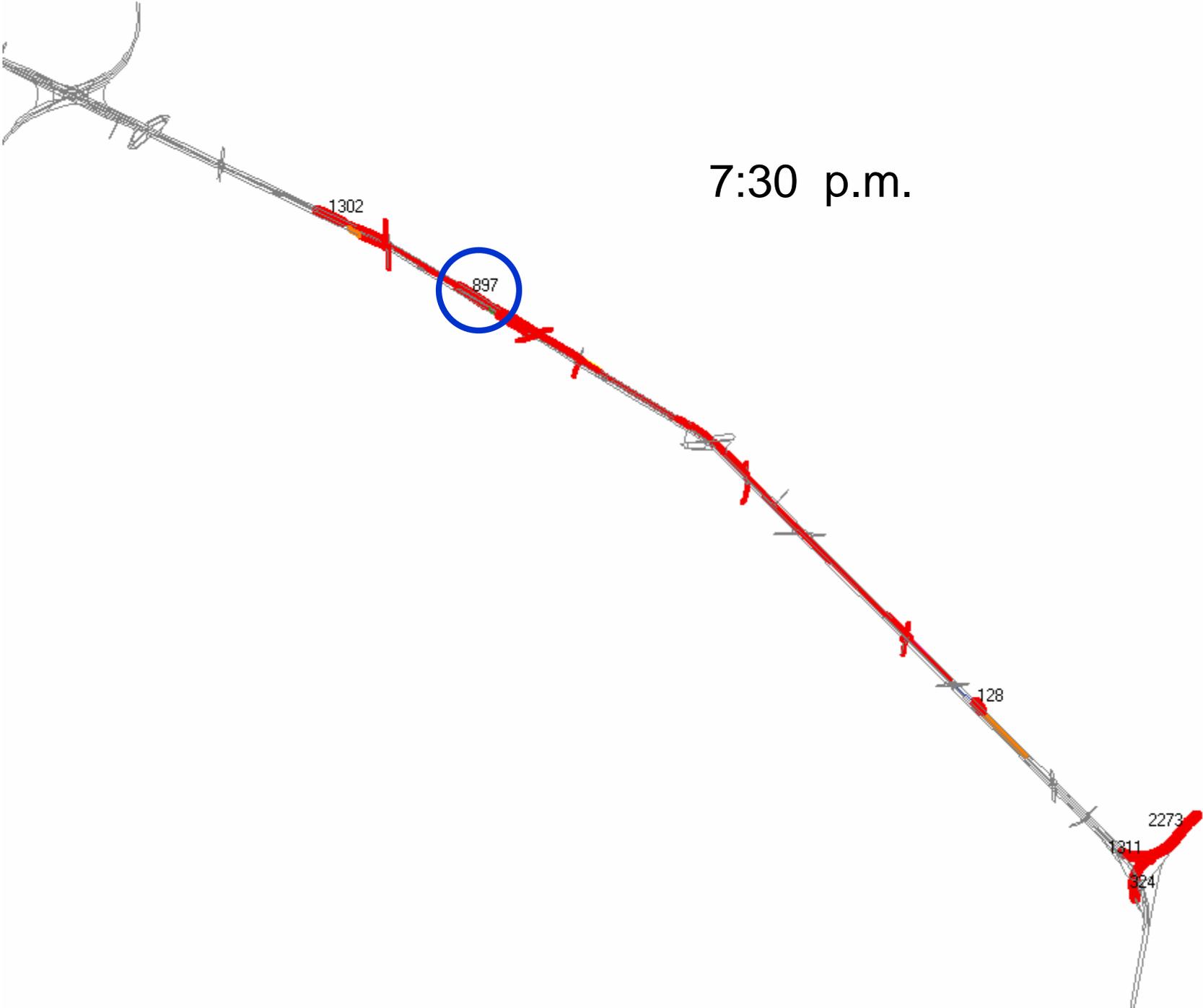
6:30 p.m.

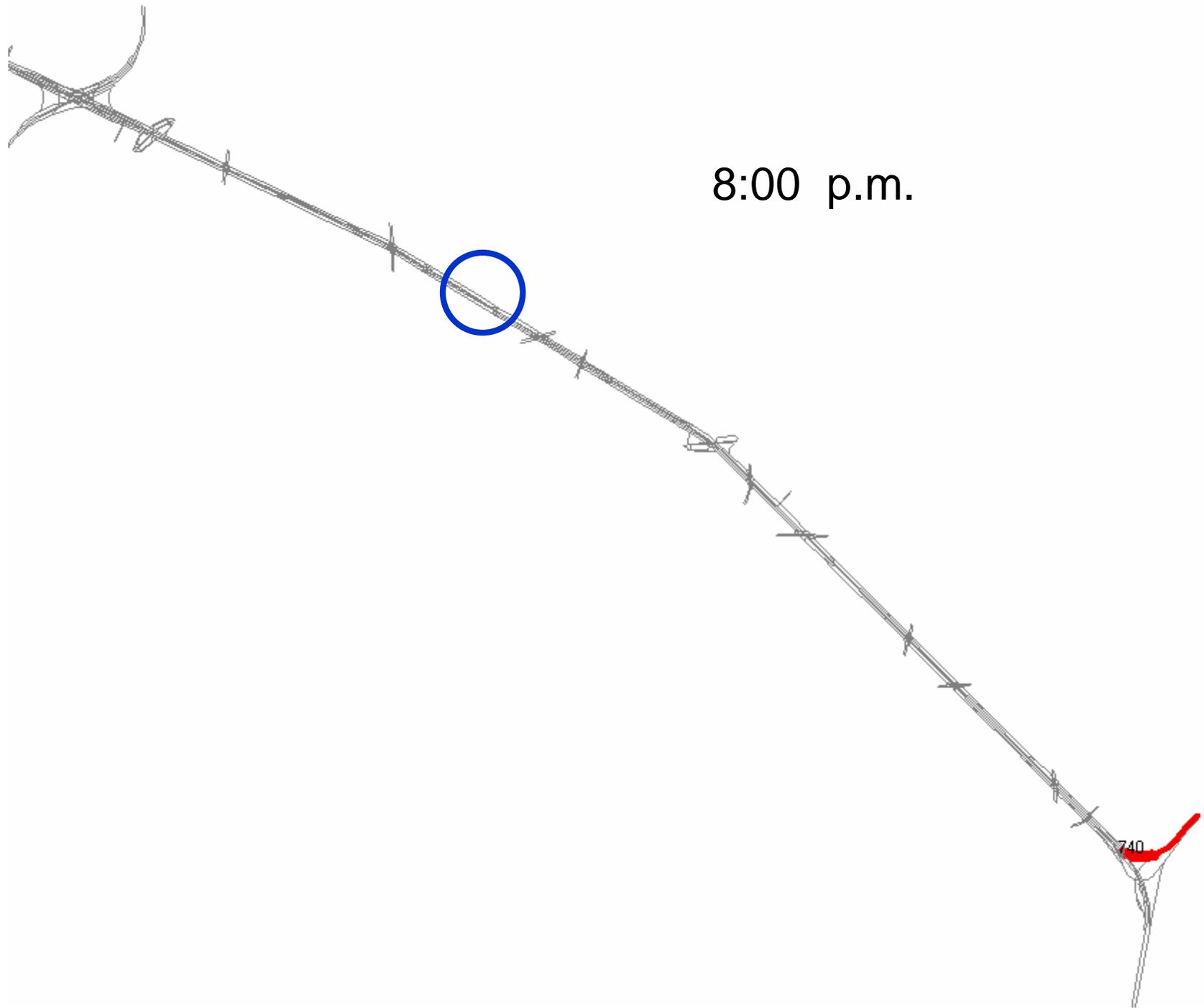


7:00 p.m.



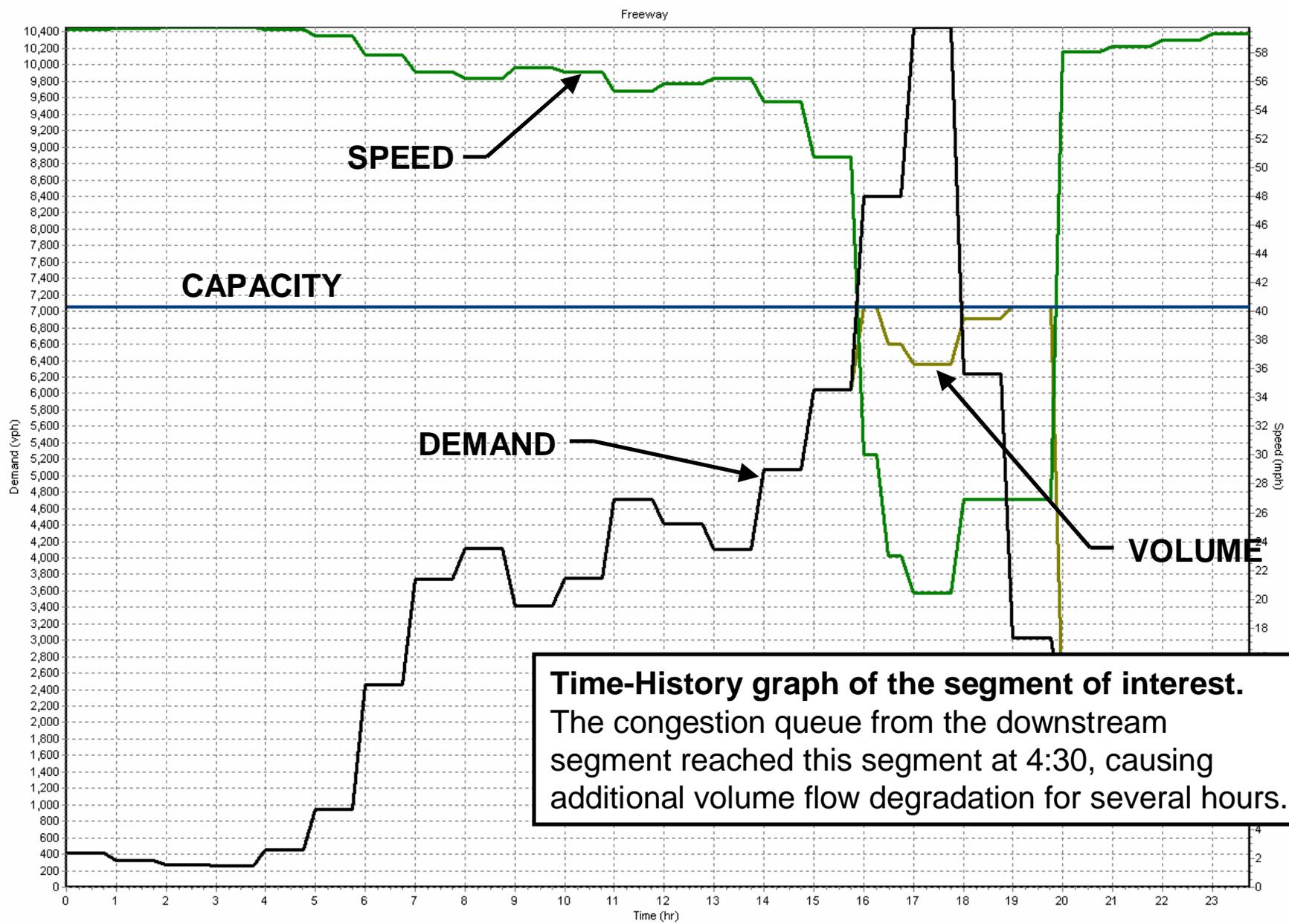
7:30 p.m.

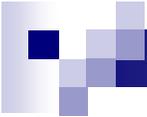




8:00 p.m.

740





Tier 3 Mesoscopic/Microscopic Hybrid Applications

The examples that follow show an analysis technique that applied mesoscopic processing (HCM type of flow theory) while tracking each individual vehicles location through successive time intervals, but transitioning to embedded microscopic processing (driver logic) for each vehicle as it approaches the curbsfront.



Tier 3 Mesoscopic/Microscopic Hybrid Applications

- n Large Hub Airport (2006) – Owner confidentiality restrictions prevent current project from being discussed.
- n Private Client Curbfront/Valet Operations (2005)

Tier 3 Mesoscopic/Microscopic Hybrid Applications

Video Examples – Private Client Curbfront / Valet Operations (2005)

Circular Curbfront,
Taxi Stand and Valet
Park Above

Ramps up to
Circular Curb
From Arterial

Arterial Street Below

Demonstration of Latest Hybrid Techniques

Hybrid Simulation Techniques

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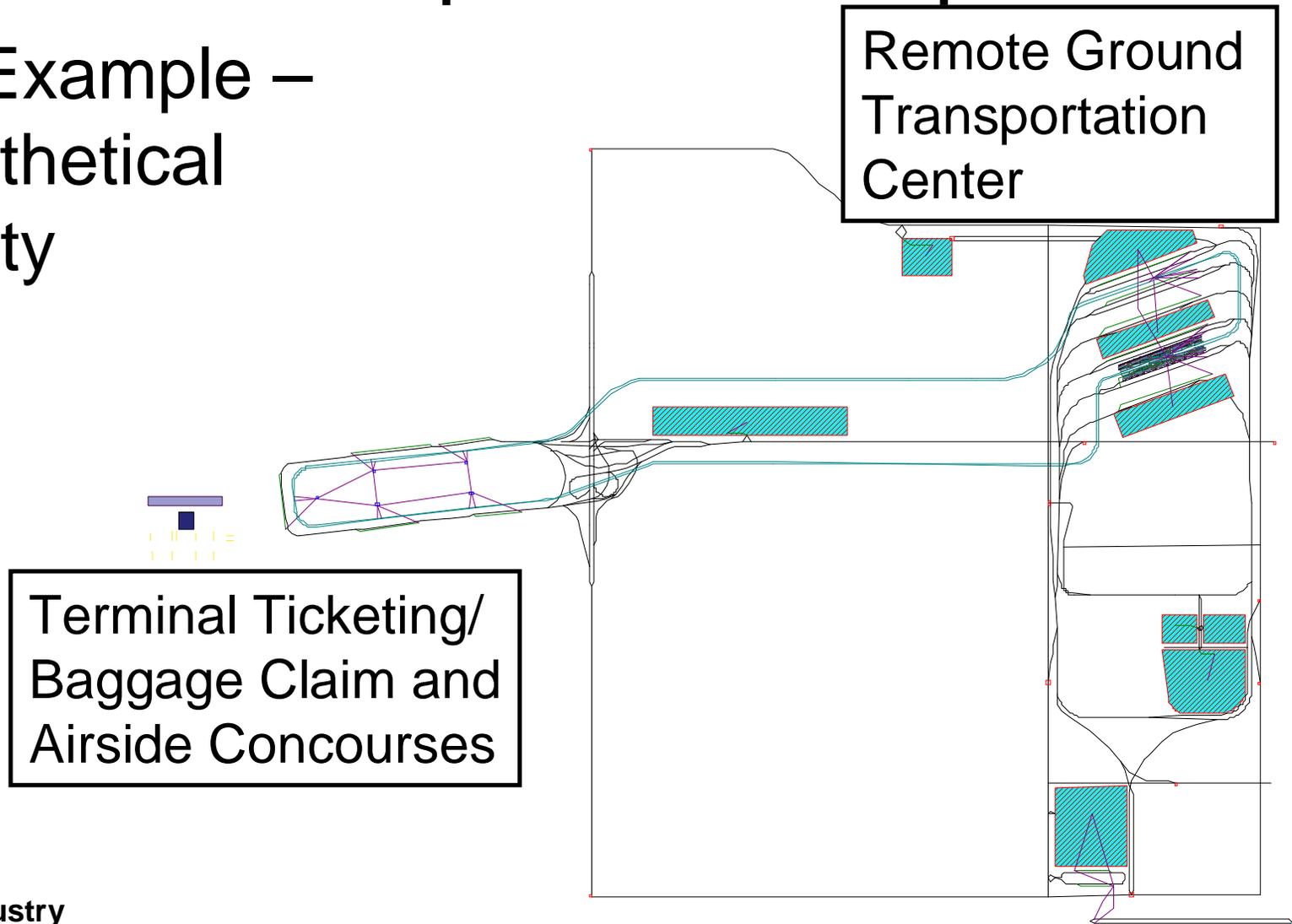
Demonstration of Latest Hybrid Techniques

Hypothetical Example

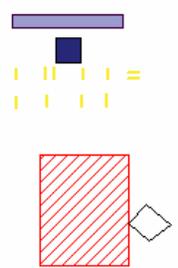
Based on Los Angeles International Airport
Remote Ground Transportation Center --
Alternative D Concept

Tier 3 Mesoscopic/Microscopic

Video Example –
Hypothetical
Facility

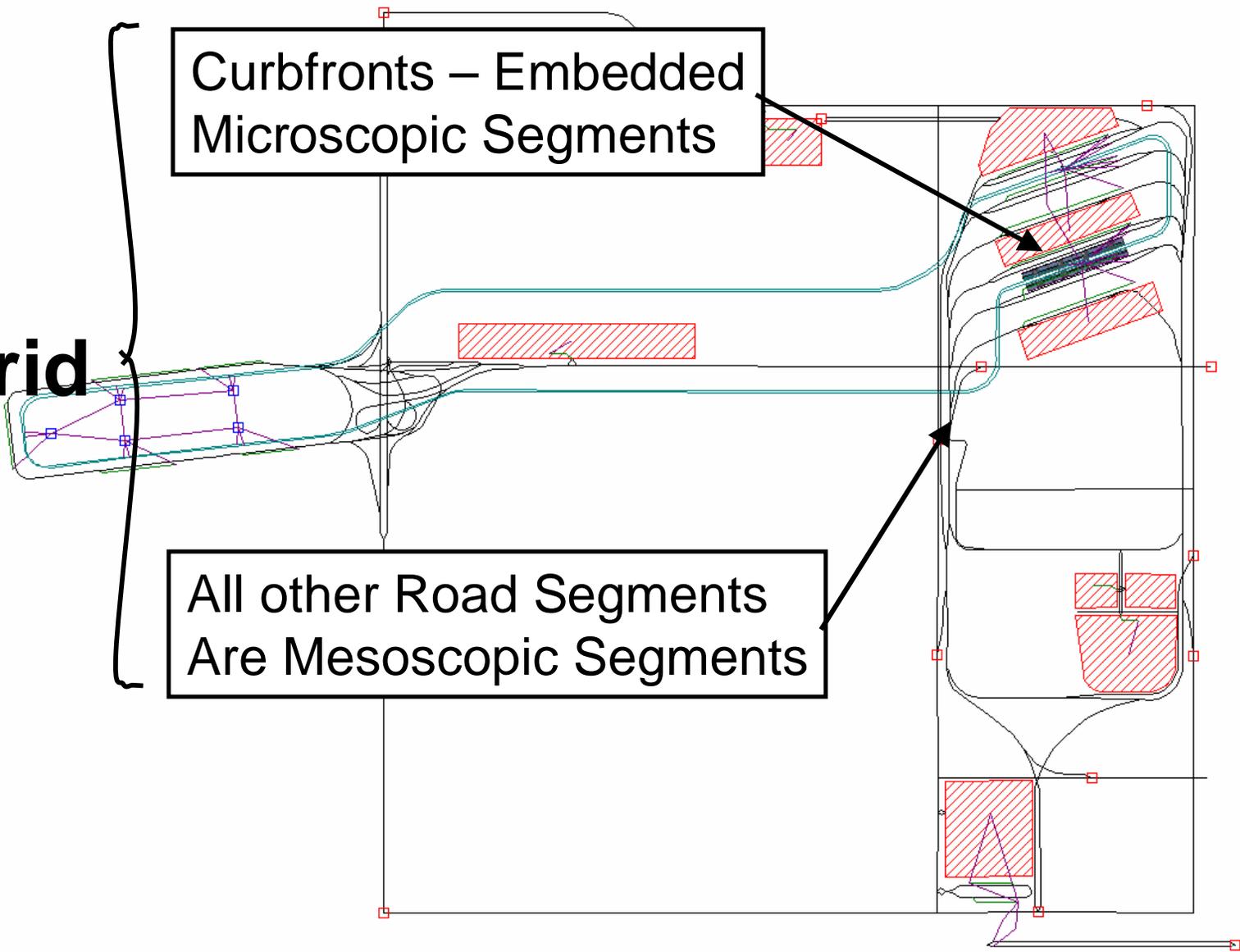


Hybrid

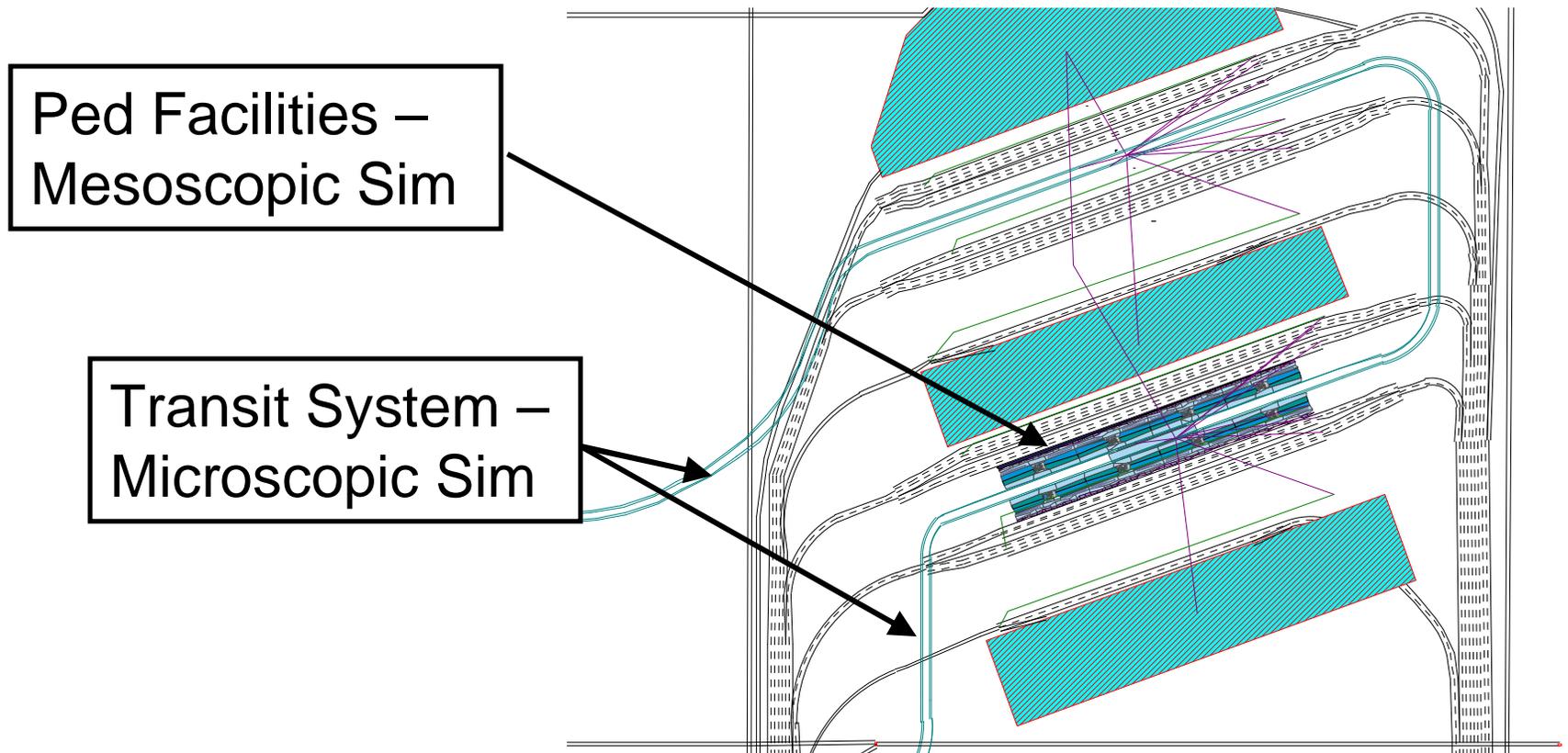


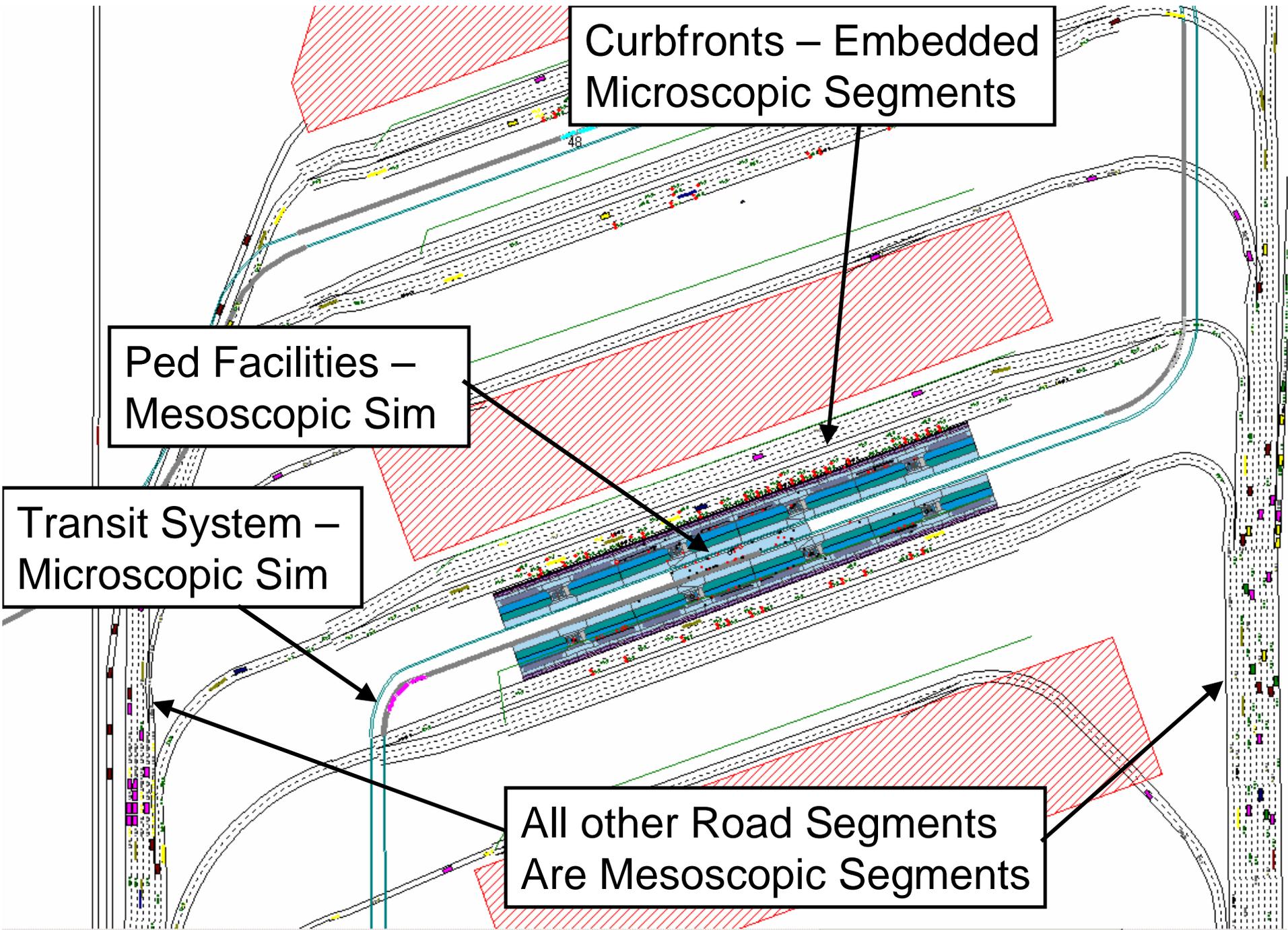
Curbfronts – Embedded
Microscopic Segments

All other Road Segments
Are Mesoscopic Segments



And Synchronous Simulations





Curbfronts – Embedded
Microscopic Segments

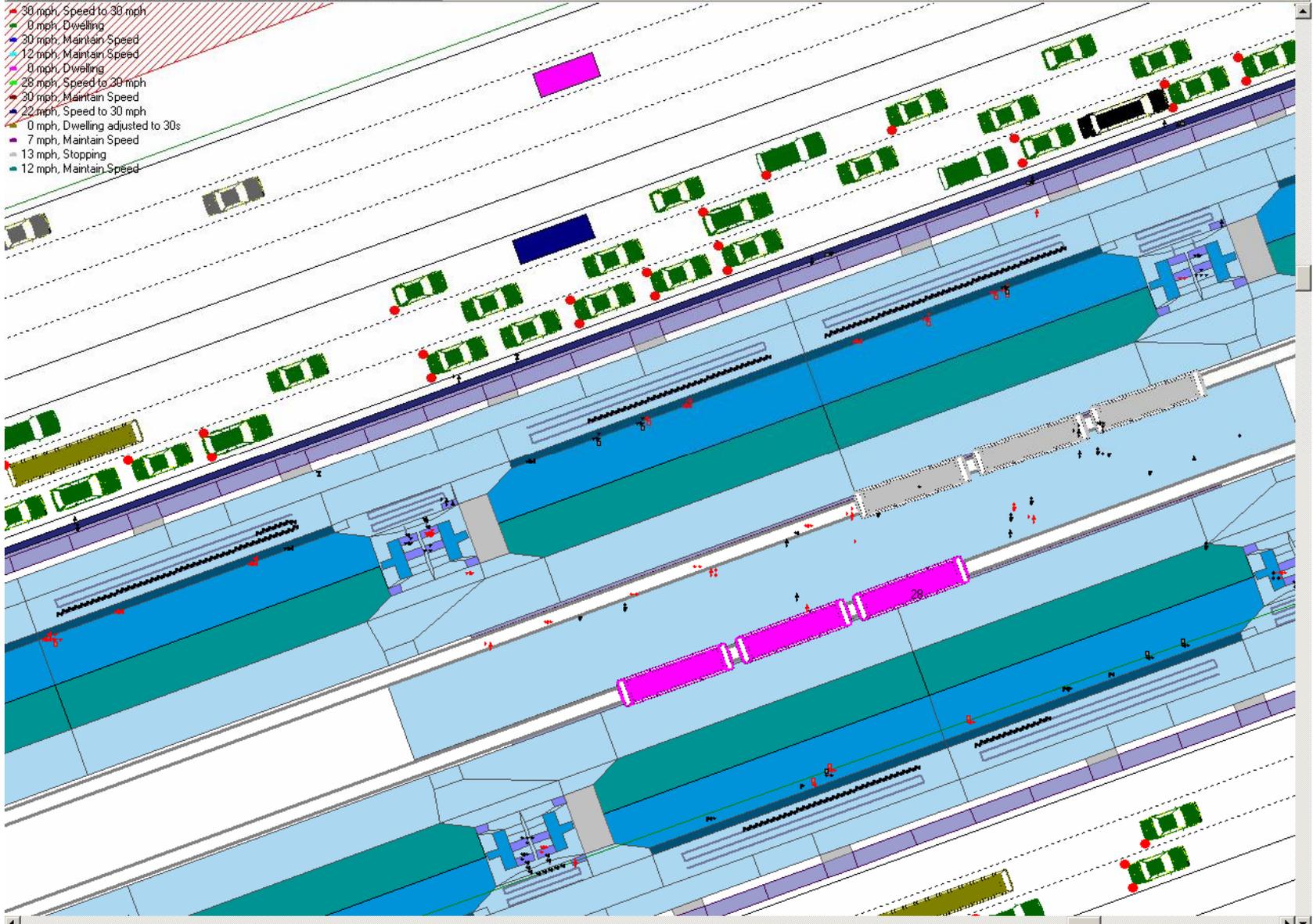
Ped Facilities –
Mesoscopic Sim

Transit System –
Microscopic Sim

All other Road Segments
Are Mesoscopic Segments

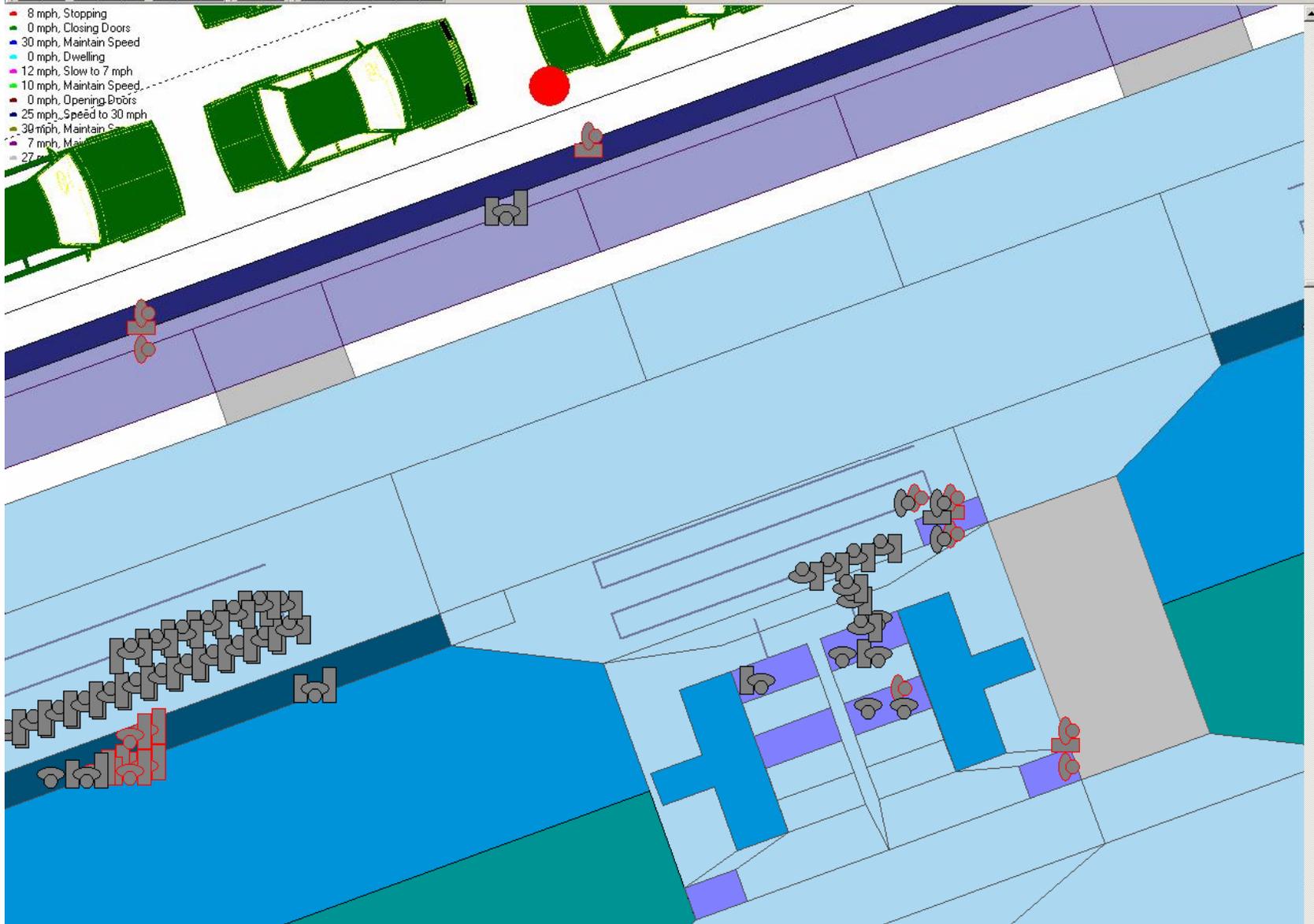


- 30 mph, Speed to 30 mph
- 0 mph, Dwelling
- 30 mph, Maintain Speed
- 12 mph, Maintain Speed
- 0 mph, Dwelling
- 28 mph, Speed to 30 mph
- 30 mph, Maintain Speed
- 22 mph, Speed to 30 mph
- 0 mph, Dwelling adjusted to 30s
- 7 mph, Maintain Speed
- 13 mph, Stopping
- 12 mph, Maintain Speed





- 8 mph, Stopping
- 0 mph, Closing Doors
- 30 mph, Maintain Speed
- 0 mph, Dwelling
- 12 mph, Slow to 7 mph
- 10 mph, Maintain Speed
- 0 mph, Opening Doors
- 25 mph, Speed to 30 mph
- 30 mph, Maintain Speed
- 7 mph, Maintain Speed
- 27 mph, Maintain Speed



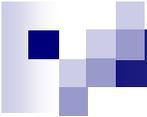
Airport Capacity Analysis Implications

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Airport Capacity Analysis

Implications of Hybrid Techniques

- n Land-access transportation modeled for all modes
- n Full Intermodal and terminal facilities modeled
- n Complete operational conditions simulated
- n Interaction between simulated objects where relevant
- n Time-limited operational capacity constraints imposed (e.g. MOT lanes out of service)
- n Security/emergency evacuation simulated



Next Steps for Hybrid Analysis Tools

- n Aircraft airfield taxiing models with GSE vehicle interactions
- n Embedded vertical circulation systems
- n Comprehensive landside model with all modes included in a single simulation
- n Applications to real time operations management and control centers

Hybrid Simulation Techniques for the Analysis of Landside and Terminal Capacity Issues

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