# Managing Construction Work Zone Traffic with NetZone

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# Outline of Presentation

- Research background
- Assessment of current construction work zone (CWZ) traffic analysis tools
- Development of a systematic CWZ traffic analysis procedure
- The Corridor work zone traffic analysis tool: NetZone
- Case study with the SR41 Fresno corridor network
- Future work

# Background

- Increasing need for highway rehabilitation/reconstruction
  - California highway system:15,181.36 miles
  - 90% built between 1955~1970
  - Typical design life : 20 years
  - Long-life pavement rehabilitation strategies (LLPRS) program by Caltrans
- CWZs often cause significant traffic delay
  - > 60 million vehicles per hour per day of capacity were estimated to be lost due to work zones over a two week period during the peak summer roadwork season throughout the country

    (U.S. DOT,FHWZ, *A Snapshot of Peak Summer Work Zone Activity Reported on State Road Closure and Construction Websites*. Washington, D.C., August 2002)

# Background-continued

- Lack of a systematic, easy-to-use yet methodologically sound analysis and design tool to quantify CWZ induced traffic delay and balance construction & user (delay) costs, particularly in corridor networks
  - On the construction side:

    Which type of construction schedule will cause less traffic delay (e.g., 10-hour nighttime closures, 55-hour weekend closures, etc.), or combined construction and user costs?
  - On the traffic management side:

    What traffic management strategies to employ and how effective they are in reducing traffic congestion in the impacted area of a CWZ?

# Research Objectives

- Review current CWZ traffic analysis tools, identify their strengths and weaknesses
- Develop a systematic procedure for quickly assessing network-wide traffic impact of a given construction plan and designing effective CWZ management plans
- Implement the procedure in a user-friendly software tool
- Apply the developed models and tools to candidate projects to demonstrate their usage and evaluate their performance

# Pros and Cons of existing CWZ tools

| Existing CWZ modeling tools | Strength | Weakness |
|---|---|---|
| **D/C analysis** | - based on HCM 2000<br>- provides a quick estimate | - only for an isolated work zone, incapable of quantifying network-wide impact<br>- not adequately consider management measures and users' behavior response |
| **QuickZone** | - based on HCM 2000<br>- models a corridor with alternative routes<br>- take account of certain management measures | -corridor features are not explicitly modeled<br>- Many critical parameters such as capacity reduction, diversion rates etc have to be provided by the user |
| **planning tools (TransCAD, EMME/2, etc.)** | - models a large network<br>- models route choice based on principle of static network equilibrium | -does not model queuing and peak spreading<br>-many traffic control strategies such as ramp metering and signal coordination are not considered |
| **Microscopic simulation tools (Paramics, Vissim, MITSIM, etc)** | - very detailed modeling of road geometry and driver characteristics<br>- nice graphical user interface<br>- has many user specified MOEs | - needs very detailed input<br>- needs to calibrate many parameters<br>- has limited user diversion behavior modeling<br>- Labor intensive |

# An effective CWZ traffic impact analysis tool should be able to…

- model different geographic scopes

  e.g., isolated work zones, corridor, multiple CWZs in a large network…

- model diverse traffic management measures

  e.g., changes in signal timing, provision of traveler information, changes in speed limit, lane re-stripping, etc.

- model travelers' responses to travel delay and management measures

  e.g., no response, divert to an alternative route, change departure time, cancel trips, switch to other modes, etc.

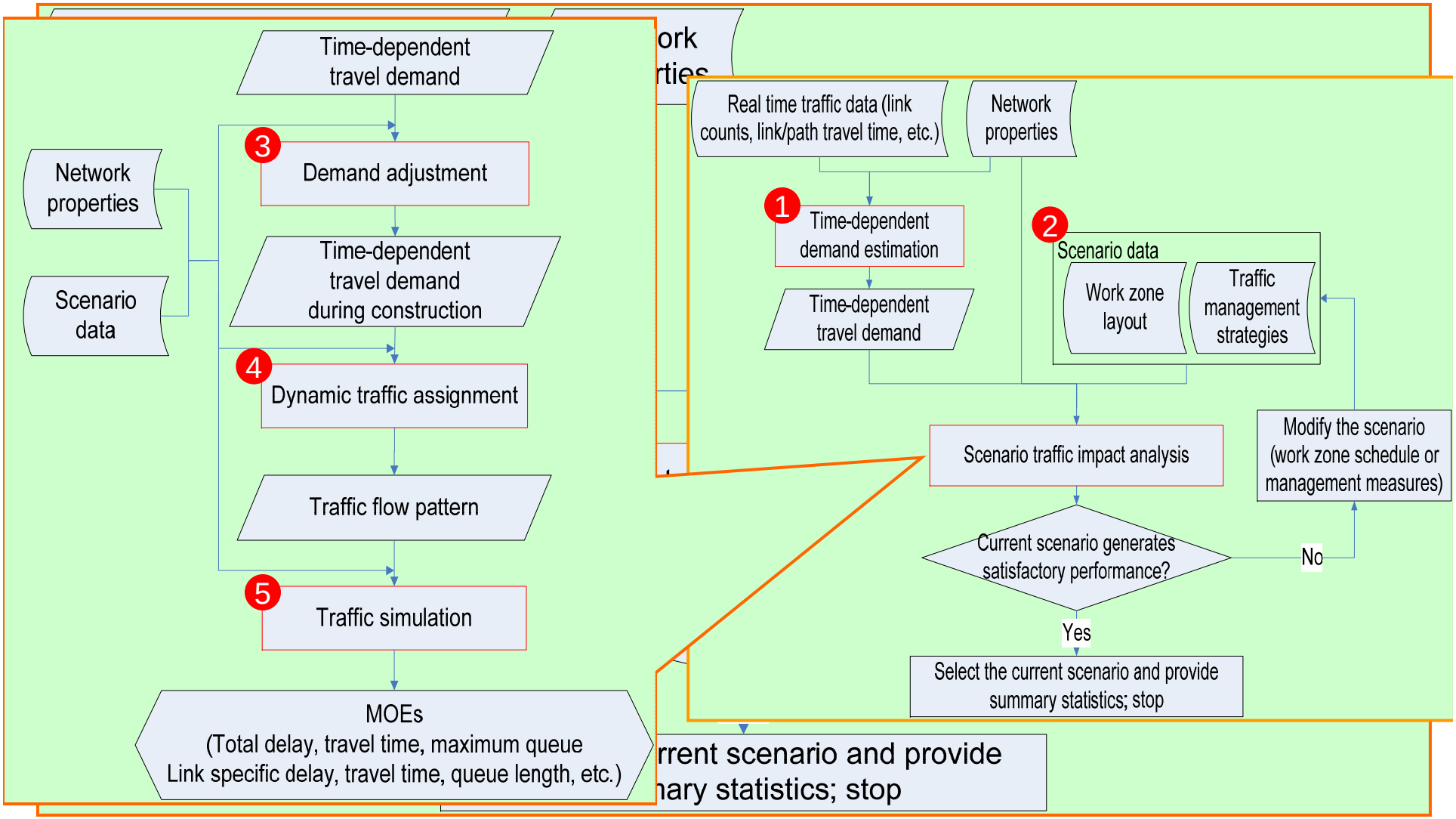
- produce detailed performance measures

  e.g., aggregate MOEs (e.g., total travel time, delay, maximal queue) and disaggregate MOEs (e.g., delay and queuing on specific links)

- be easy to use

  easy to collect input data, calibrate parameters, and set up the model; provide reasonable results with acceptable computational overhead

# The NetZone traffic analysis procedure



# 1 Prepare time-dependent demand

- Option 1: Synthesize from static O-D demand
  - Input: static O-D demand + temporal demand distribution profile
  - Suitable for: a rough and quick estimation
- Option 2: TD-LPFE: time-dependent logit path flow estimator
  - Originally proposed by Michael Bell (1997), implemented through TO 4135 and TO 5502 (Visual PFE and Visual-PFE TD)
  - Input: Link flow counts, historical time-dependent O-D demand data
  - Suitable for: large scale network, relatively low estimation accuracy (compared to option 2)

# 2 Modeling CWZ attributes and management measures

- Work zone data
  - a temporal capacity reduction to a certain section of a link
  - Other attributes: time of day (day or night) , time of week (weekday or weekend)

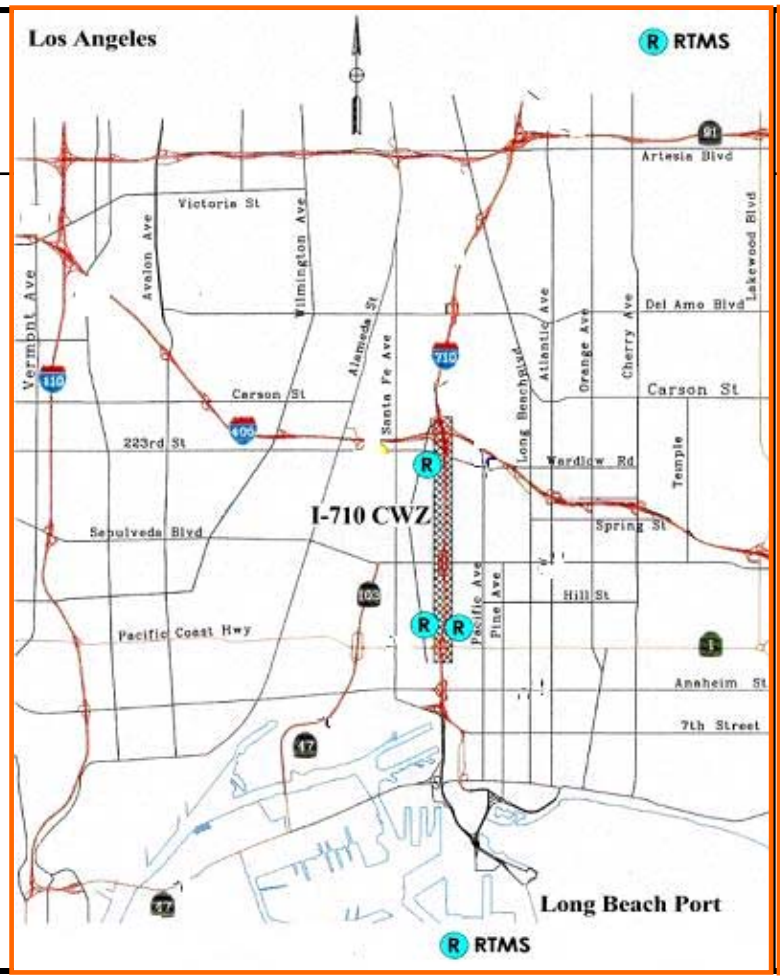
- Traffic management measures
  - Signal control (pre-time or actuated)
  - ramp metering (pre-time or ALINEA)
  - Pre-trip traveler information
  - Media campaign
  - Highway advisory radio
  - Variable message signs

Modeled qualitatively, i.e., it is assumed that these attributes and (or) measures will affect the demand pattern during the construction period

# 3 Demand diversion during construction

- Heuristic diversion models are developed based on observations of real traffic data
- Real CWZ project overview:

| | |
|---|---|
| **Project** | |
| **Network characteristics**<br>**Work zone characteristics**<br>**Traffic closure time**<br>**Traffic closure plan**<br>**Traffic management**<br>**Daily traffic condition** | |



# I-15 Devore project

## – Demand reduction

Table 3 Average travel demand diversion rate for I-15 SB

| | Sun | Mon | Tue | Wed | Thu | Fri | Sat | Avg. |
|---|---|---|---|---|---|---|---|---|
| (1) ADT for regular days (veh./day) | 55,041 | 53,985 | 49,943 | 51,396 | 54,406 | 55,936 | 48,082 | 52,600 |
| (2) ADT for construction days (veh./day) | 51,904 | 54,991 | 48,821 | 50,588 | 54,575 | 52,191 | 50,436 | 51,943 |
| r = (2)/(1) | 0.94 | 1.02 | 0.98 | 0.98 | 1.00 | 0.93 | 1.05 | **0.99** |

Table 4 Average travel demand diversion rate for I-15 NB

| | Sun | Mon | Tue | Wed | Thu | Fri | Sat | Avg. |
|---|---|---|---|---|---|---|---|---|
| (1) ADT for regular days (veh./day) | 48,528 | 51,543 | 52,724 | 48,601 | 58,887 | 65,326 | 63,658 | 57,334 |
| (2) ADT for construction days (veh./day) | 50,887 | 49,119 | 47,783 | 46,642 | 52,145 | 58,023 | 58,445 | 52,032 |
| R = (2)/(1) | 1.05 | 0.95 | 0.91 | 0.96 | 0.89 | 0.89 | 0.92 | **0.91** |

# I-15 Devore project – Temporal demand redistribution

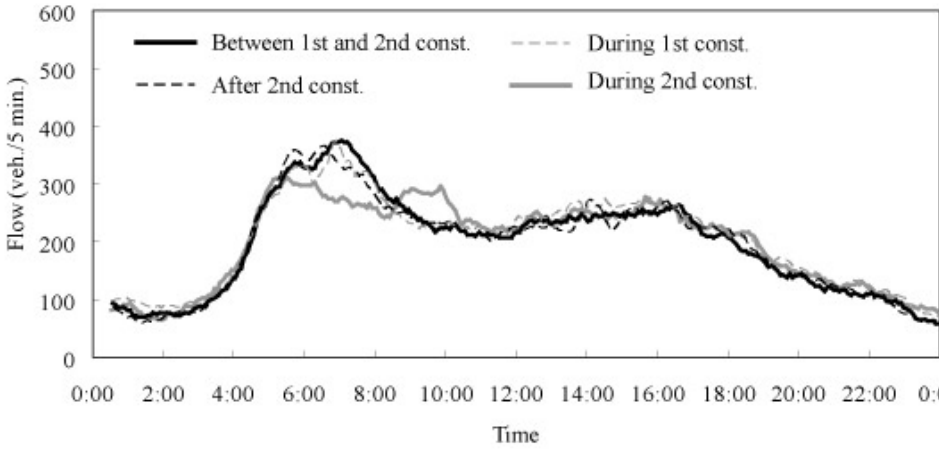



Fig. 1(a) I-15 SB (Monday)

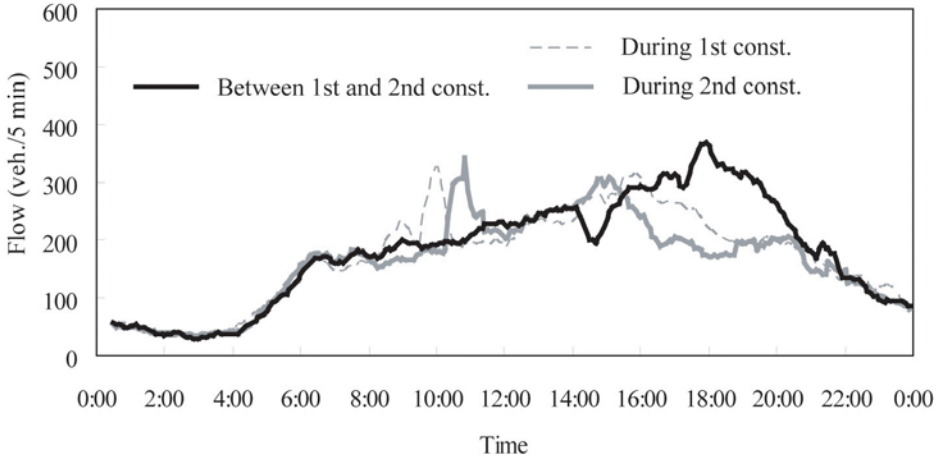



Fig. 1(c) I-15 NB (Monday)

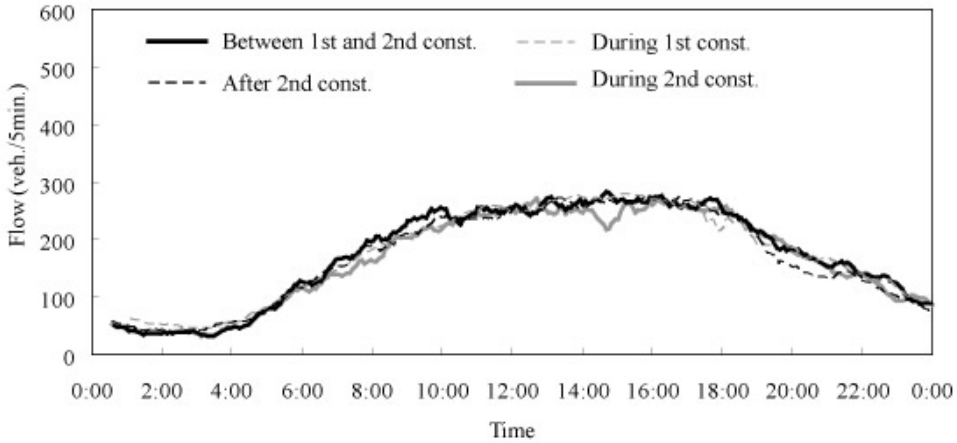



Fig. 1(b) I-15 SB (Saturday)

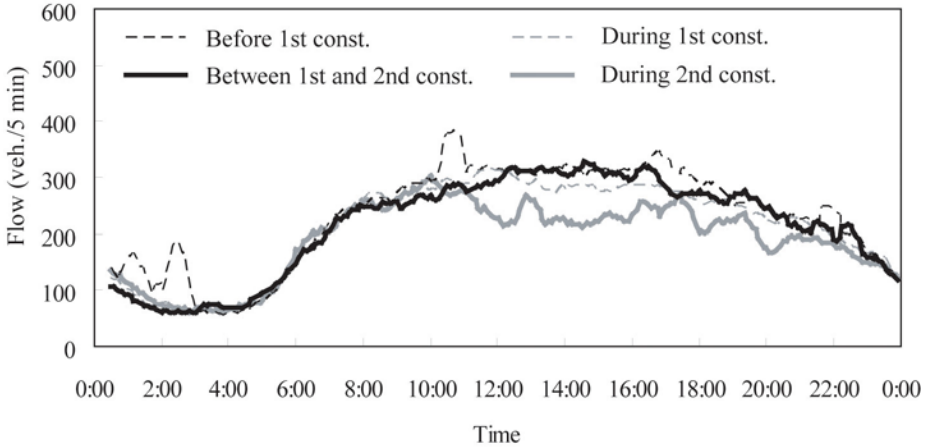



Fig. 1(d) I-15 NB (Saturday)

# I-710 Long Beach project – Demand reduction

Table 5 Average travel demand diversion rate for I-710 SB

| | Sat | Sun | Avg. |
|---|---|---|---|
| ADT for regular days (veh./day) | 48,254 | 41,278 | 44,766 |
| ADT for construction days (veh./day) | 31,626 | 30,015 | 30,820 |
| r = (2)/(1) | 0.66 | 0.73 | **0.69** |

Table 6 Average travel demand diversion rate for I-710 NB

| | Sat | Sun | Avg. |
|---|---|---|---|
| ADT for regular days (veh./day) | 50,861 | 57,489 | 54,175 |
| ADT for construction days (veh./day) | 38,476 | 36,633 | 37,554 |
| r = (2)/(1) | 0.76 | 0.64 | **0.69** |

# I-710 Long Beach project
## – Temporal demand redistribution

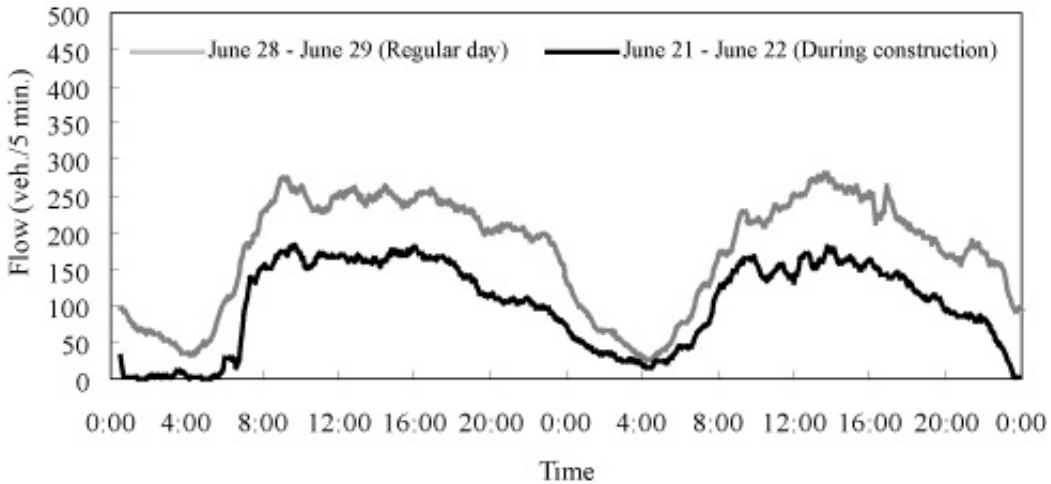



Fig. 2(a) I-710 SB

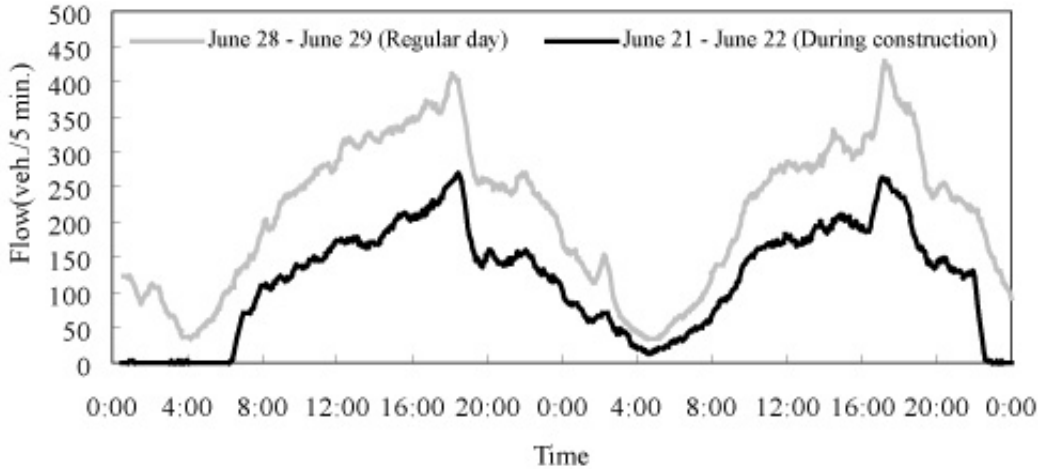



Fig. 2(b) I-710 NB

# Key observations from the empirical data

- Demand diversion rates are highly related to network topology, i.e., the availability of detour routes, and the dominant travel purpose through the CWZ area
- The time of construction (weekend or weekday), use of traveler information system, previous traffic condition, and capacity reduction proportion may affect diversion, but the effect is not pronounced in these two sites
- Compared to demand reduction, the demand temporal redistribution effect is relatively small (I-15 project, slight shifts; I-710 project, trivial)
- More convincing conclusions can only be drawn from analysis of data at more CWZ sites.

# The demand adjustment model

- Assumption: demand adjustment during construction can be characterized by two factors: no show and route diversion
- No show rate ($NSR$):

$$NSR = \begin{cases} 0 & DR \in (-\infty, 0) \\ 1 - a_1^{DR} & DR \in [0, 0.02] \\ 1 - a_1^{DR} a_2^{TIS} a_3^{Campaign} a_4^{Night} a_5^{Weekend} & DR \in (0.02, +\infty] \end{cases}$$

- Route diversion:
  - Traffic assignment with dynamic feedback:

$$RR_D = RR_B + (1 - RR_B)[1 - (1 - a_6)^{Radio} (1 - a_7)^{VMS}]$$

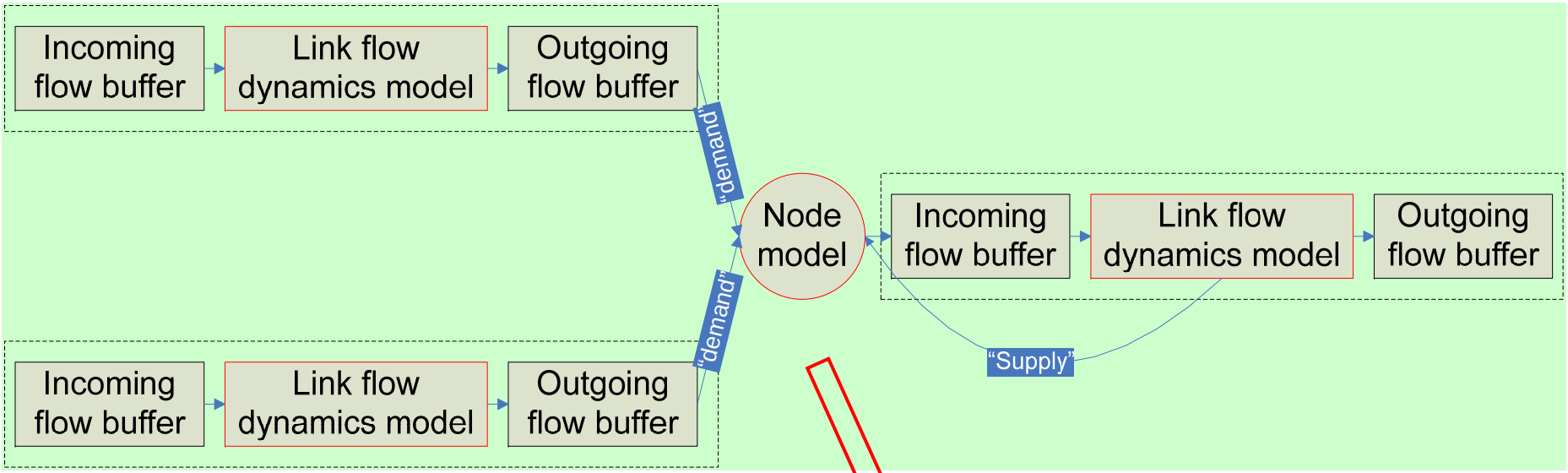
$RR_D, RR_B$ are percentage of drivers who updates their routes dynamically with and without traveler information

# 4 Determine the traffic flow pattern with mixed traffic assignment

- $(1 - RR_D)$ percentage of drivers choose the shortest path based on free-flow path travel times

- $RR_D$ percentage of drivers will make en-route path adjustments according to the level of congestion in the network

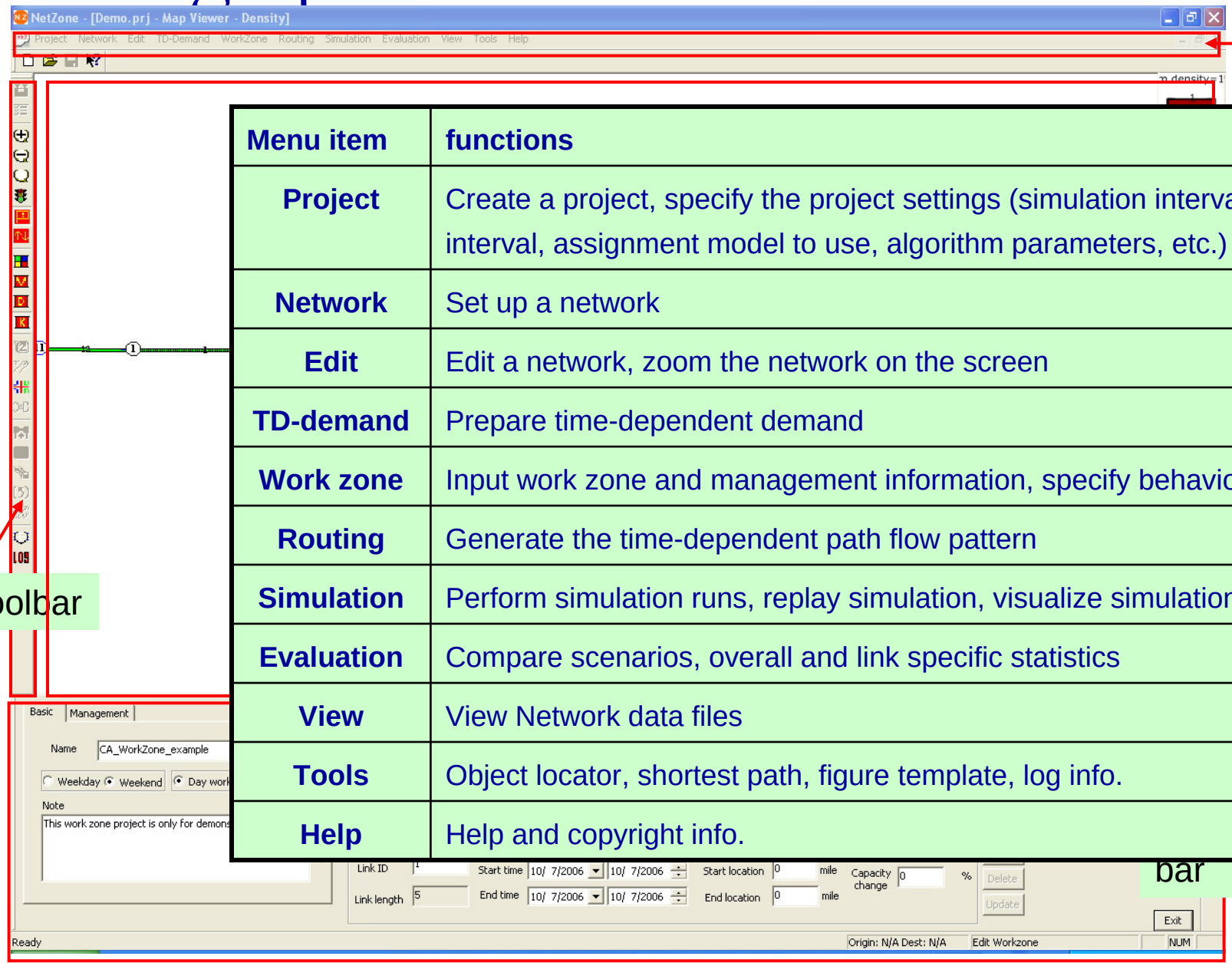
# The macroscopic traffic simulator in NetZone




Point-queue model
Spatial-queue model
CTM/LWR model
...

Uncontrolled nodes
Signal controlled intersections
Metered ramps
Movement restrictions

# The graphical user interface




Main menu

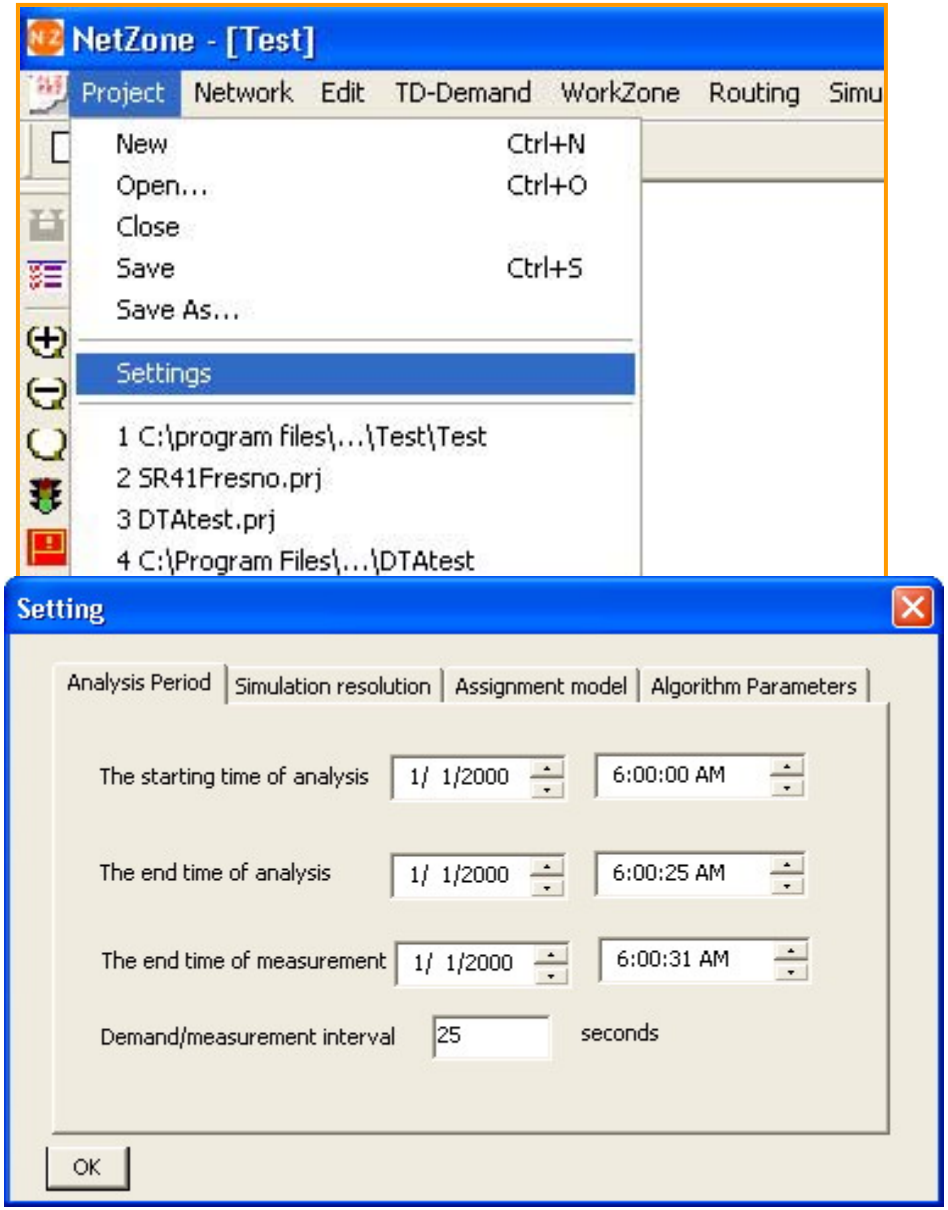
Toolbar

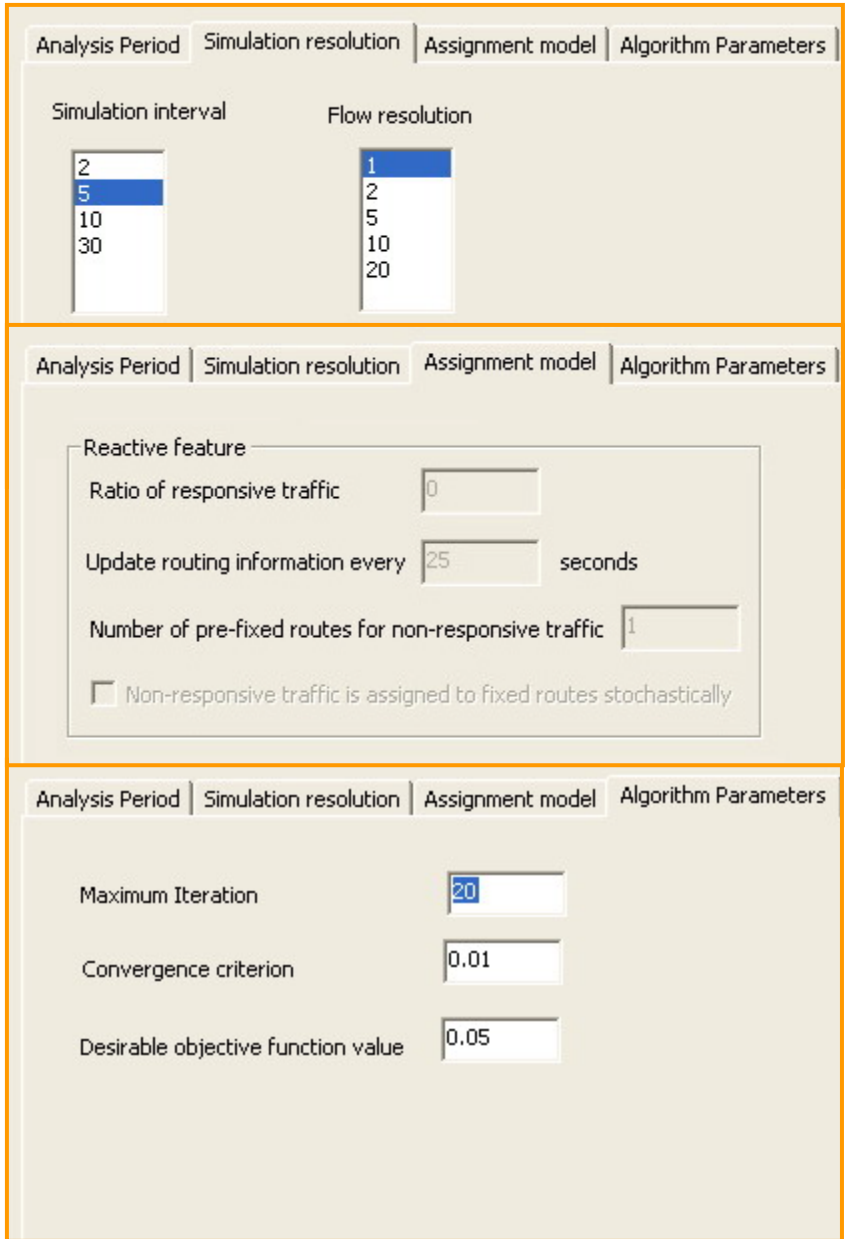
bar

| Menu item | functions |
|---|---|
| **Project** | Create a project, specify the project settings (simulation interval, demand interval, assignment model to use, algorithm parameters, etc.) |
| **Network** | Set up a network |
| **Edit** | Edit a network, zoom the network on the screen |
| **TD-demand** | Prepare time-dependent demand |
| **Work zone** | Input work zone and management information, specify behavior factors |
| **Routing** | Generate the time-dependent path flow pattern |
| **Simulation** | Perform simulation runs, replay simulation, visualize simulation results |
| **Evaluation** | Compare scenarios, overall and link specific statistics |
| **View** | View Network data files |
| **Tools** | Object locator, shortest path, figure template, log info. |
| **Help** | Help and copyright info. |

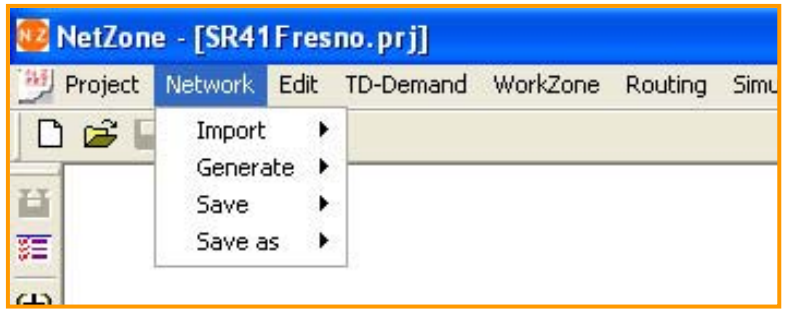
# An 8-step simple tutorial for NetZone

# Step 1: Create a project



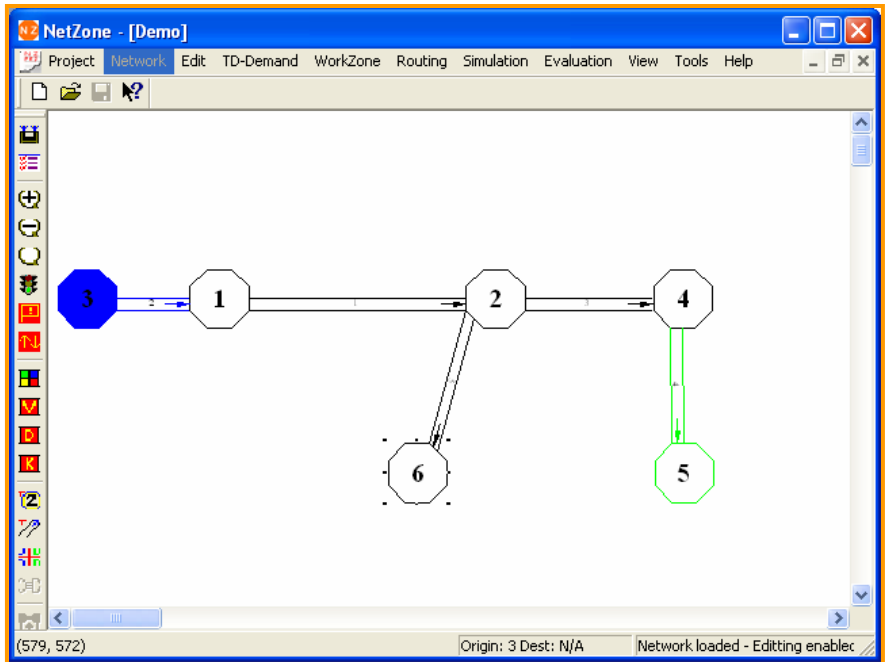



# Step 2: Set up the network




- Option 1:

  Directly construct in NetZone




- Option 2: Import from:

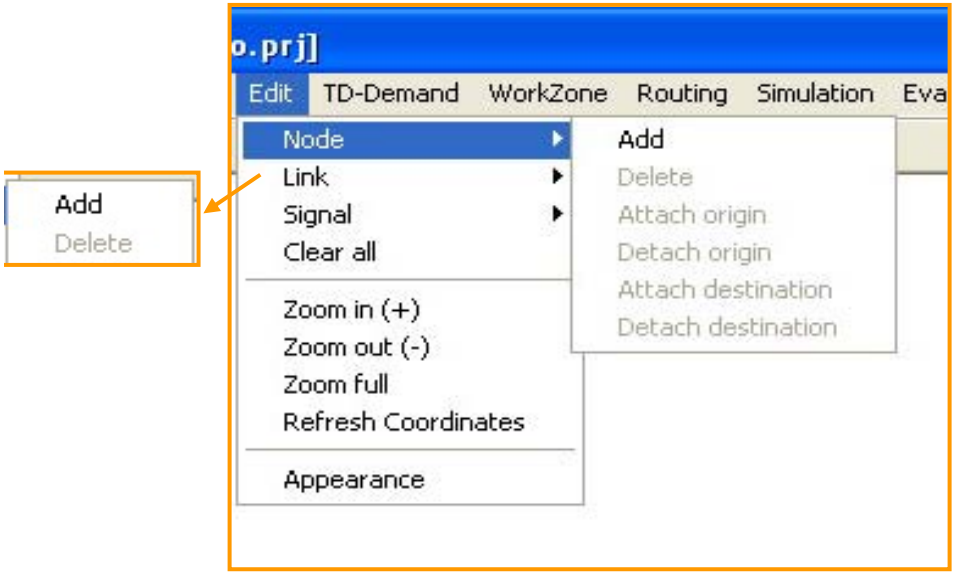
  DYNASMART-P

  ESRI Shapefiles

  FORT

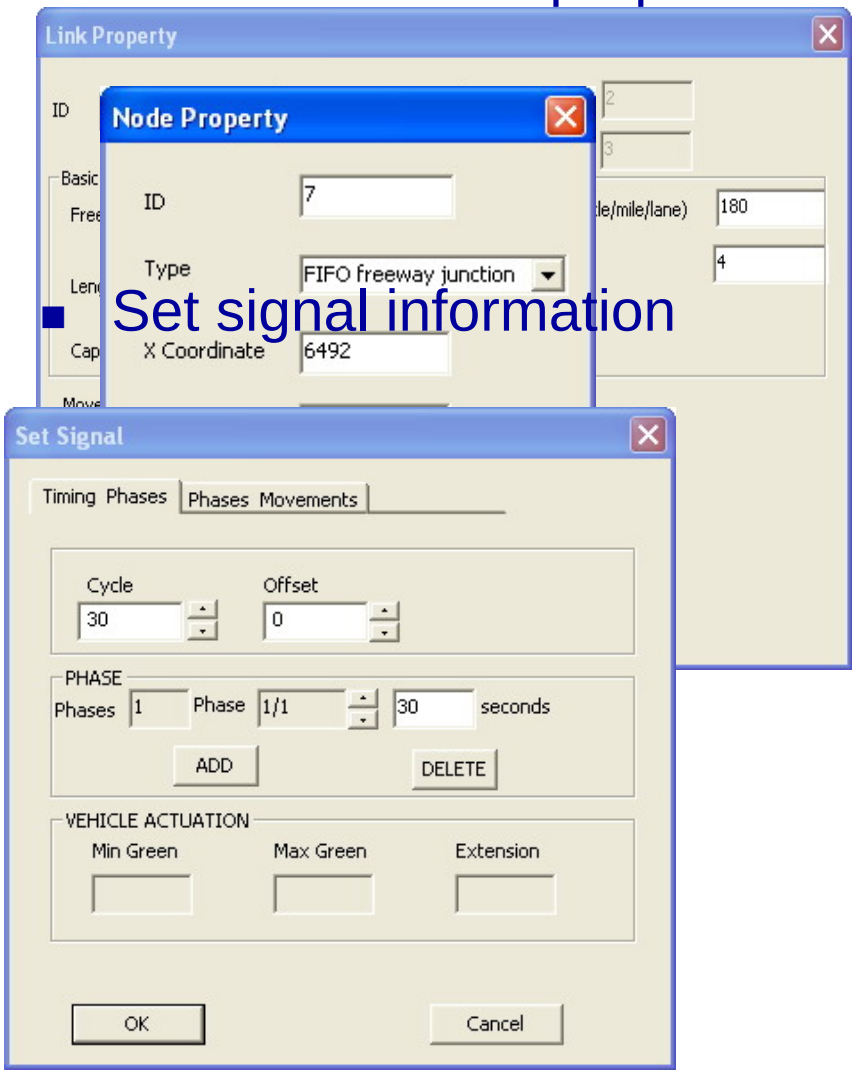
- Option 3: Generate random grid network

# Step 3: Edit the network

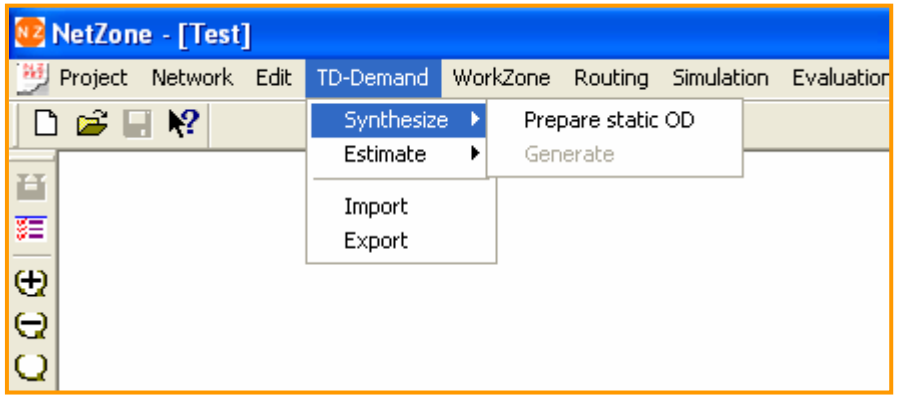



- Add/delete a node
- Attach/Detach origin/destination
- Add/delete a link

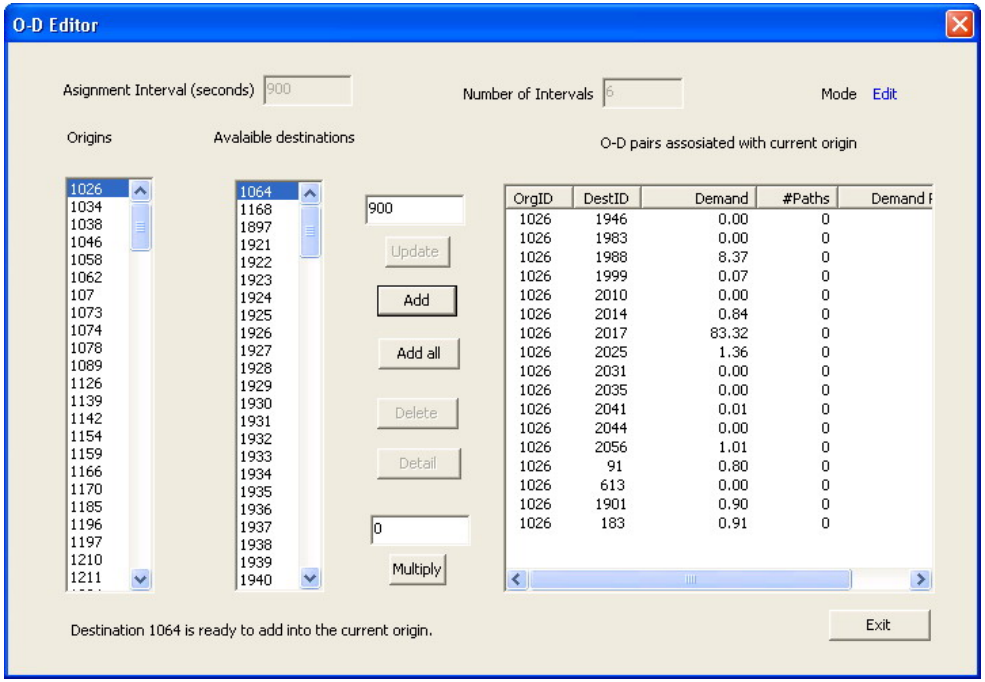
- Set node and link properties
- Set signal information

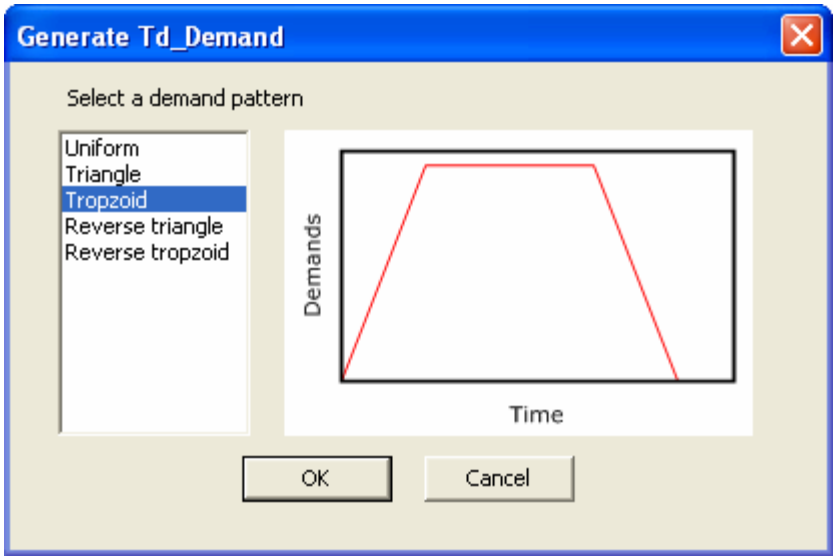


# Step 4: Prepare time-dependent demand

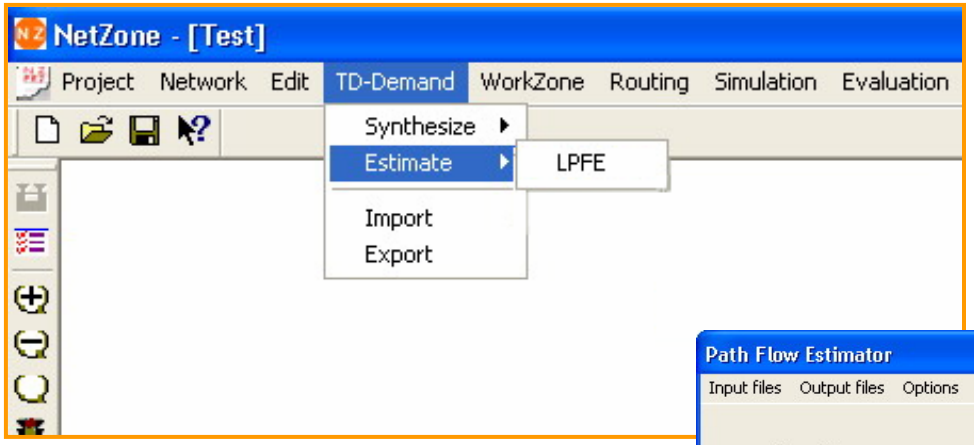


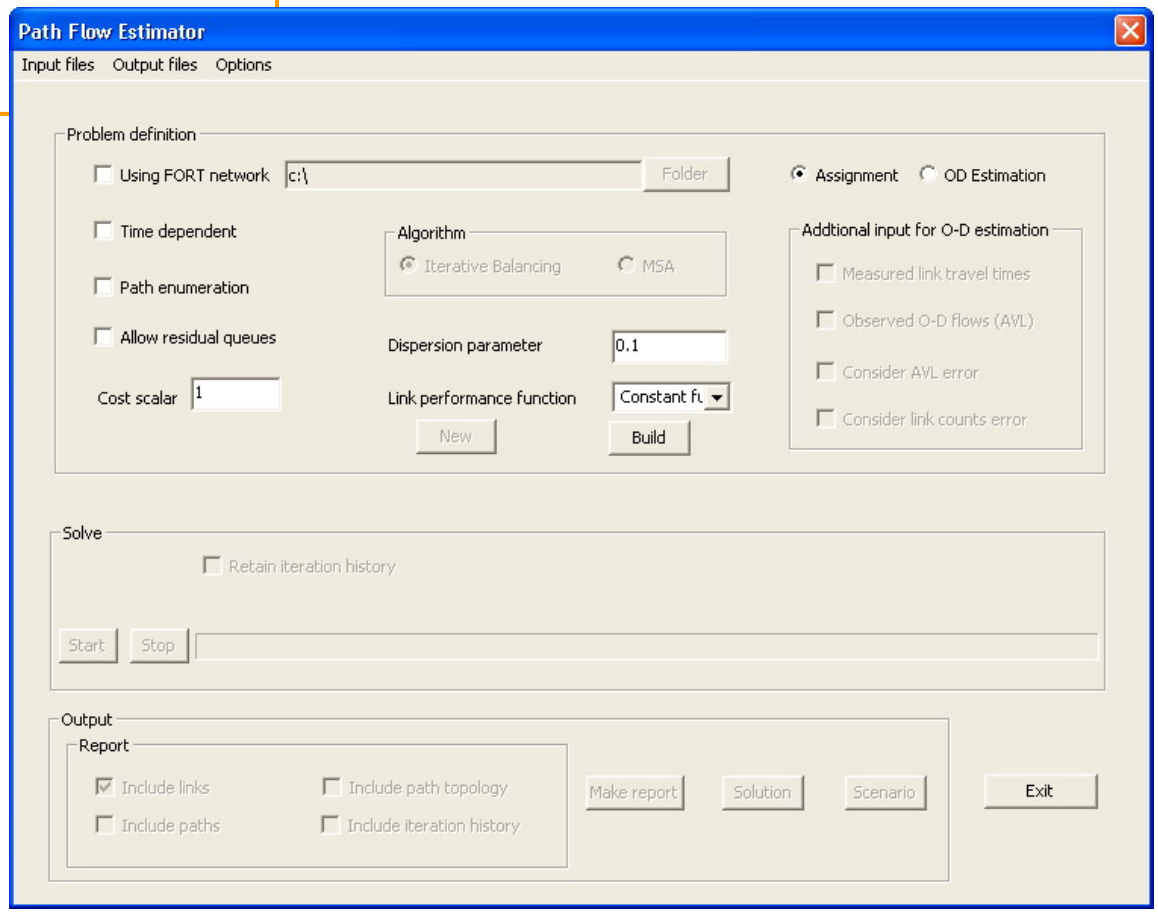

- Option 1: synthesize from static OD



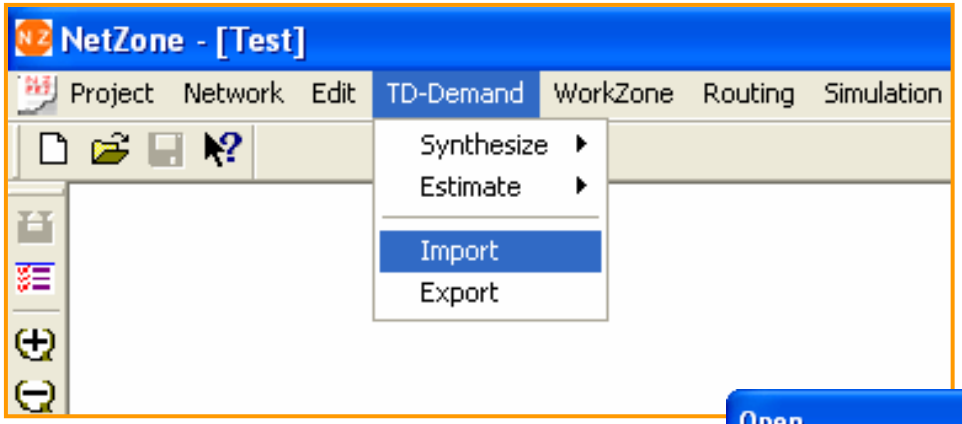
# Step 4: Prepare time-dependent demand

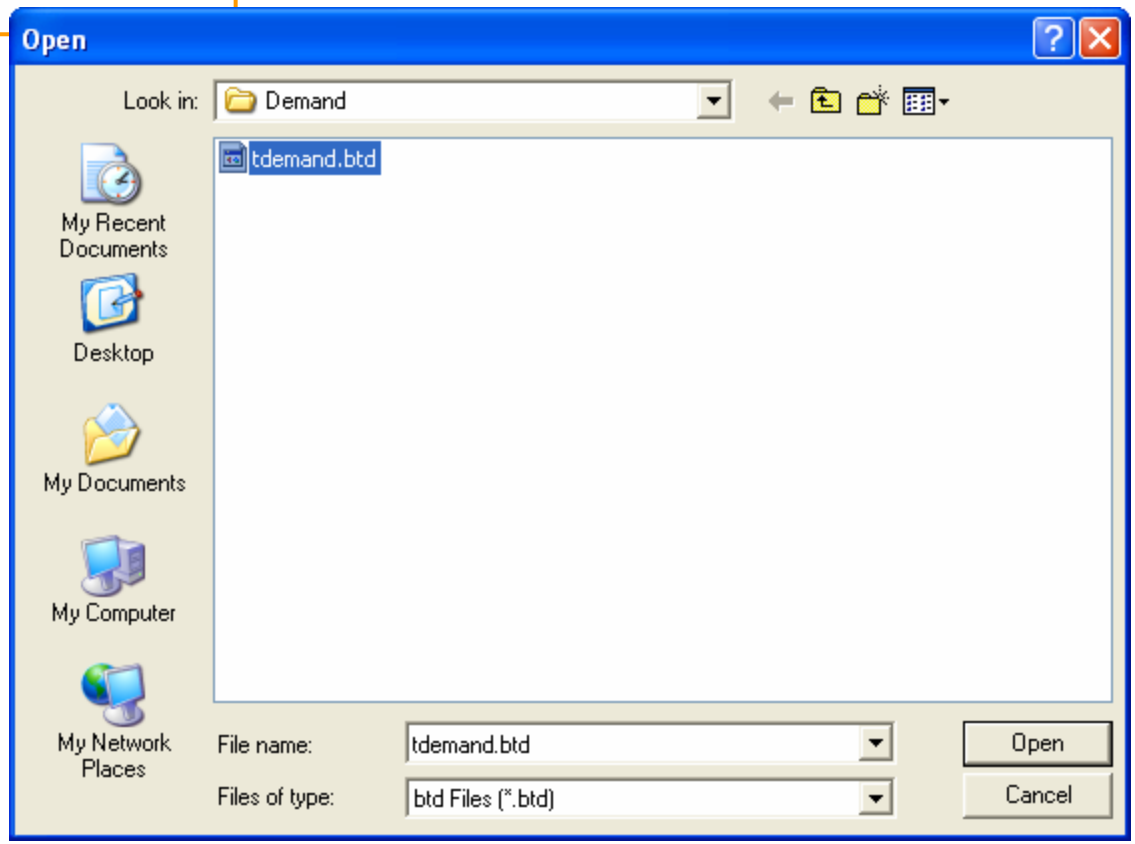



- Option 2: Estimate by LPFE

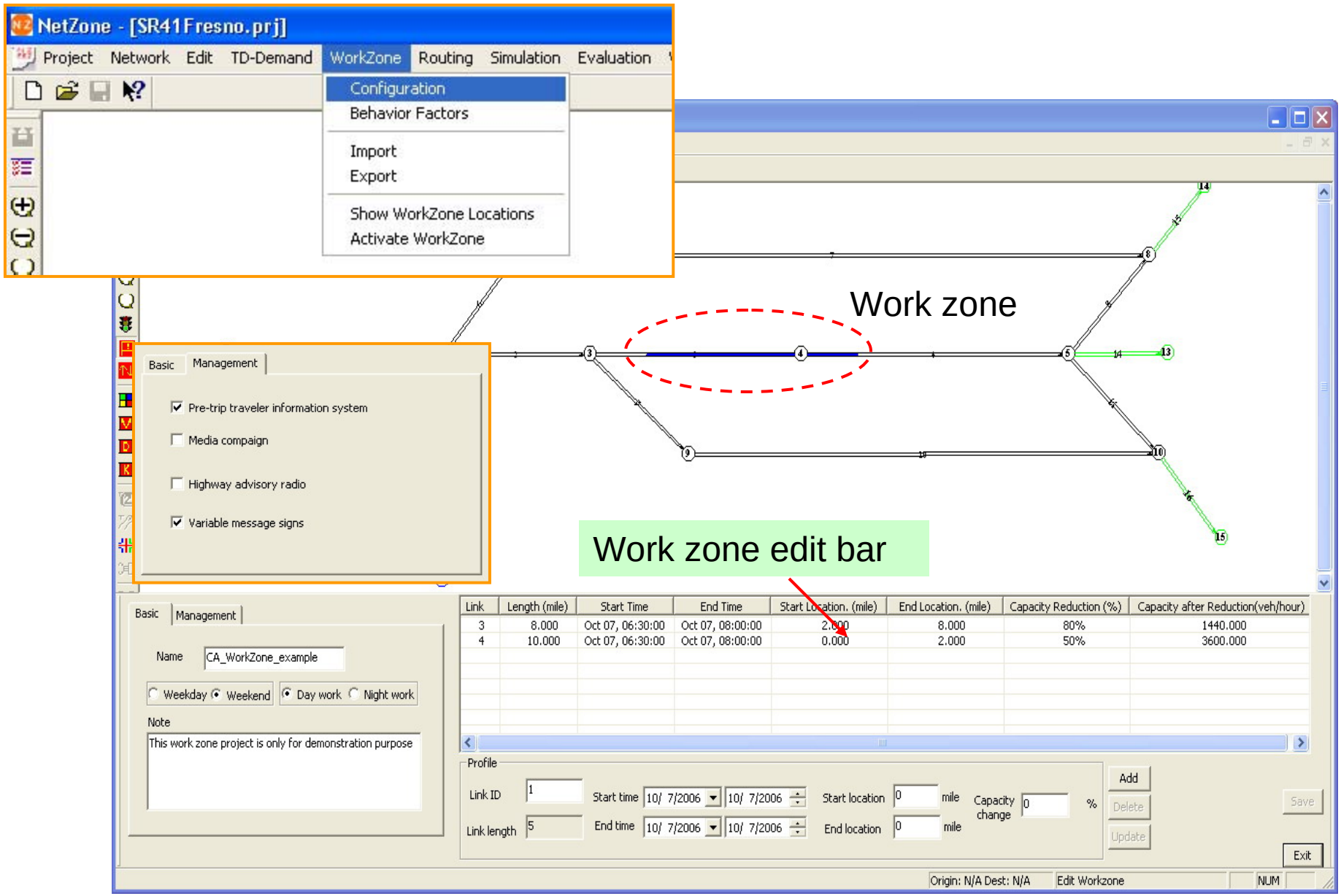
# Step 4: Prepare time-dependent demand



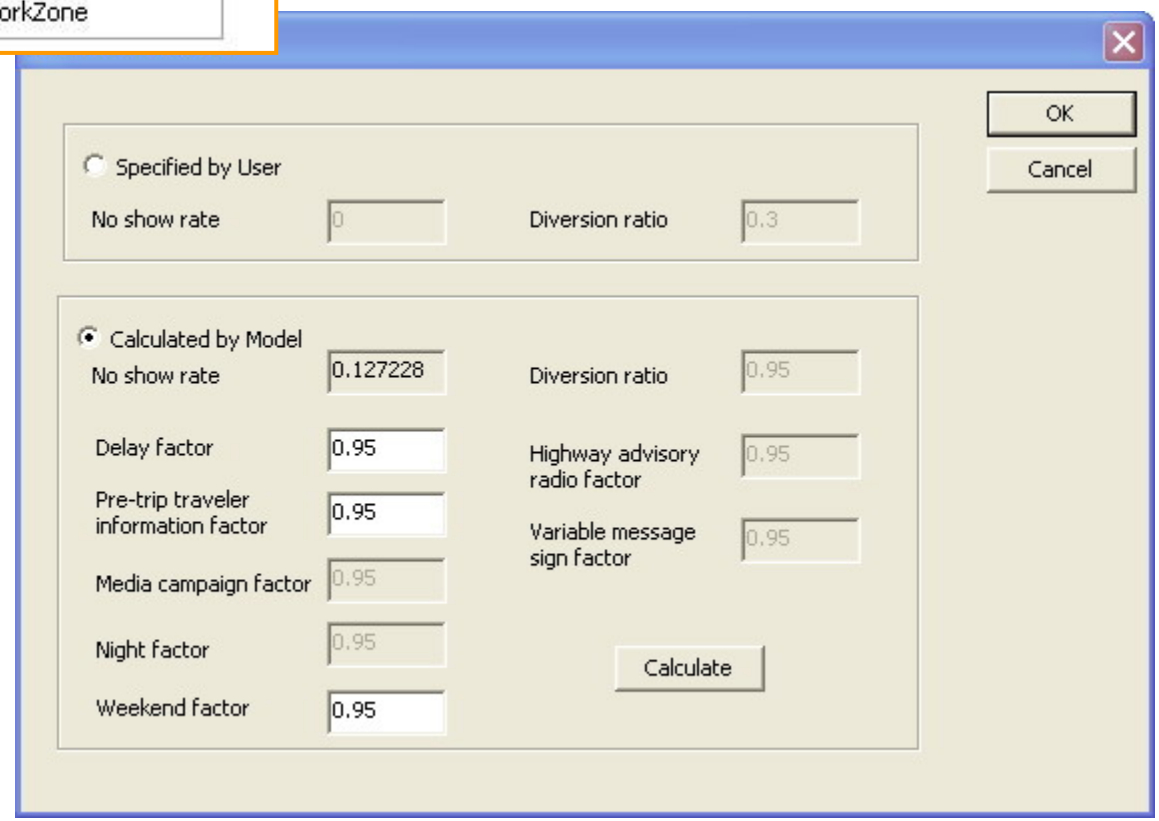




- Option 3: Import from a previously constructed demand file

# Step 5: Input CWZ and management plans



# Step 6: Specify behavior factors



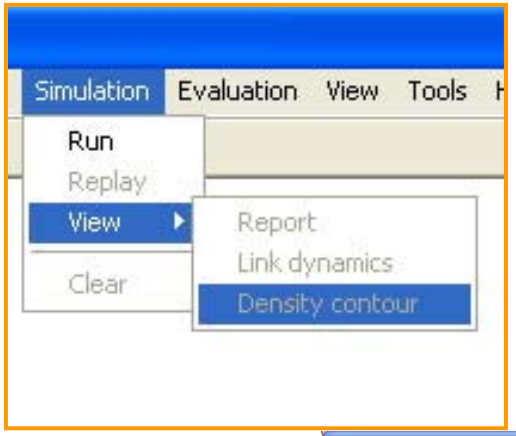

- Option 1:

  Specified by User

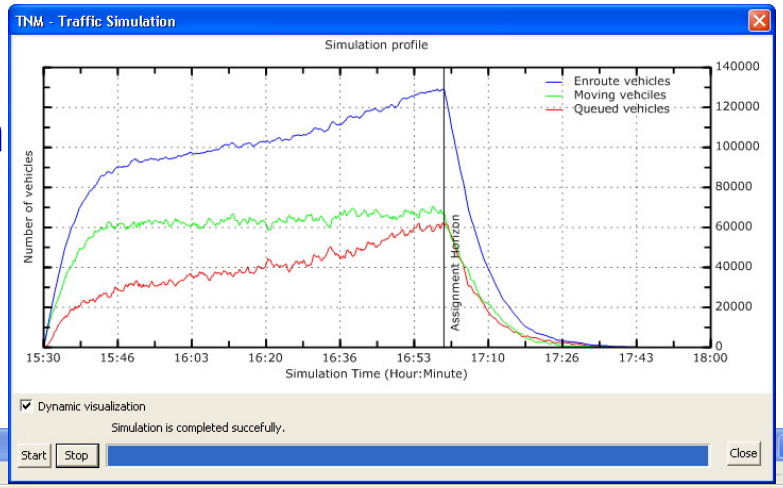
- Option 2:

  Calculated by Model

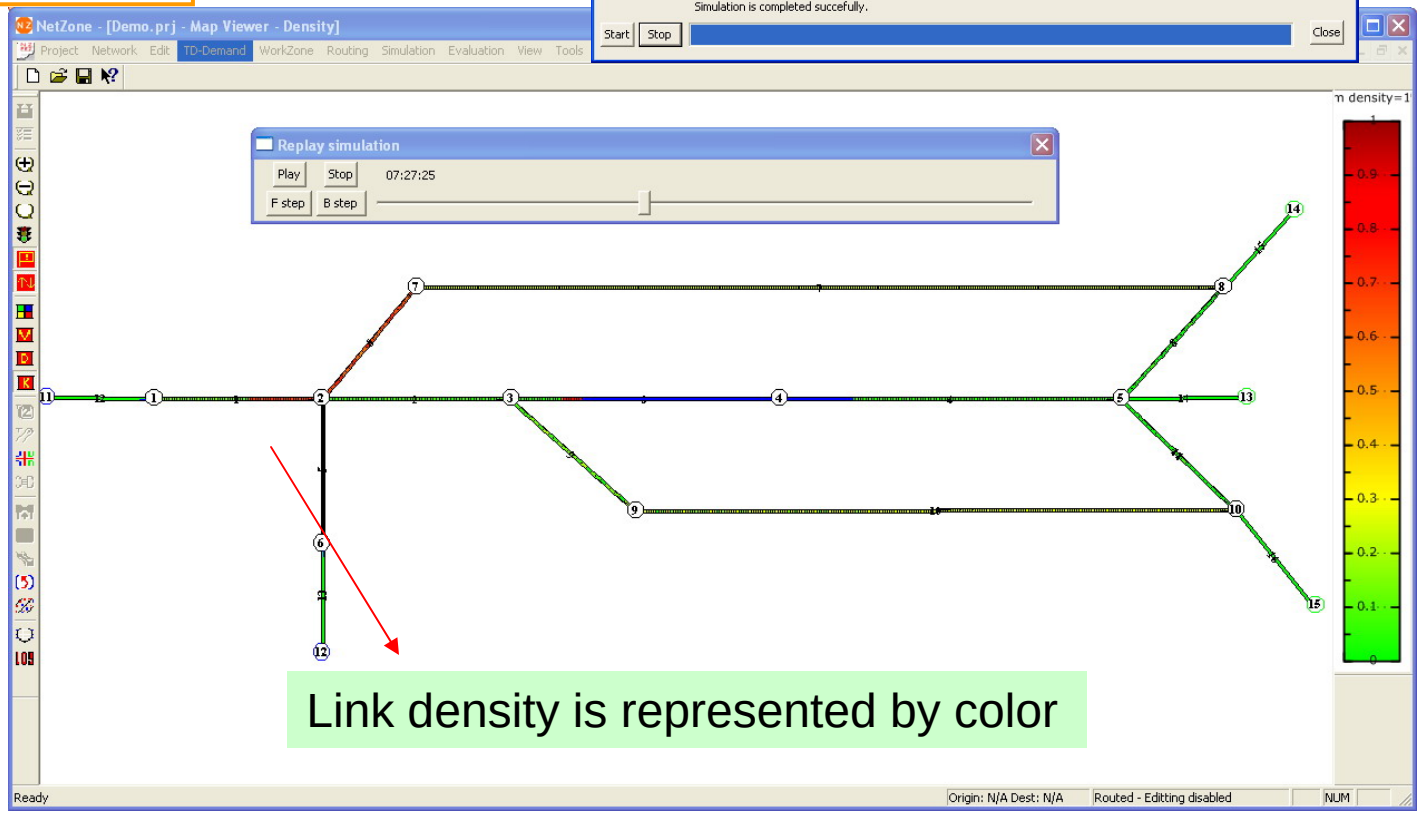
# Step 7: Perform Simulation




- Perform simulation



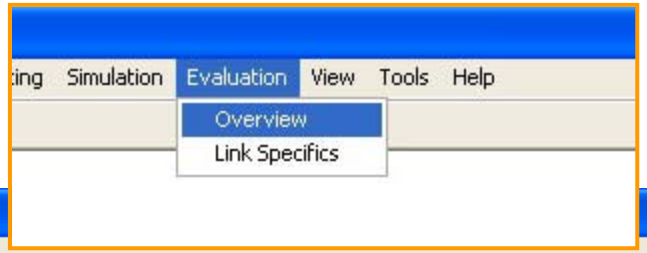

- Replay

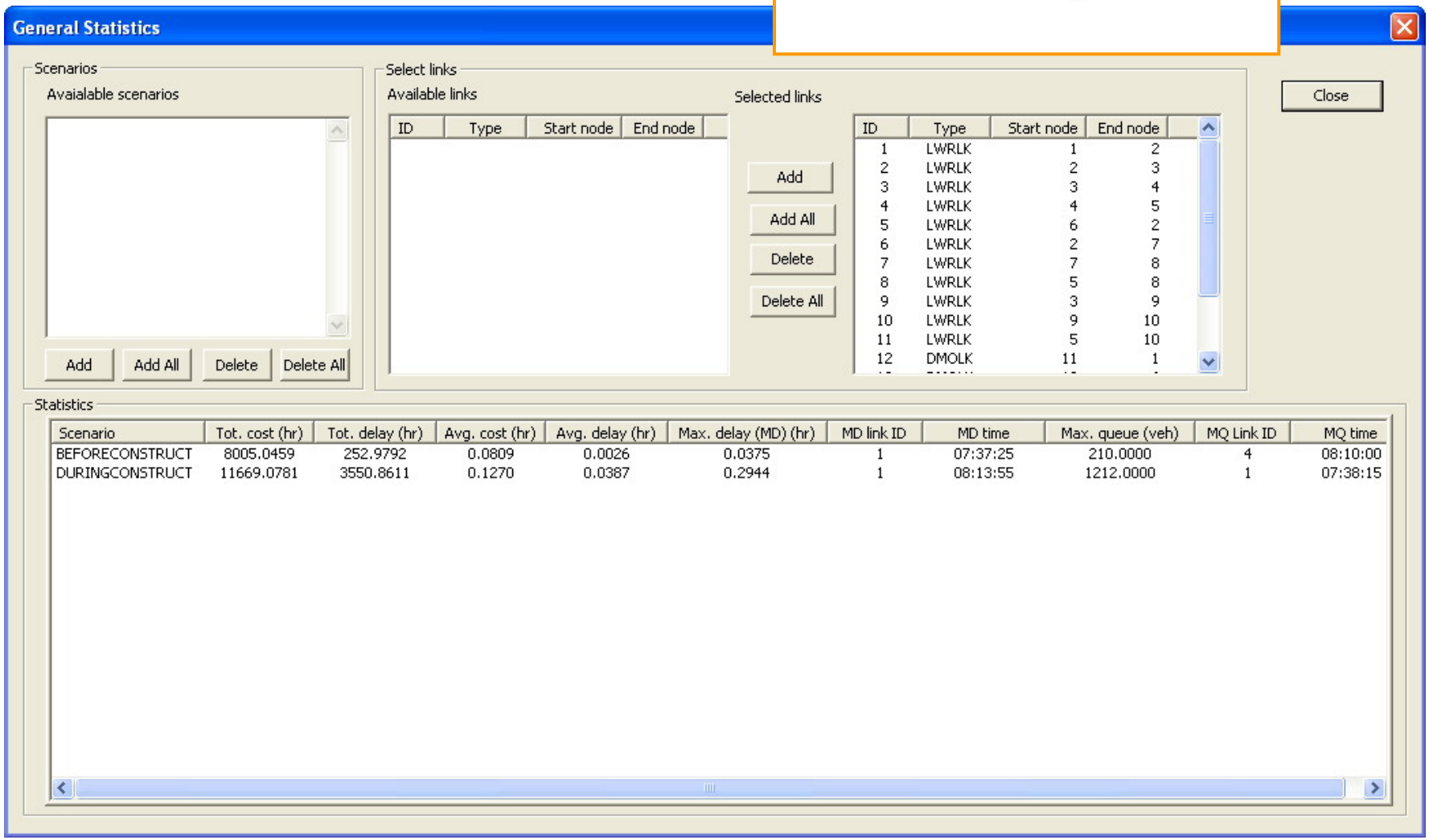



Link density is represented by color

# Step 8: Scenario comparison

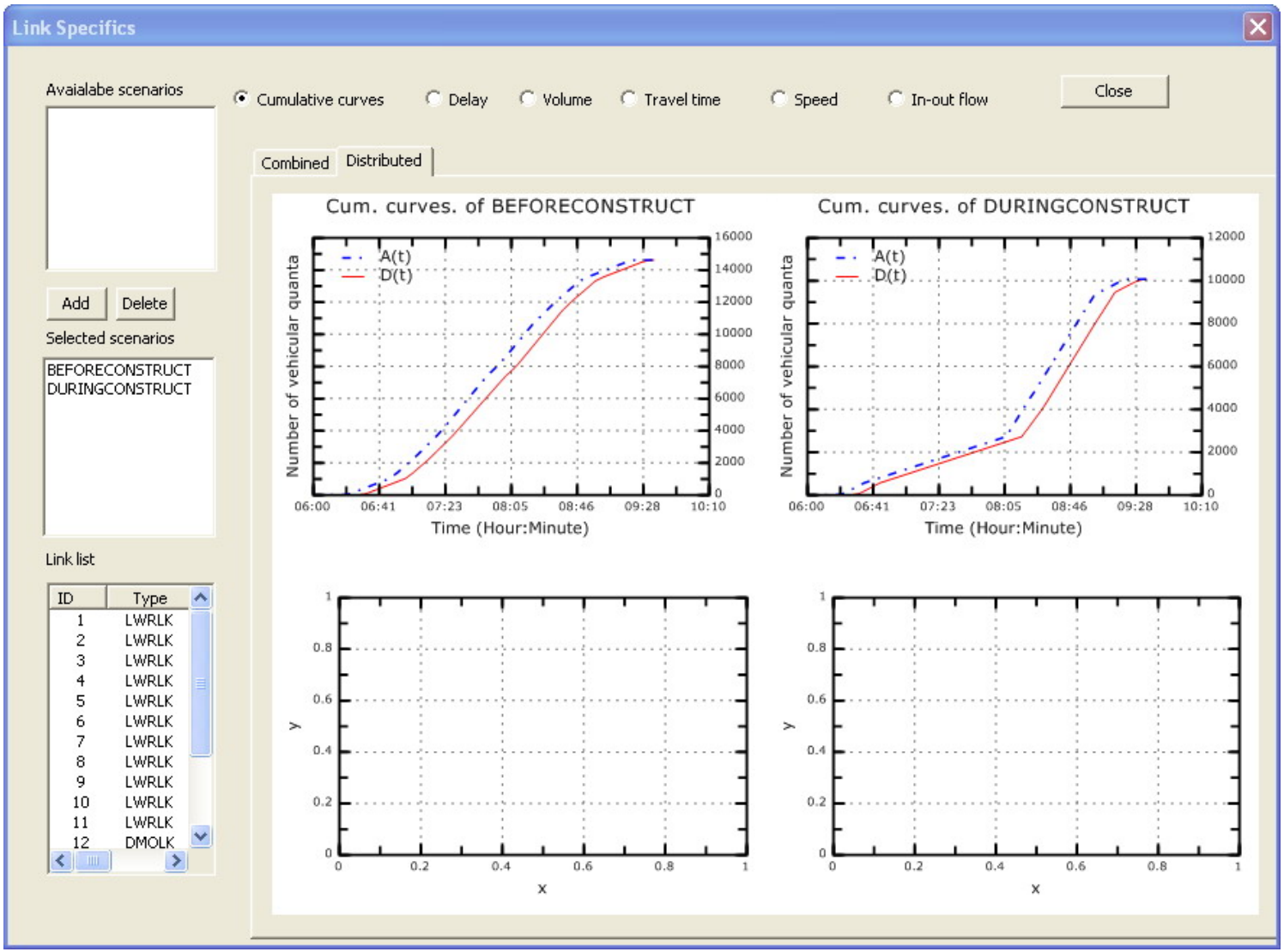
- General performance indices



# Step 8: Scenario comparison

- Link specific



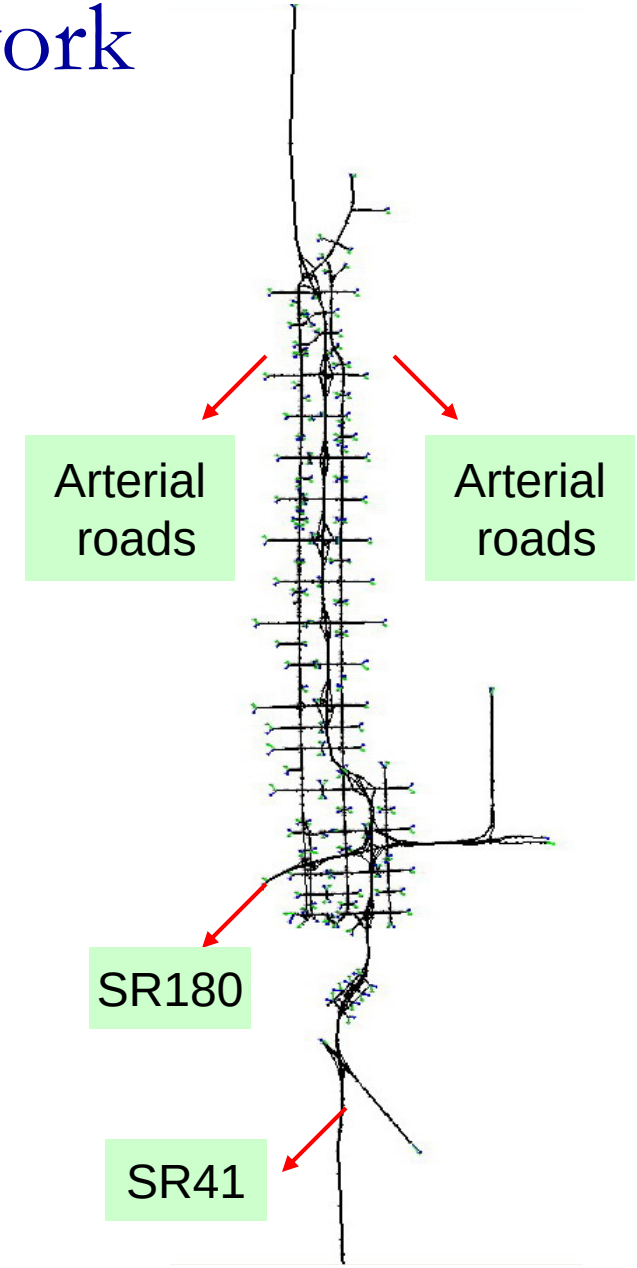
Case Study:

SR41Fresno Corridor construction work zone traffic impact study

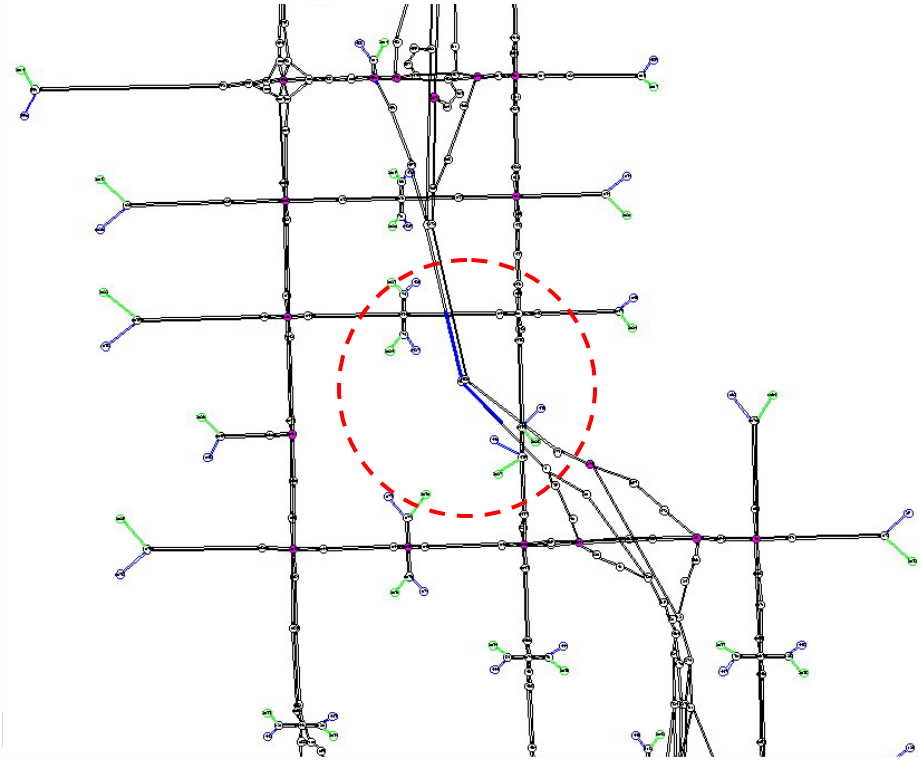
# SR41Fresno Corridor Network

- Major characteristics:
  - About 18 miles long
  - # of nodes: 1465
  - # of links: 2090
  - # of origins: 174
  - # of destinations: 168
  - # of OD pairs: 7110
  - # of signalized intersections: 83  (actuated control)
  - # of ramp meters: 16 (ALINEA)

- Project settings:
  - Study period: 2/2/2005 3:30 pm ~ 5:00:00 pm
  - Route choice behavior: dynamic feedback with R = 1.0
  - Demand interval: 15 min
  - Simulation interval: 2 seconds



# Hypothetical CWZ info

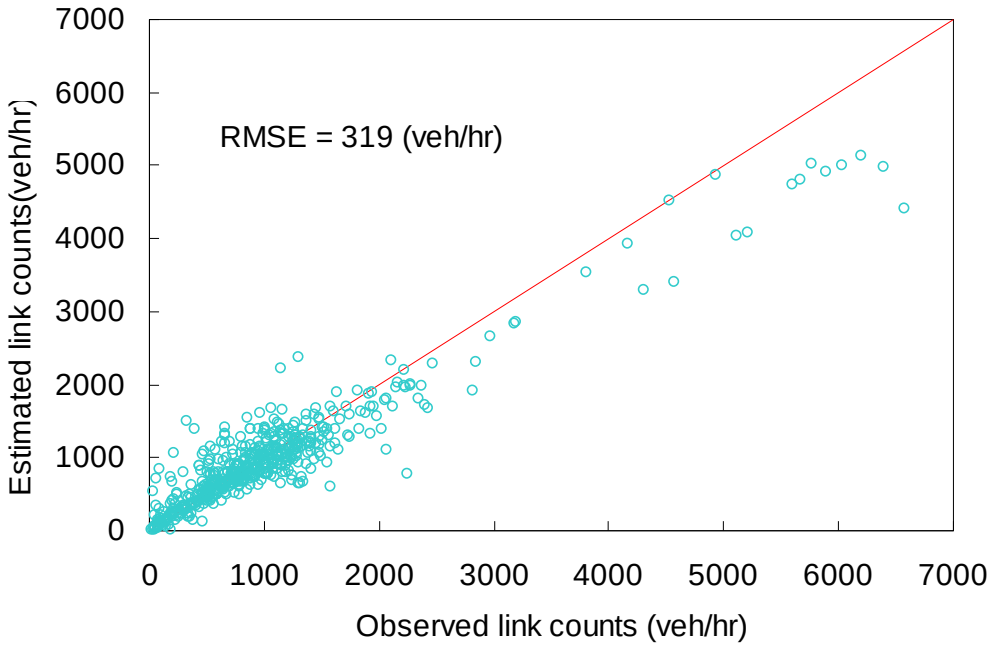


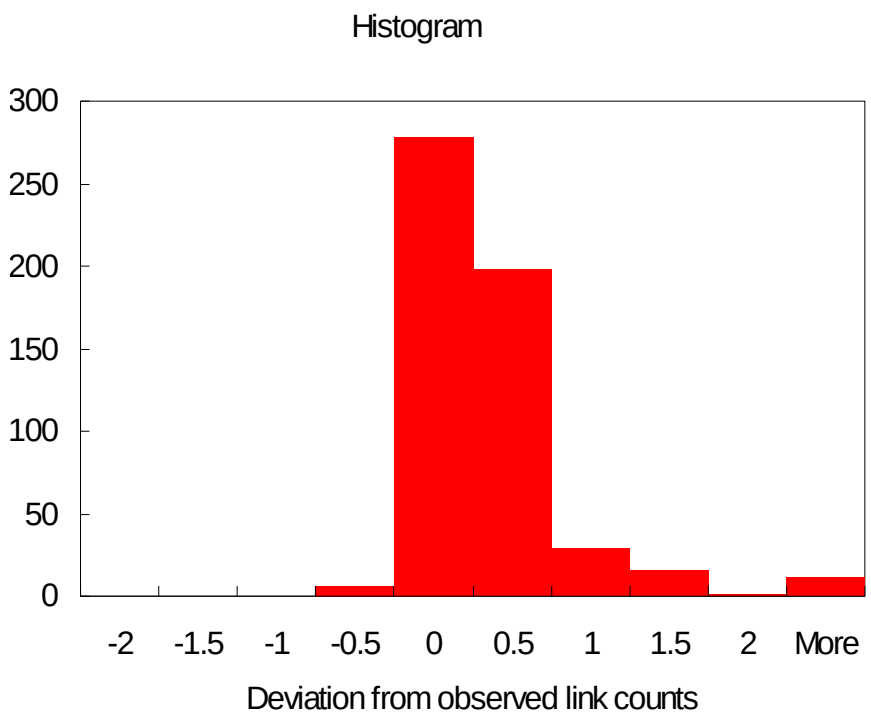
- Length: 0.437 miles
- Location:
  - link 10 (0.3 mile~0.537 mile)
  - link 1115 (0 mile ~ 0.2 mile)
- Duration:
  - 3:35 pm ~ 4:35 pm
- Capacity reduction:
  - Two of the three lanes will be closed

  (remained capacity: 1/3*7200 = 2400 ve
- Other attributes: weekend daytime work
- Other info: the on-ramp right upstream of the CWZ (comprises of links 12, 83, 1126) will be shut down during the construction period

# Time-dependent OD demand by LPFE

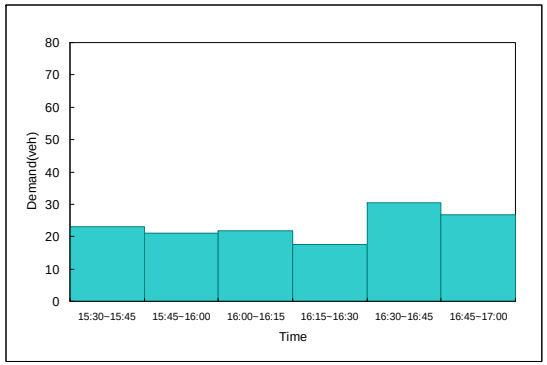
- Inputs: observed link traffic counts, historical time-dependent demand from PARAMICS

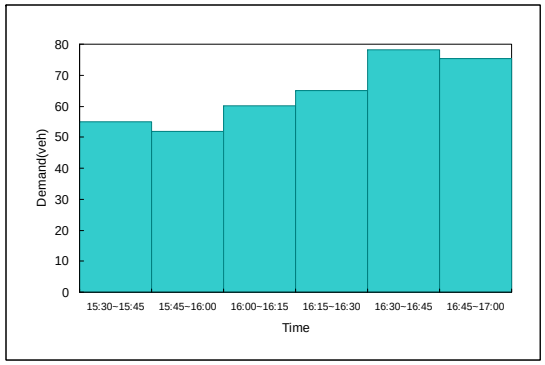


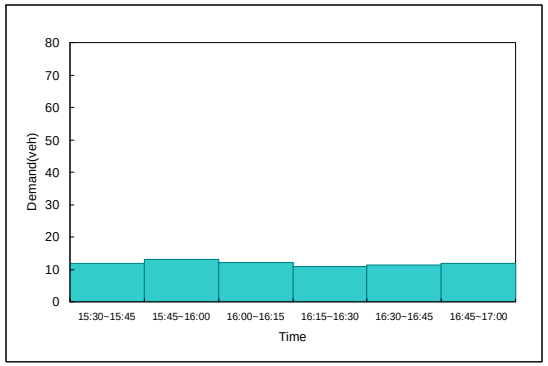




Observed and estimated link counts (one hour total: 4:00pm ~ 5:00 pm)

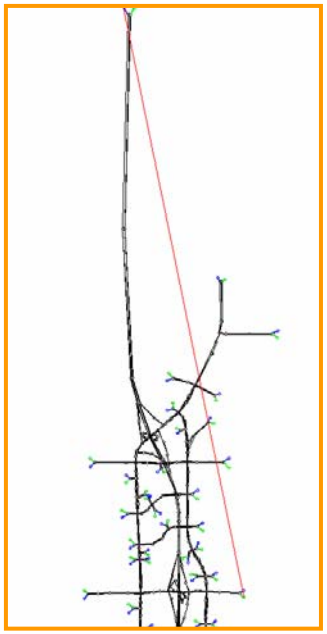
# Examples of OD demand



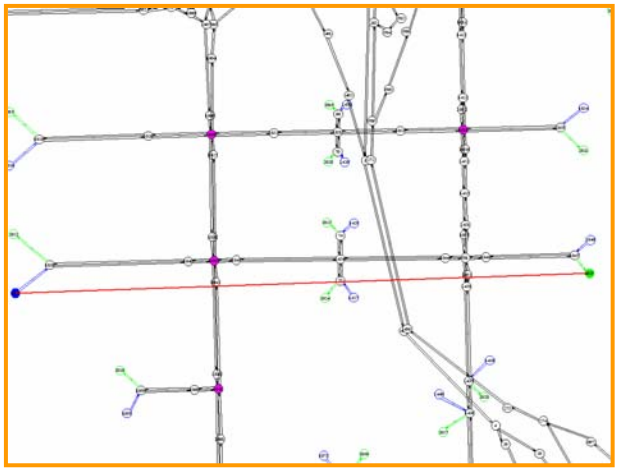



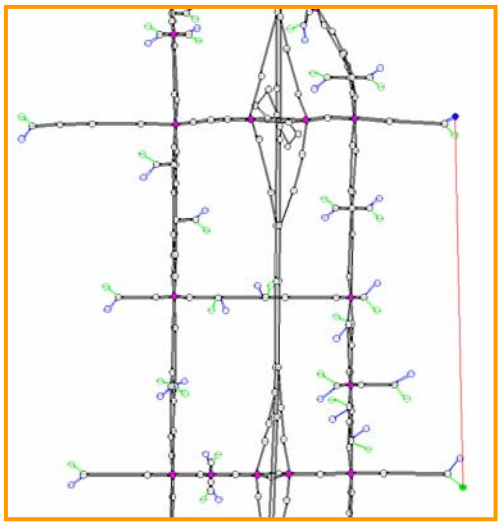

OD pair 669-1946



OD pair 1038-2025

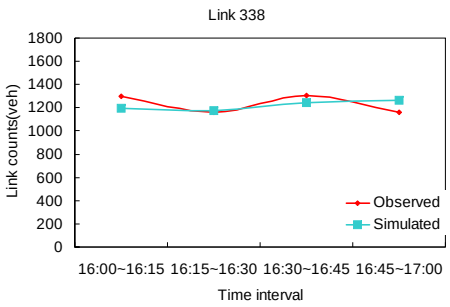


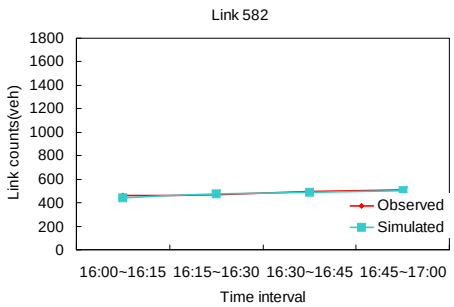
OD pair 831-2025

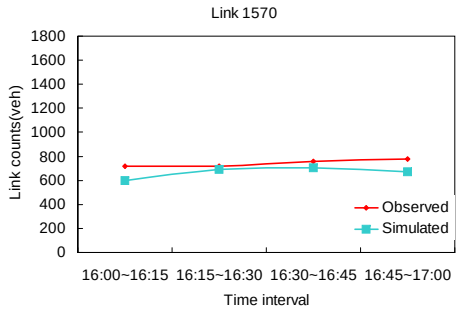


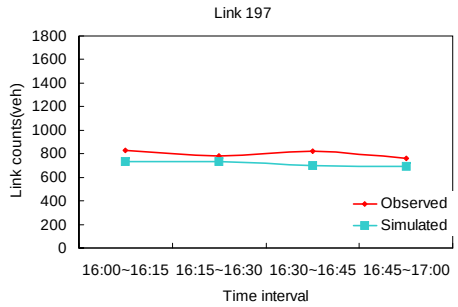
# Time-dependent OD demand by LPFE (cont.)

- Temporal traffic flow distribution on selected links

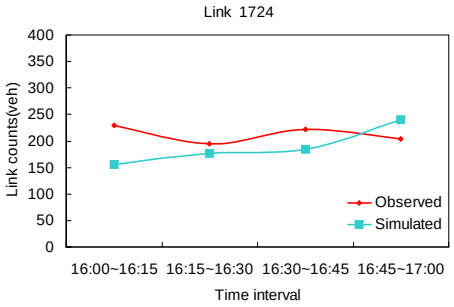


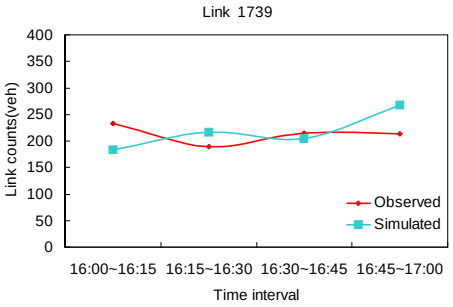



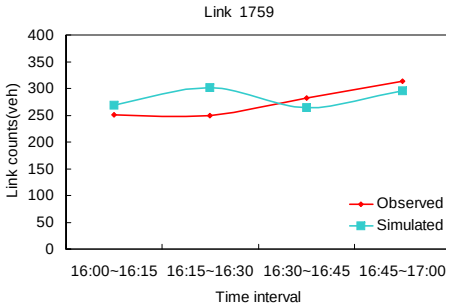



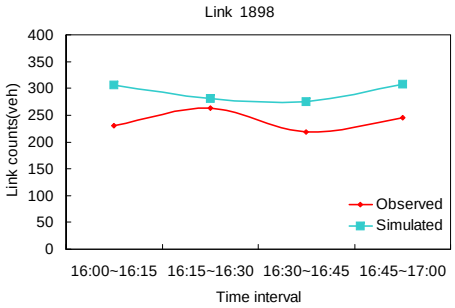




Freeway links




Arterial links

# Scenarios

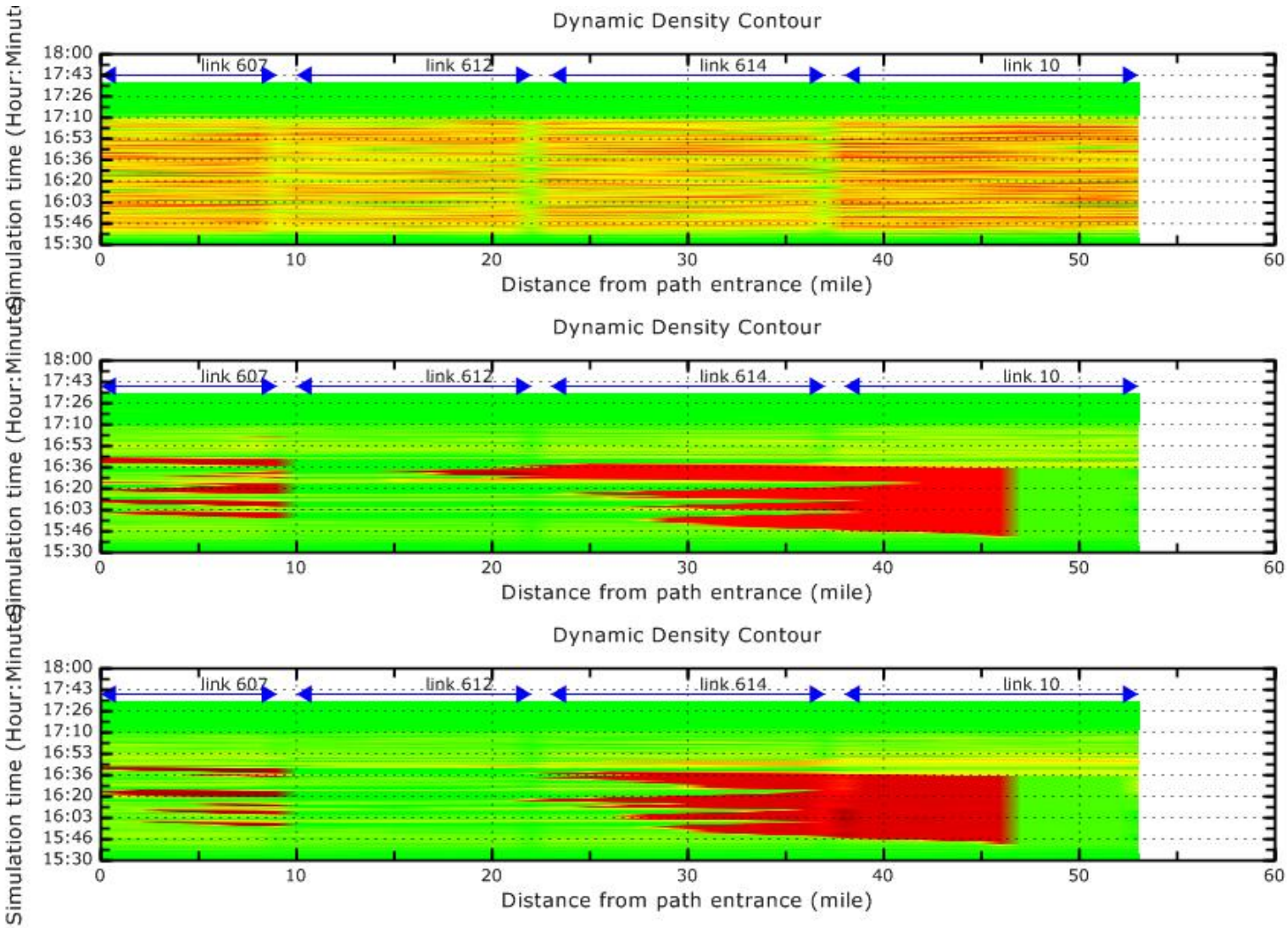
| Before construction | During construction | |
|---|---|---|
| | No traffic management plans | With pre-trip traveler information and media campaign |
| Scenario 1 | Scenario 2 (No show rate: 0.1%) | Scenario 3 (No show rate: 3.11%) |

# Network wide MOEs

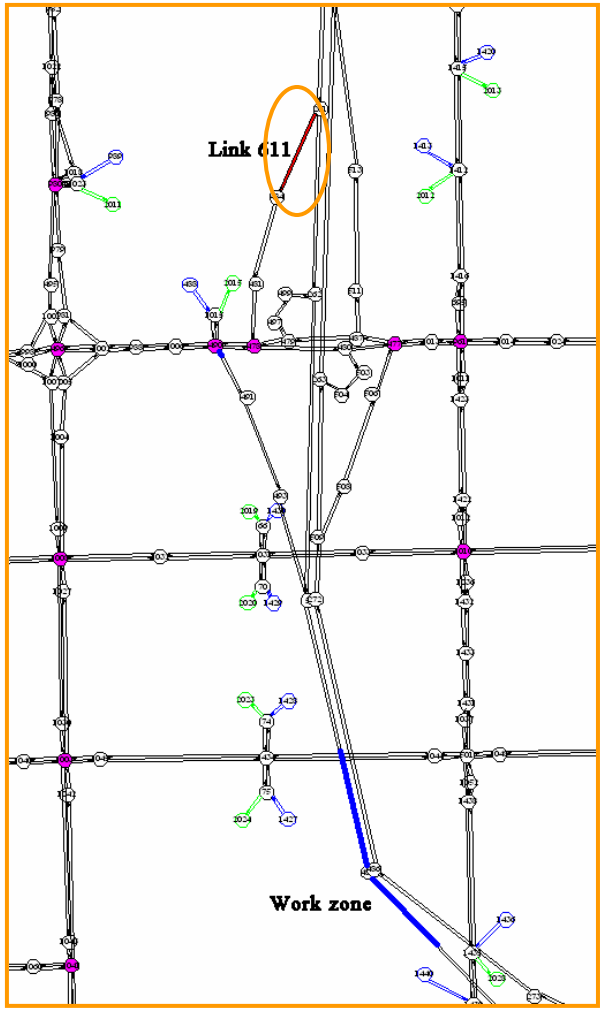
| | Total Travel Time (hr) | Total delay (hr) | Percentage change in delay |
|---|---|---|---|
| Scenario 1 | 11560 | 3796 | - |
| Scenario 2 | 13303 | 5232 | +38% |
| Scenario 3 | 12378 | 4659 | +23% |

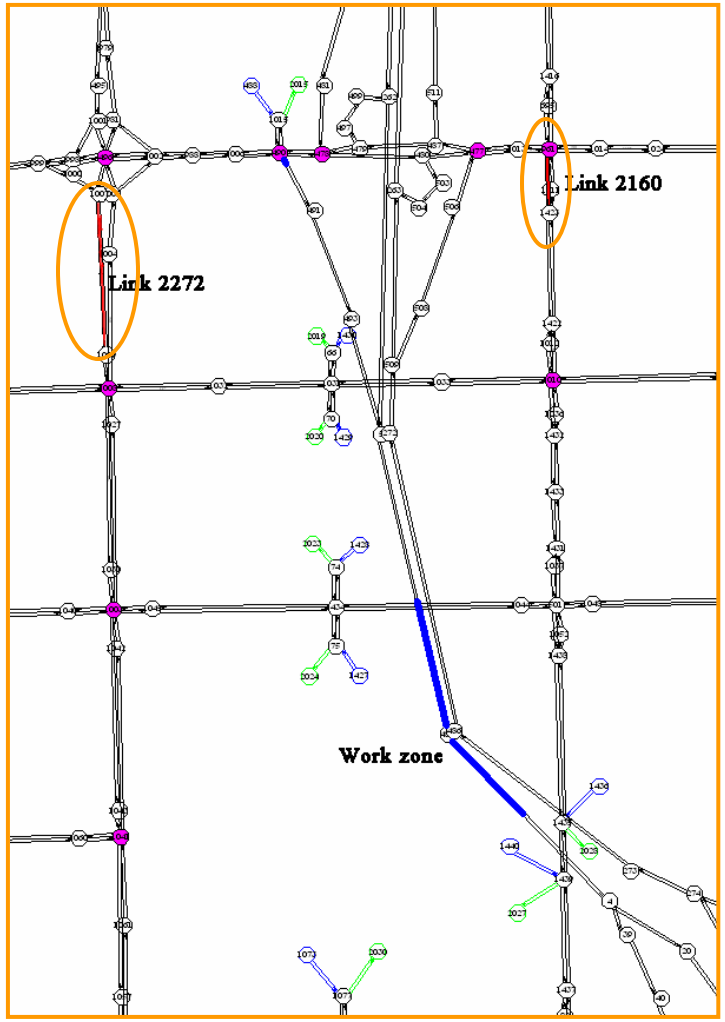
15% reduction

# Queuing pattern on SR41 upstream of the CWZ

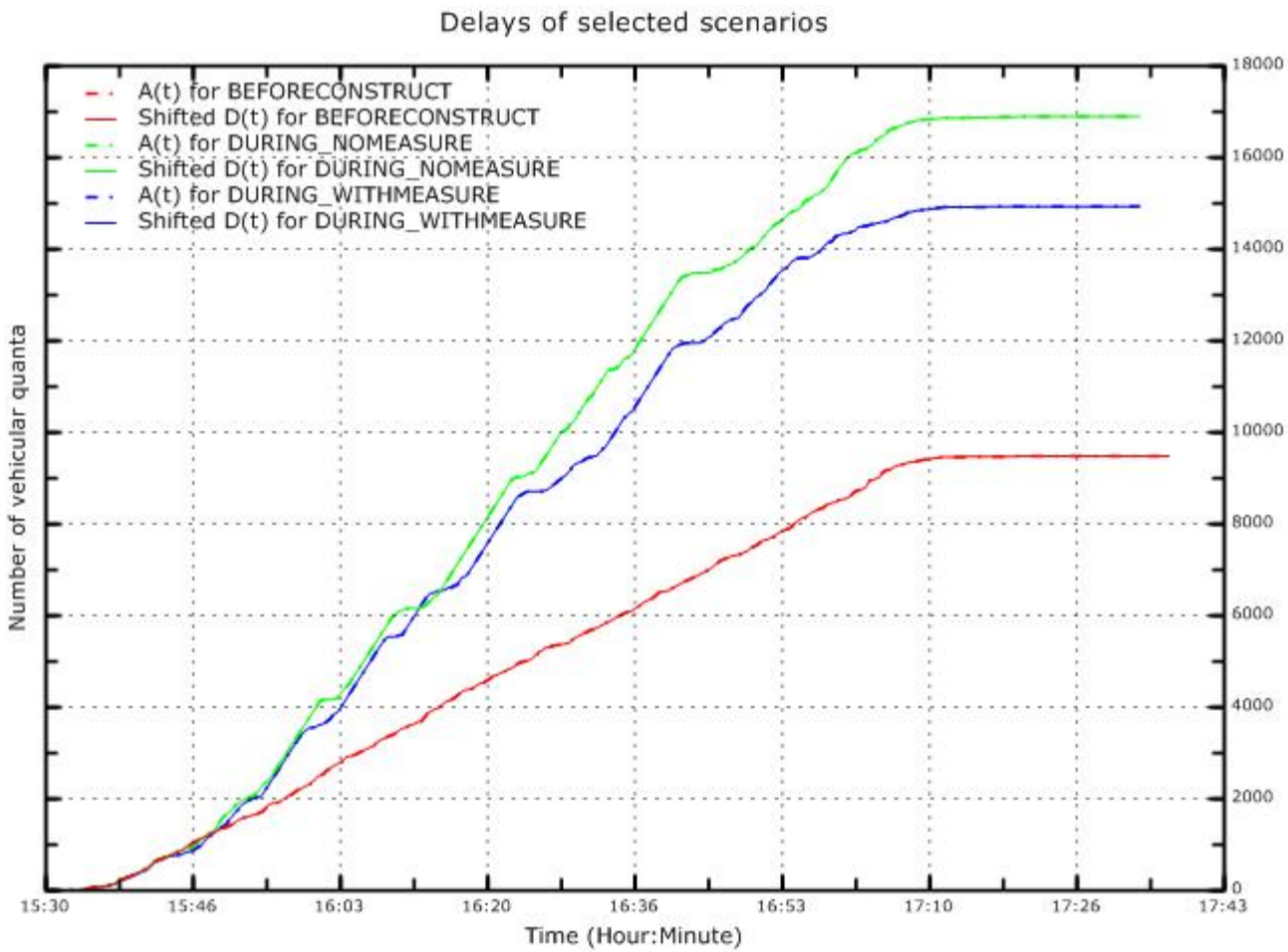


# Traffic diversion



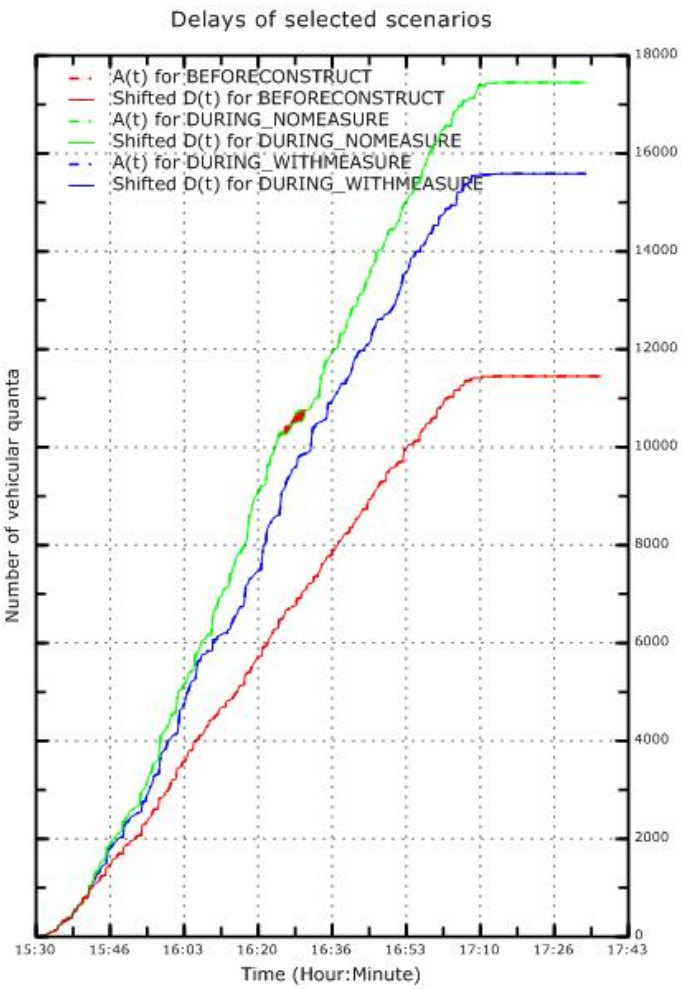



# Traffic diversion at an exit ramp

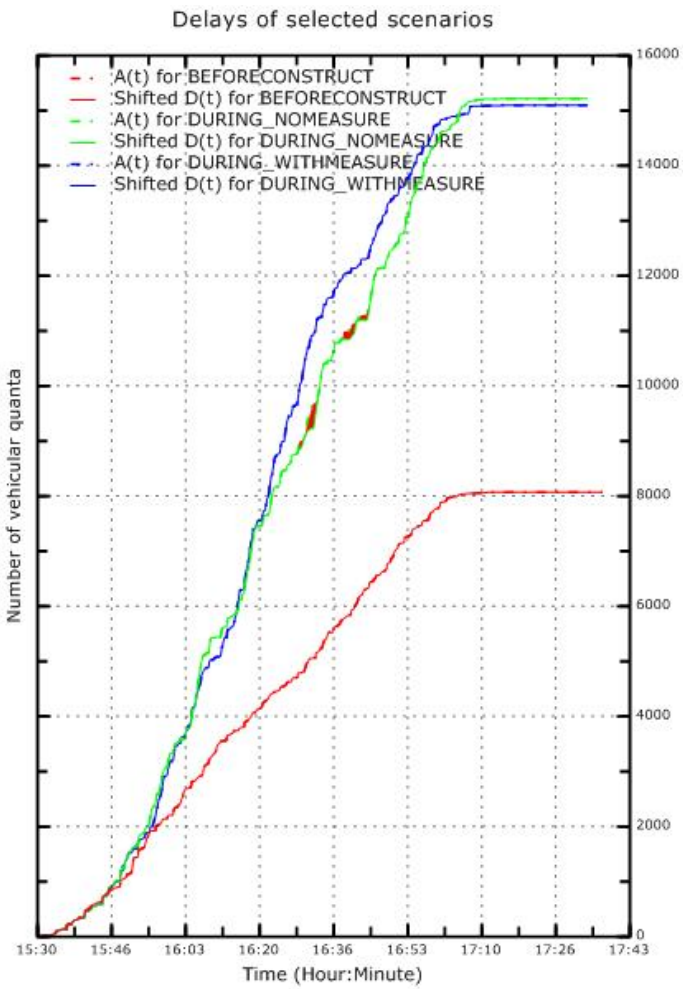



Flow on off-ramp (link 611) right upstream of the CWZ

# Traffic diversions on arterial segments




Link 2272




Link 2160

# In summary, NetZone

- is a **powerful, versatile** and **user-friendly** analysis tool for work zone projects that takes into account
  - Demand changes
  - Route diversions
  - Ramp metering
  - Arterial traffic operations
  - Traveler information
- provides **detailed statistics** on delays and queues on specific links and routes as well as the entire network
- is **macroscopic**, thus consumes much less computational and human resources to calibrate and apply than microscopic simulations
- is **dynamic**, thus captures peak spreading and queuing
- can be used as **a general purpose corridor study tool** with suitable modifications.

# Future work

- NetZone is prototype software that needs further enhacements
- Refine the CWZ traffic model, in particular, integrate speed limit within the CWZ area
- Continue to implement different types of signal control methods, eventually provide some optimal signal control strategies based on evaluation results
- Continue to assemble CWZ traffic data
- Improve, validate and calibrate the demand adjustment models
- Further test and validate the developed models and tools
- Hands-on workshops

# Acknowledgements


- Financial support from Caltrans through TO 5300
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