Advanced Transportation Simulation Modeling for Transportation System Evaluation and Management during Emergencies

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Presentation Outline

- Introduction
- Problem Statement
- Solution approach
  - Large-scale ABM of Buffalo-Niagara in TRANSIMS
  - Human-in-the-loop simulation
- Conclusions

Introduction

- A transportation system as an example of a complex adaptive system
- ABMS for studying complex systems
- ABMS & transportation
  - Supply side – traffic simulators
  - Demand side (activity-based modeling)

Problem Statement

- Four limitations:
  - Modeling small networks and ignoring important interactions
  - Lack of integration & inconsistencies in the way agents are developed (e.g. traffic simulation & agent-based modeling)
  - Agents behavior rather simplistic and idealistic
  - Lack of modeling the impact of “shocks” or “extreme events” on the transportation system performance

Research Approach

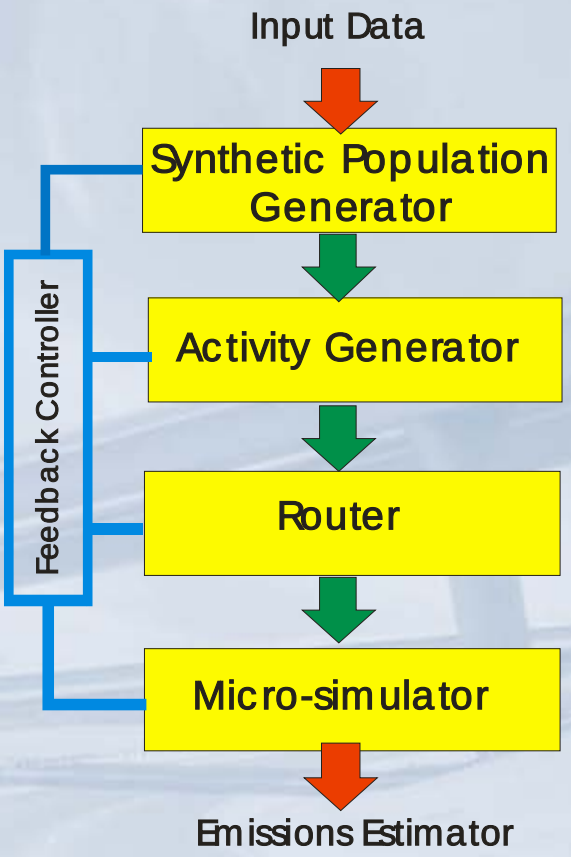
- TRANSIMS Deployment & Extension
  - Large-scale ABM of the Buffalo-Niagara Metropolitan area under inclement weather (funded by FHWA)

- Integrating Traffic Simulators (TS) and Driving Simulators (DS) to allow for human-in-the-loop simulation (funded by NSF)
  - Integrating the PARAMICS traffic simulation model (Quadstone) with UB's Driving Simulator

What is TRANSIMS?

- Initially developed at Los Alamos National Lab as representing the next generation of transportation models

- A person-based simulator which combines detailed modeling of traffic flow dynamics with the ability to model traveler behavior



Scope of Work

- Project Objectives/Outcomes:
  - Further development of the Buffalo TRANSIMS model
  - Modifying TRANSIMS to allow for modeling impact of inclement weather
  - Simulating emergency scenarios in the Buffalo-Niagara area
  - Feasibility of using TRANSIMS for **online** transportation system management **during emergencies**
  - Use TRANSIMS as an aid for predicting border crossing delays

Scope of Work

- Why Buffalo-Niagara?
  - One among a handful sites nationwide selected for TRANSIMS deployment
  - Well known for its winter weather and lake-effect snow events
  - Critical links – the three border crossings
  - Not too big and not too small

Research Tasks

- Task 1: Further Development of the Buffalo Model
- Tasks 2 & 3: Define traveler behavior during emergencies
- Task 4: Model the new behavior in TRANSIMS
- Task 5: Use TRANSIMS to evaluate likely emergency scenarios in the Buffalo-Niagara area

Task 1. Further Development of TRANSIMS Model

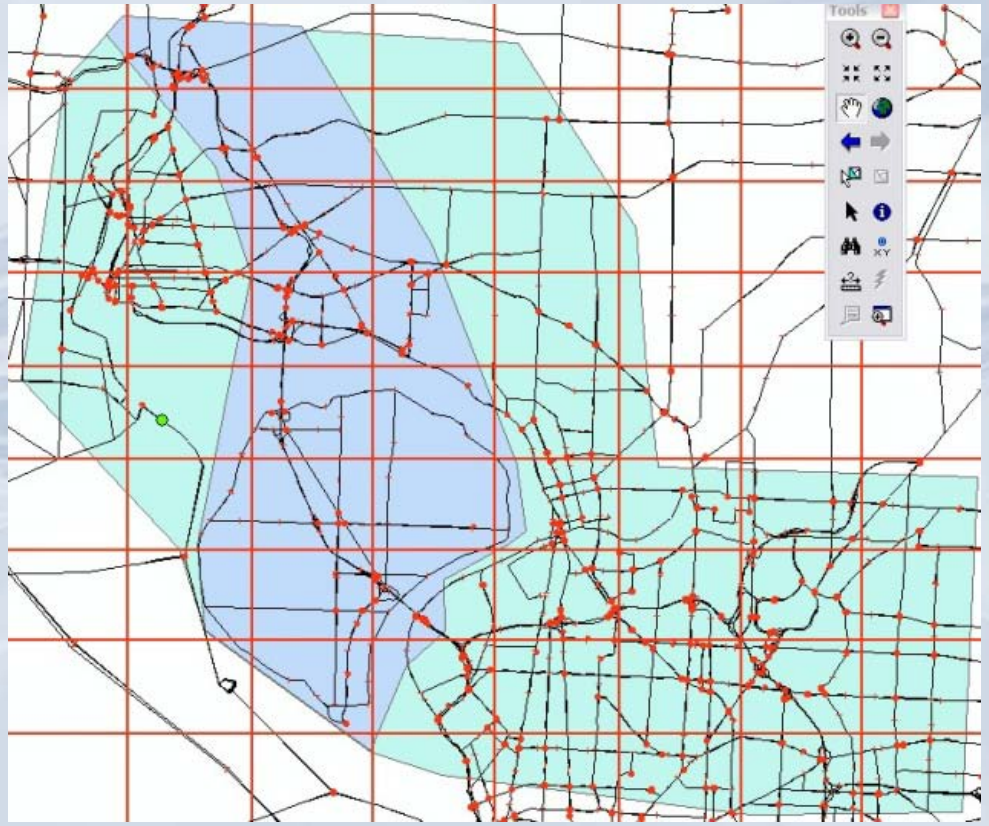
- A four-step model is typically used as a first step
- TransimsNet then used to convert network into a TRANSIMS network using default logic
- Challenges in transitioning from a planning-level network to a micro-simulation network
  - Turning or pocket lanes
  - Lane connectivity
  - Signal timing

Task 1. Further Development of TRANSIMS Model

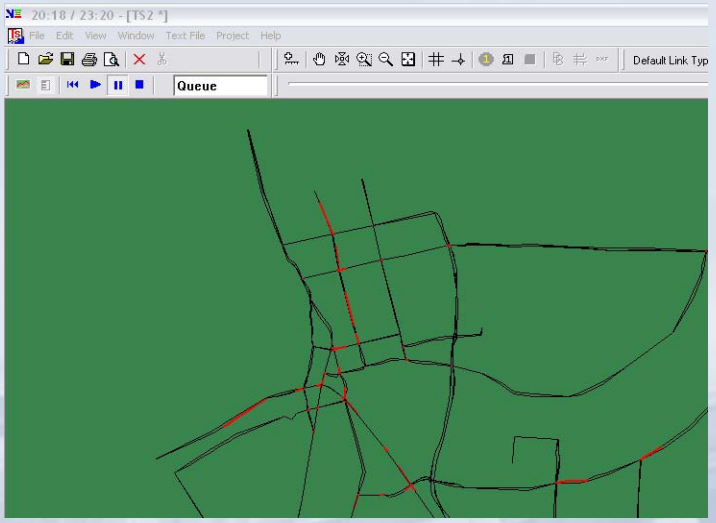
- Network Extension Methodology
  - Error detection Procedure
  - Example Errors
    - Lane Connectivity Errors
    - Network Configuration Errors
- Calibration and Validation
  - "Continuous" Counts (92 locations)
  - Short-term count stations from NYSDOT's Traffic Viewer website (70 locations)

Extension of the Subarea

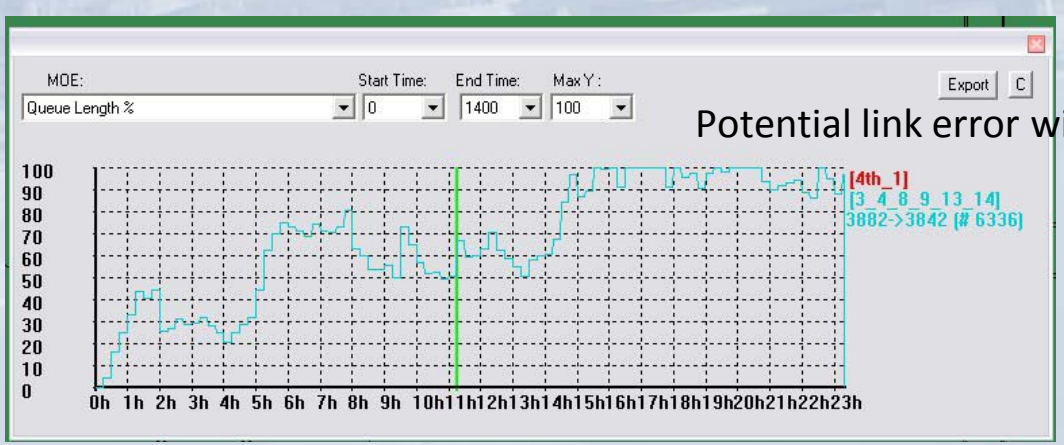
- Preliminary Steps
  - Shorten the running time
  - Reduce the storage space
  - Divide into a grid



- Error Detection Methodology:
  - Step 1: Long Queue Detection

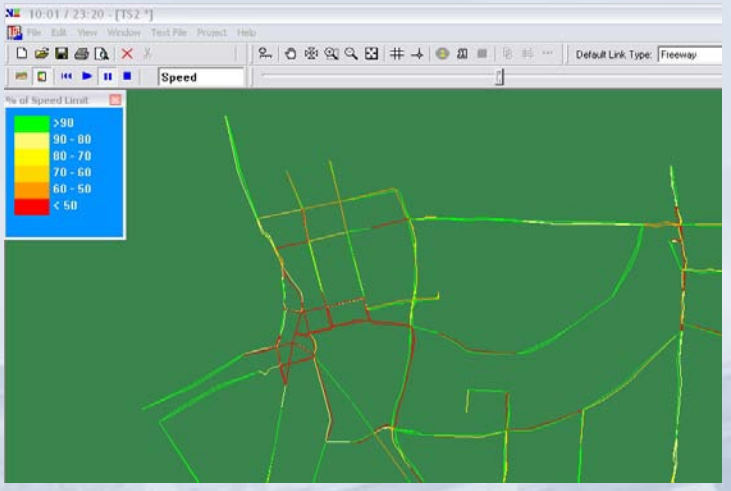


NEXTA Network Queue

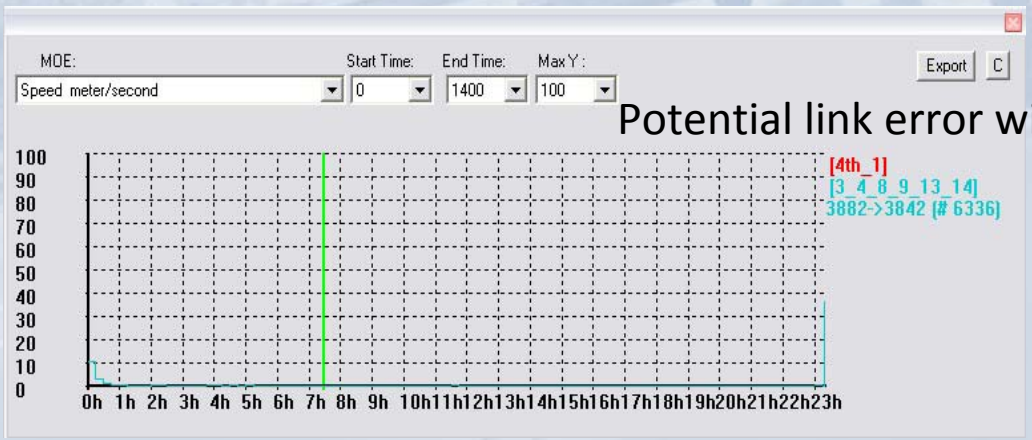


Potential link error with 24-hour long queues

- Error Detection Methodology:
  - Step 2: Low Speed Detection

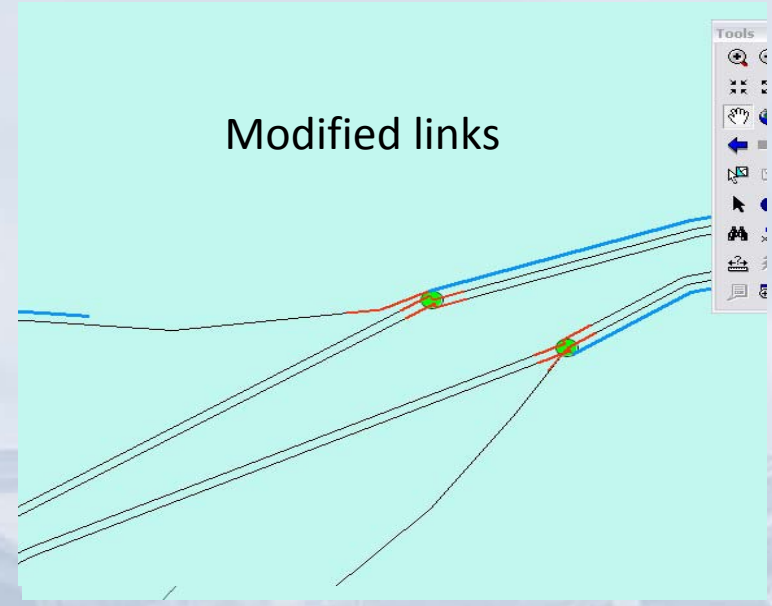


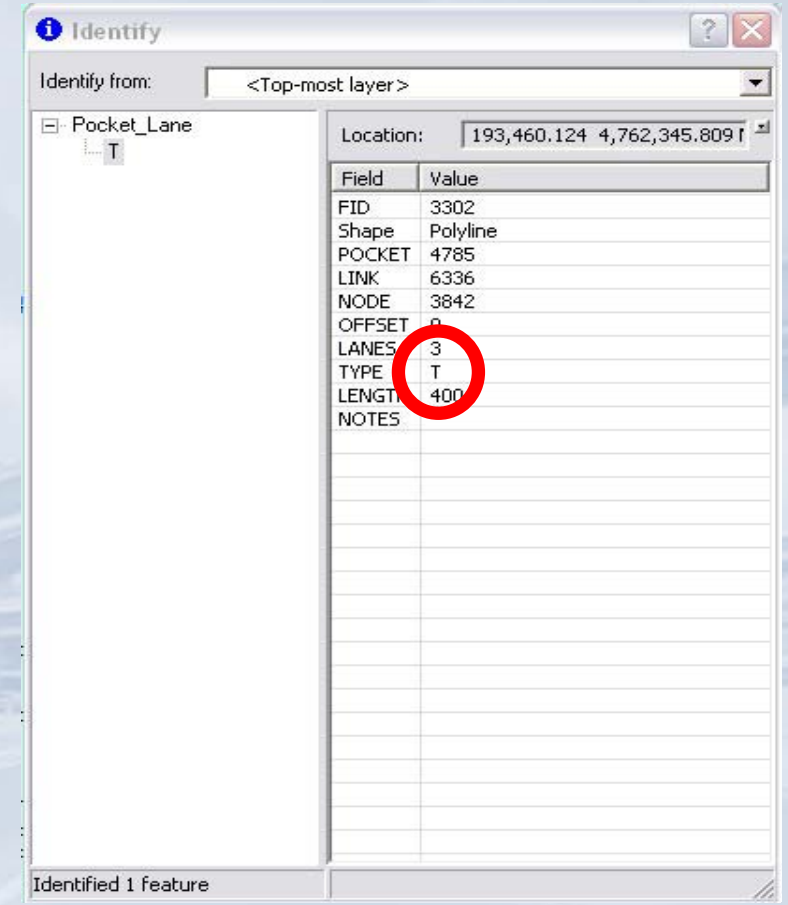
NEXTA Link Speed



Potential link error with 24-hour low speed

Examples of Lane Connectivity Errors





Black: links

Blue: pocket lanes

Red: lane connectivity

- Network Configuration Errors

Black: links
Blue: pocket lanes
Red: lane connectivity

Modified Intersection

Task 1. Further Development of TRANSIMS Model

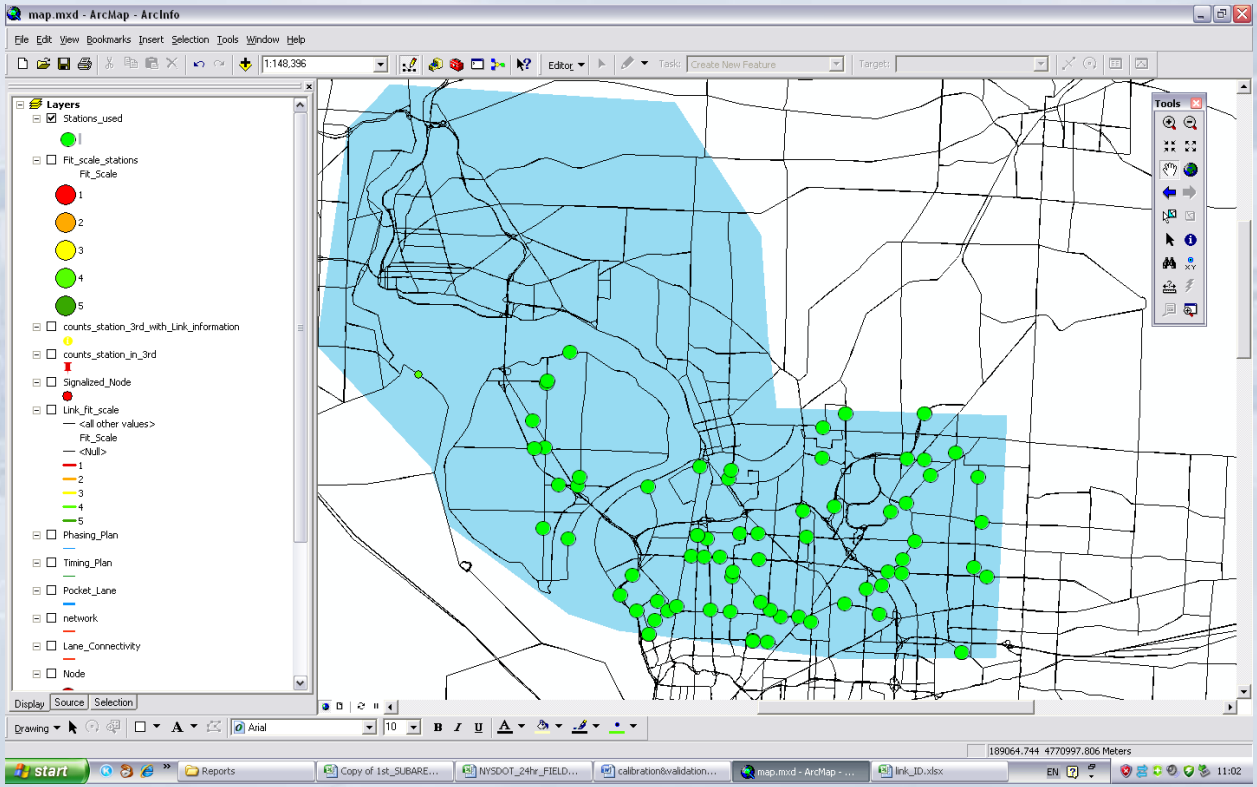
- Extension of the Subarea
  - Several Preliminaries
  - Error detection
    - Lane Connectivity Errors
    - Network Configuration Errors
- Calibration and Validation
  - "Continuous" Counts (92 locations)
  - Short-term count stations from NYSDOT's Traffic Viewer website (70 locations)

Calibration and Validation

- 92 Continuous Count Stations
  - **Toll Counts:** toll-based counts from the 4 international bridges
  - **FHWA:** Classification counts based on axle counts and supplied by NYSDOT and GBNRTC
  - **Length:** Length-based counts from the New York State Thruway Traffic Data System
  - **Non-Classified:** These are non-classification counts that provide volumes by hour of day.

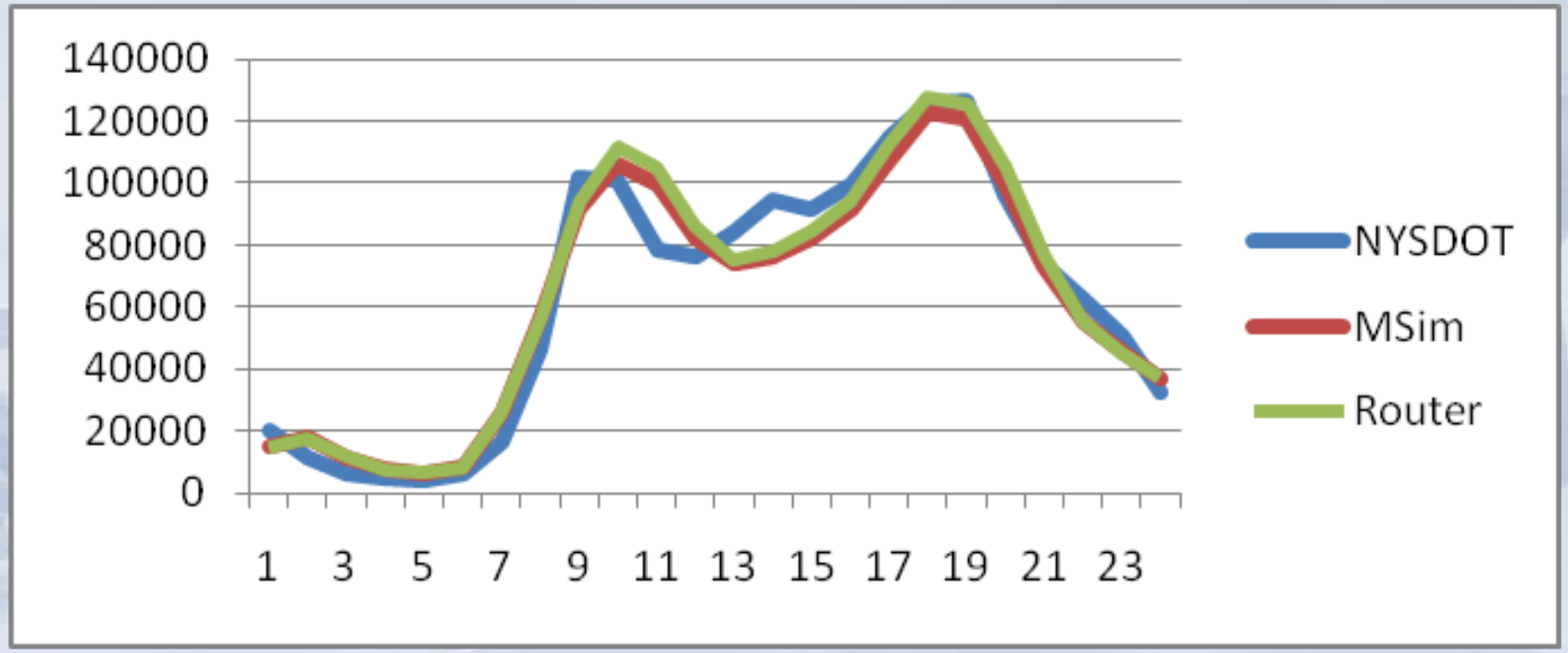
70 Short-term Count Stations (NYSDOT website)

- Short-term count program
- No attempts were made to apply yearly or monthly adjustments factors to those counts, since the impact of those adjustment factors was judged to be rather small.



Calibration

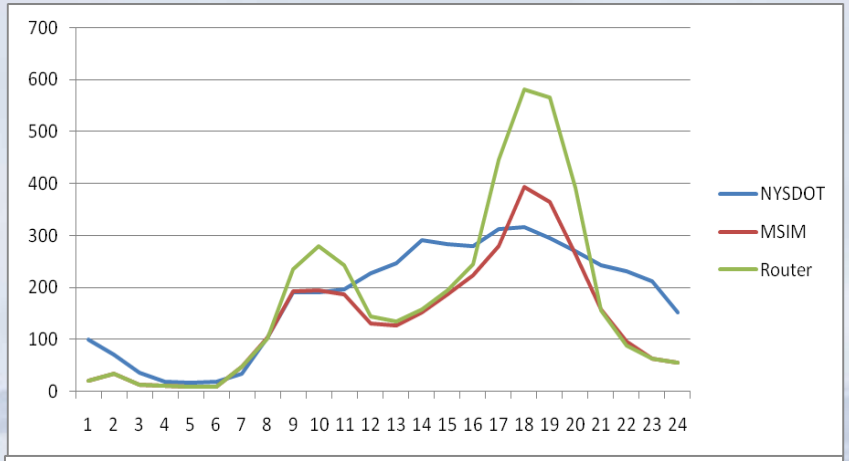
Demand and Diurnal Distribution Adjustment

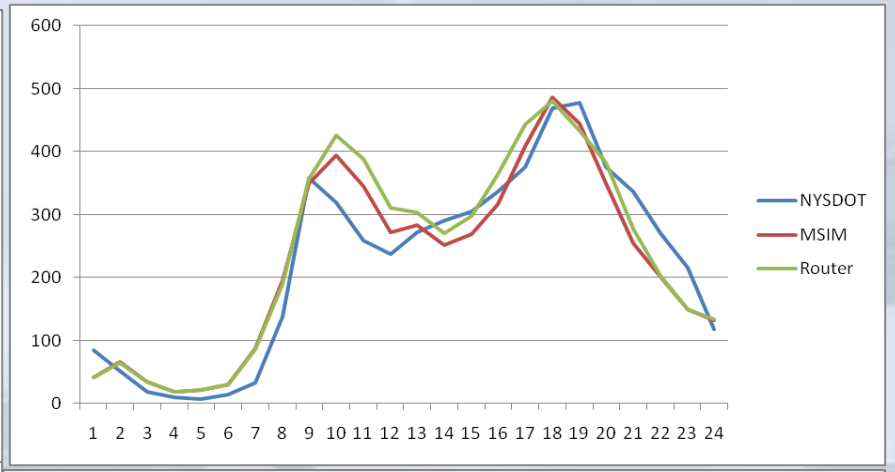


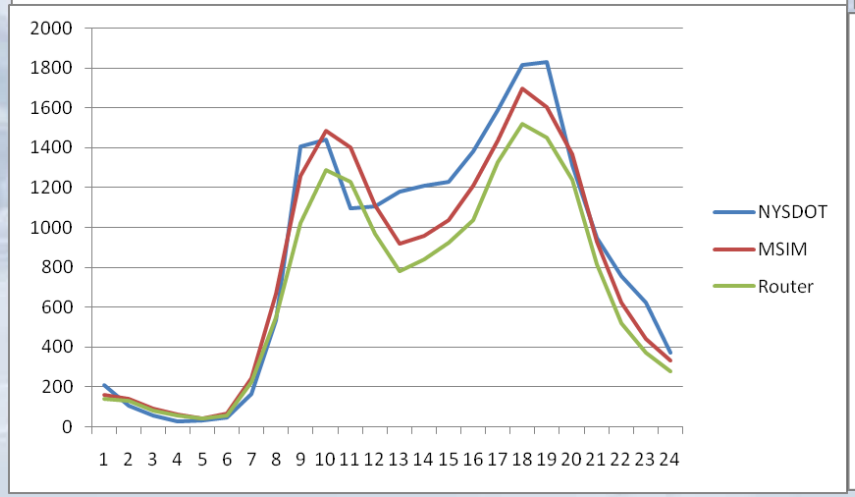
Trip Distribution of Scenario Three

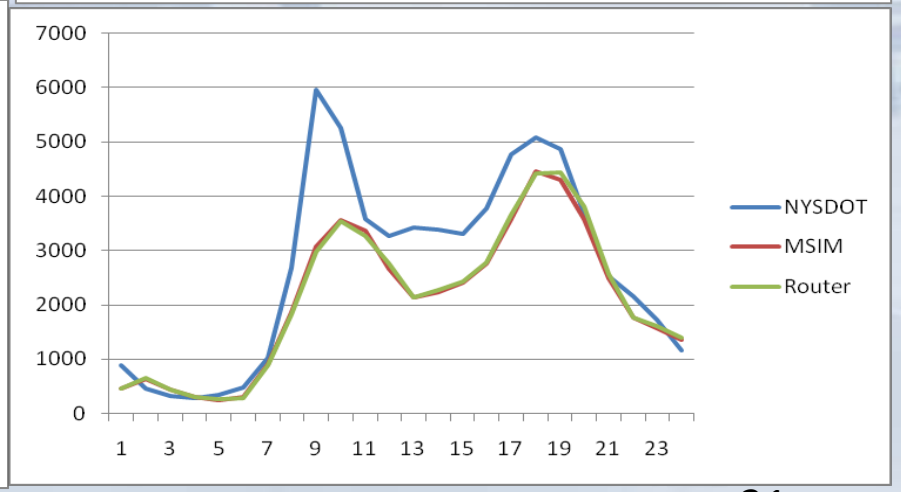
Validation

1. Percentage Error









Validation

2. Regression Analysis

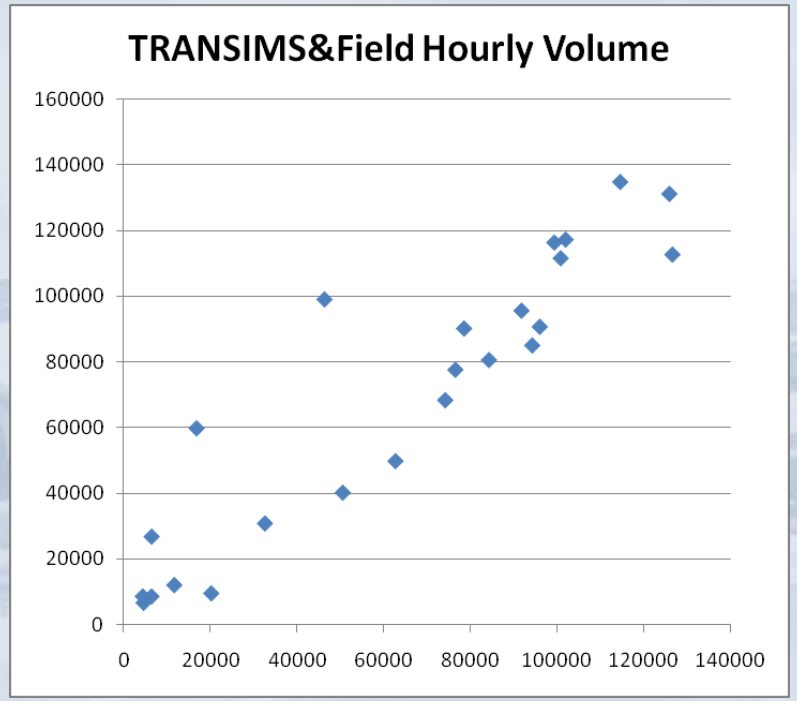
Why regression analysis?

- percentage error: exaggeration of errors at low traffic volumes;
- U-statistic: overly sensitive to differences in the temporal variations;
- GEH statistic: sensitive to volume variation;

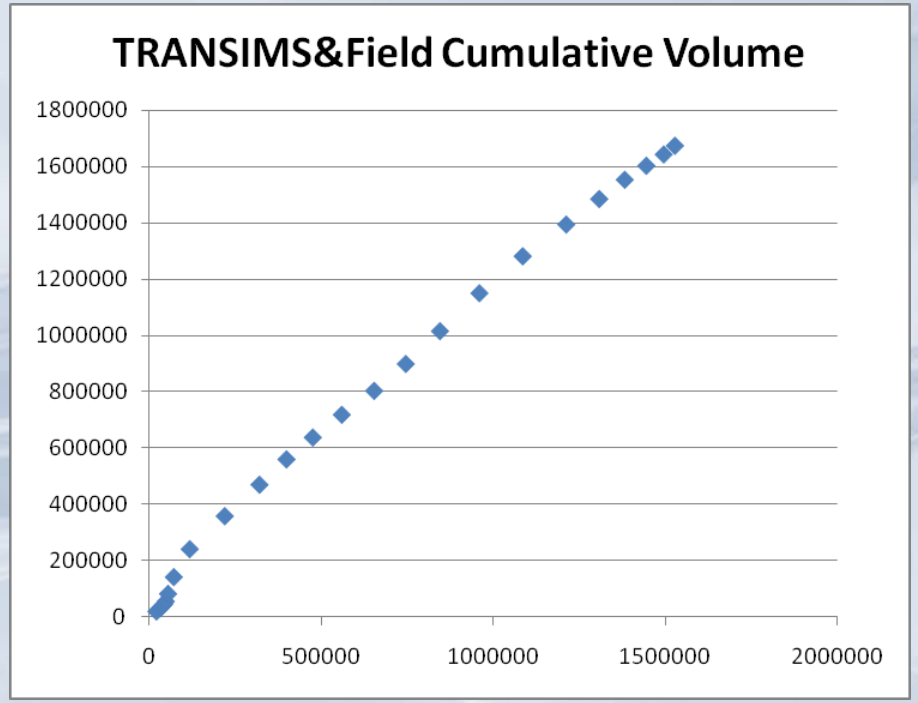
Validation

2. Regression Analysis (Scott adjusted demand)

R^2=0.825



R^2=0.935

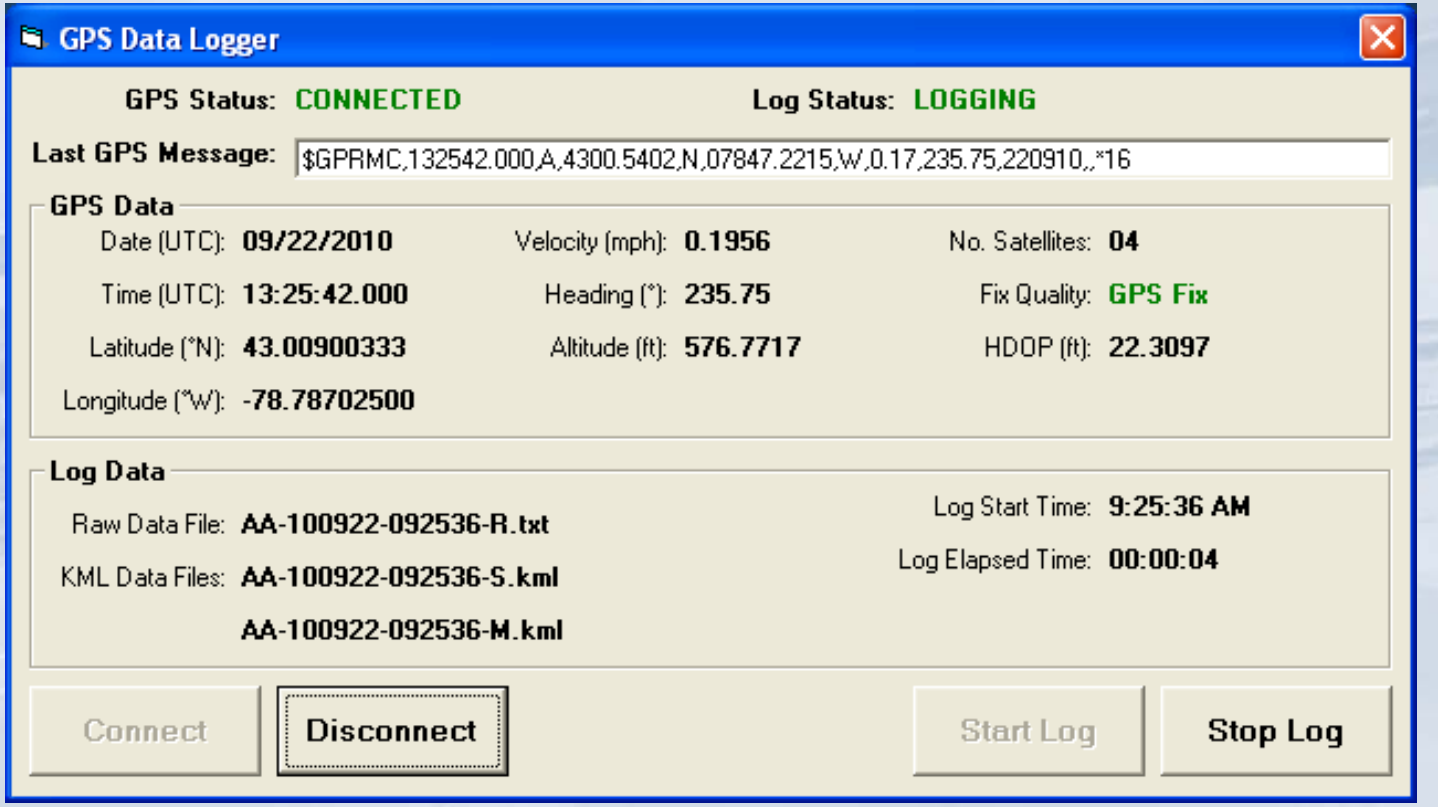


Tasks 2 & 3: Data Acquisition

- Two Primary Sources:
  - NITTEC's monitoring and surveillance network
    - Data archiving – working on building a prototype ITS data warehouse
  - Instrumented Vehicles
    - A very small fleet of 3 vehicles
    - Hope to be able to augment with data from the naturalistic driving experiment
- Some studies exist in the literature (2010 & 2011 TRB Meeting)
- Data used to quantify changes in volume, speed & travel time during inclement weather conditions.

Real-Time Data Acquisition

- Example Screen Capture of GPS Data Logger



Real-Time Data Acquisition

- Example of Raw GPS Data

AA-100827-105114-R.txt - Notepad

File Edit Format View Help

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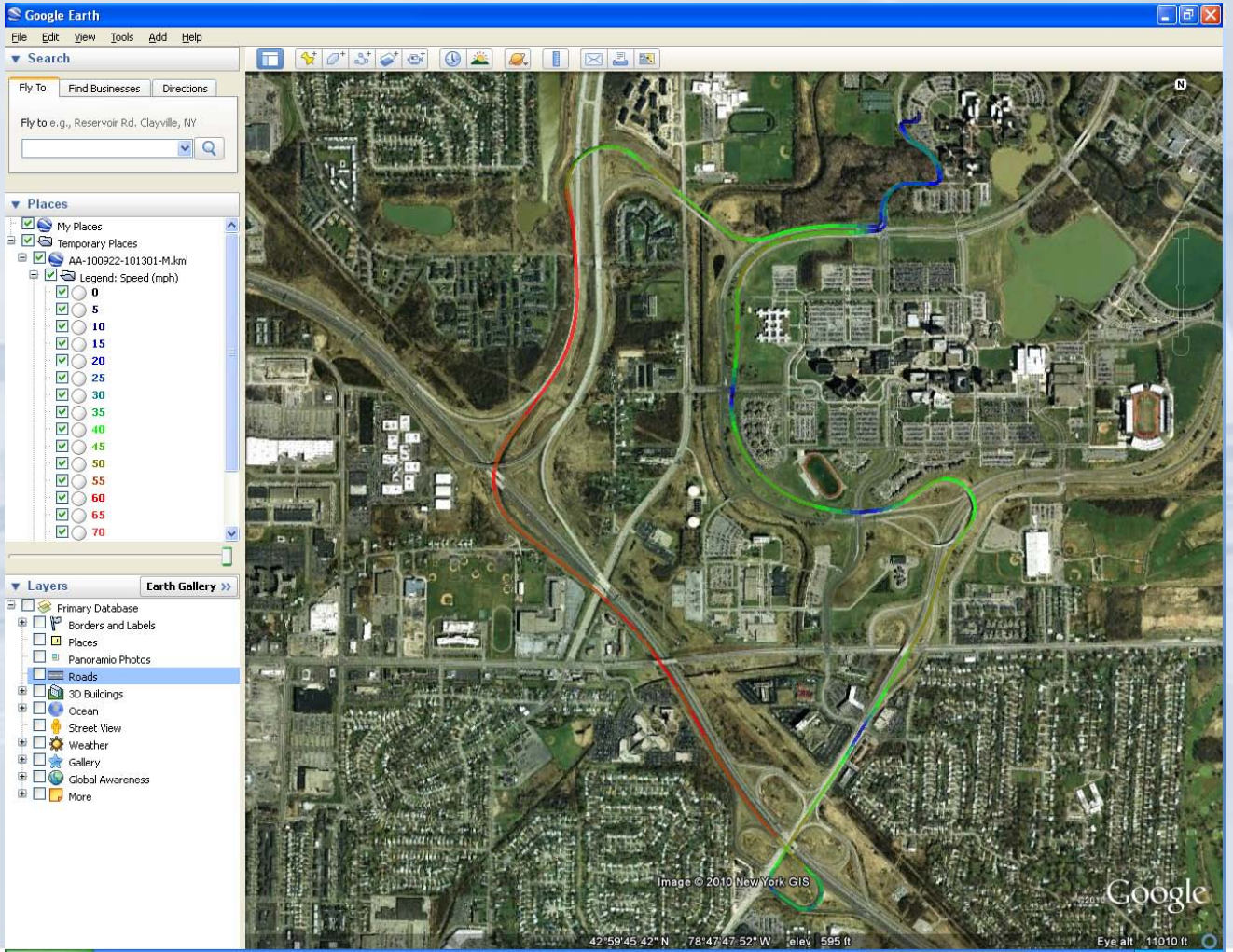
Real-Time Data Acquisition

- Example #2 of Google Earth Plot (Color-Coded Speed)



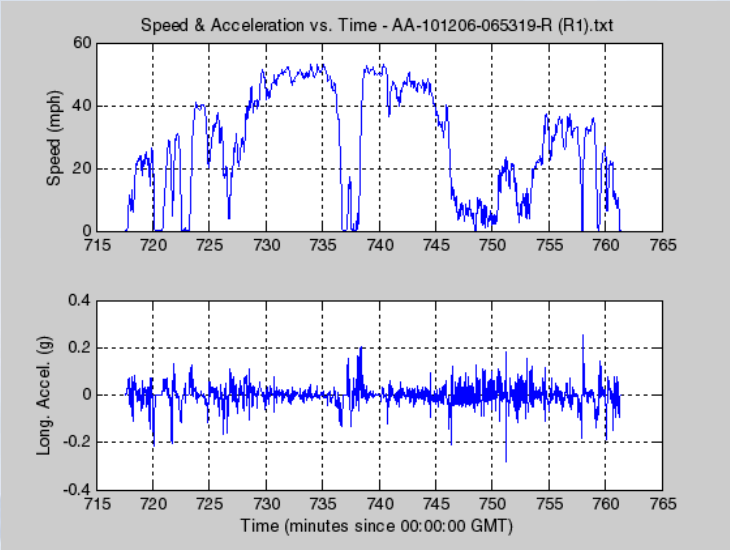
On-Road Data Collection

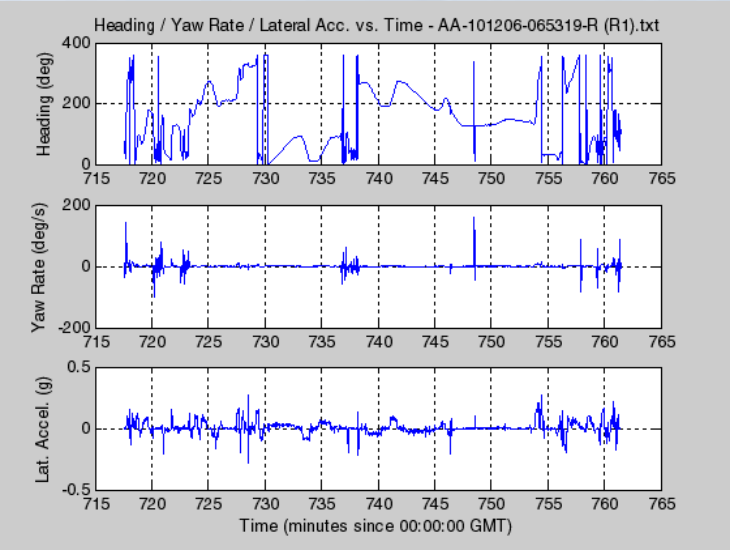
- Trip Analysis #1 (Route 1 – I-990) – Simple Statistics

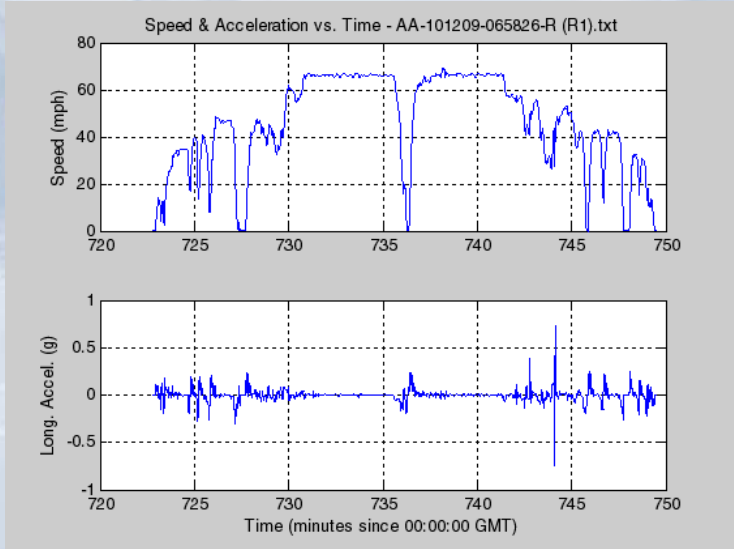
Parameter		06-Dec-2010 (Inclement Weather)	09-Dec-2010 (Clear Weather)
Data File Name		AA-101206-065319-R (R1).txt	AA-101209-065826-R (R1).txt
Number of Data Points		**2634**	**1607**
Total Trip Time (minutes)		**43.87**	**26.75**
Mean:	Velocity (mph)	**28.15**	**46.10**
	Longitudinal Acceleration (g)	-7.966e-006	1.012e-005
	Lateral Acceleration (g)	5.675e-003	1.106e-002
Std Dev:	Velocity (mph)	17.04	20.03
	Longitudinal Acceleration (g)	**0.04**	**0.07**
	Lateral Acceleration (g)	**0.05**	**0.10**
Skew:	Velocity	-0.17	-0.74
	Longitudinal Acceleration	-0.11	0.02
	Lateral Acceleration	0.26	0.04
Kurtosis:	Velocity	**1.69**	**2.56**
	Longitudinal Acceleration	**7.84**	**25.95**
	Lateral Acceleration	**7.43**	**5.67**

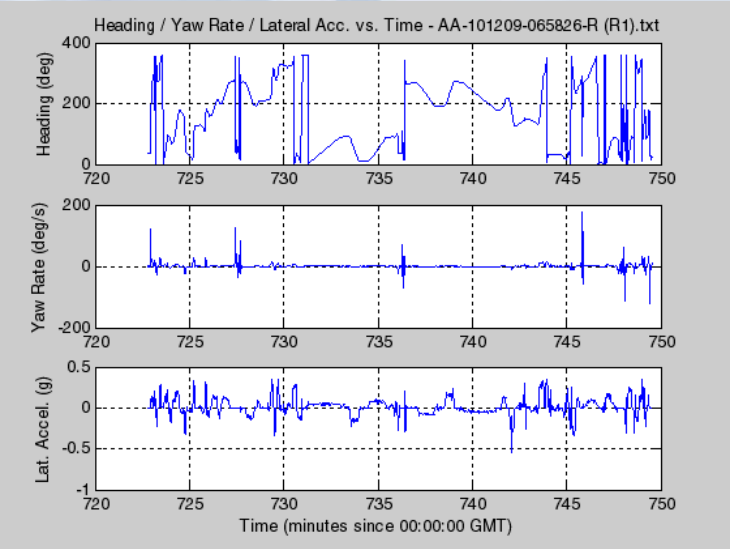
On-Road Data Collection

- Trip Analysis #1 (Route 1 – I-990) – Speed, Heading, Acceleration



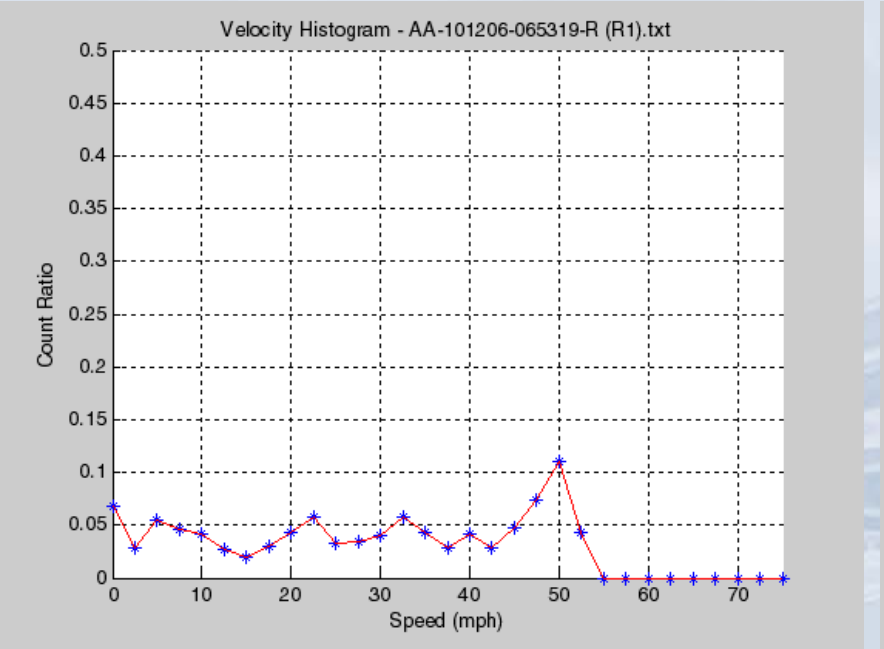


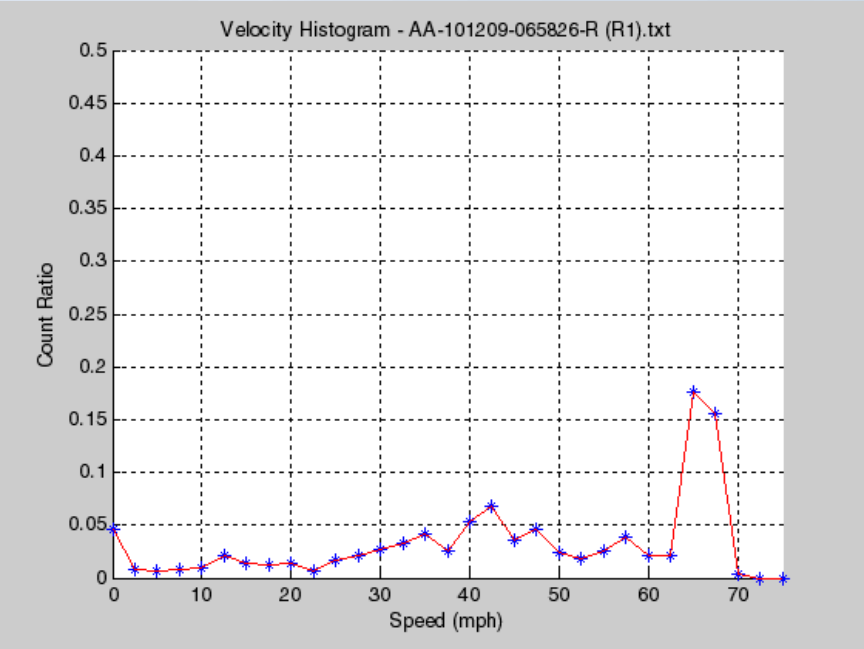




On-Road Data Collection

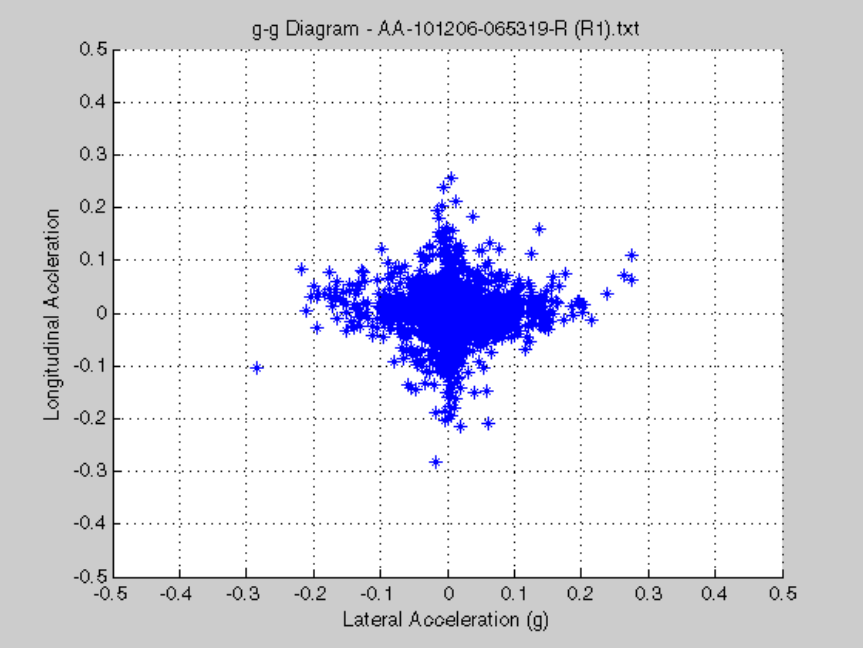
- Trip Analysis #1 (Route 1 – I-990) – Velocity Histograms

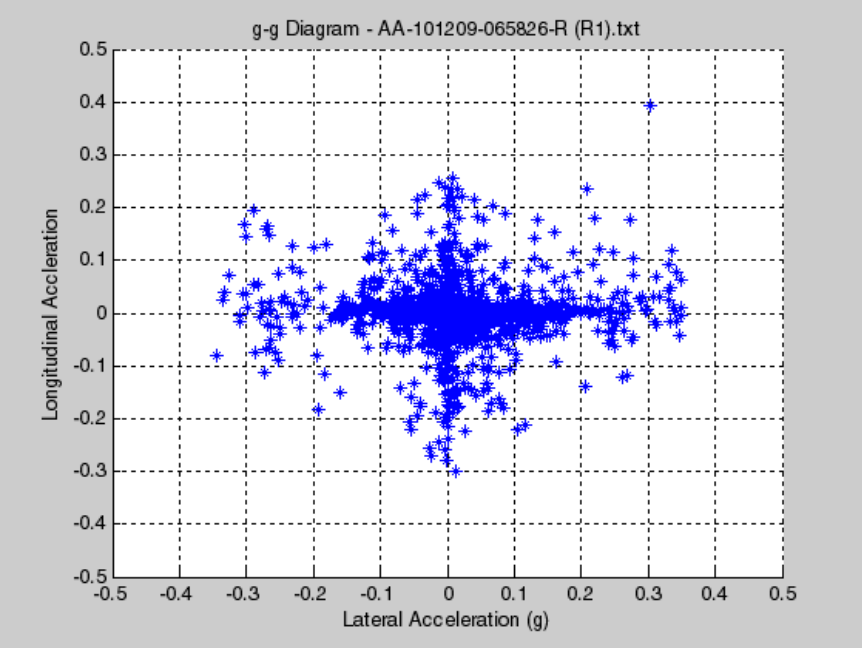




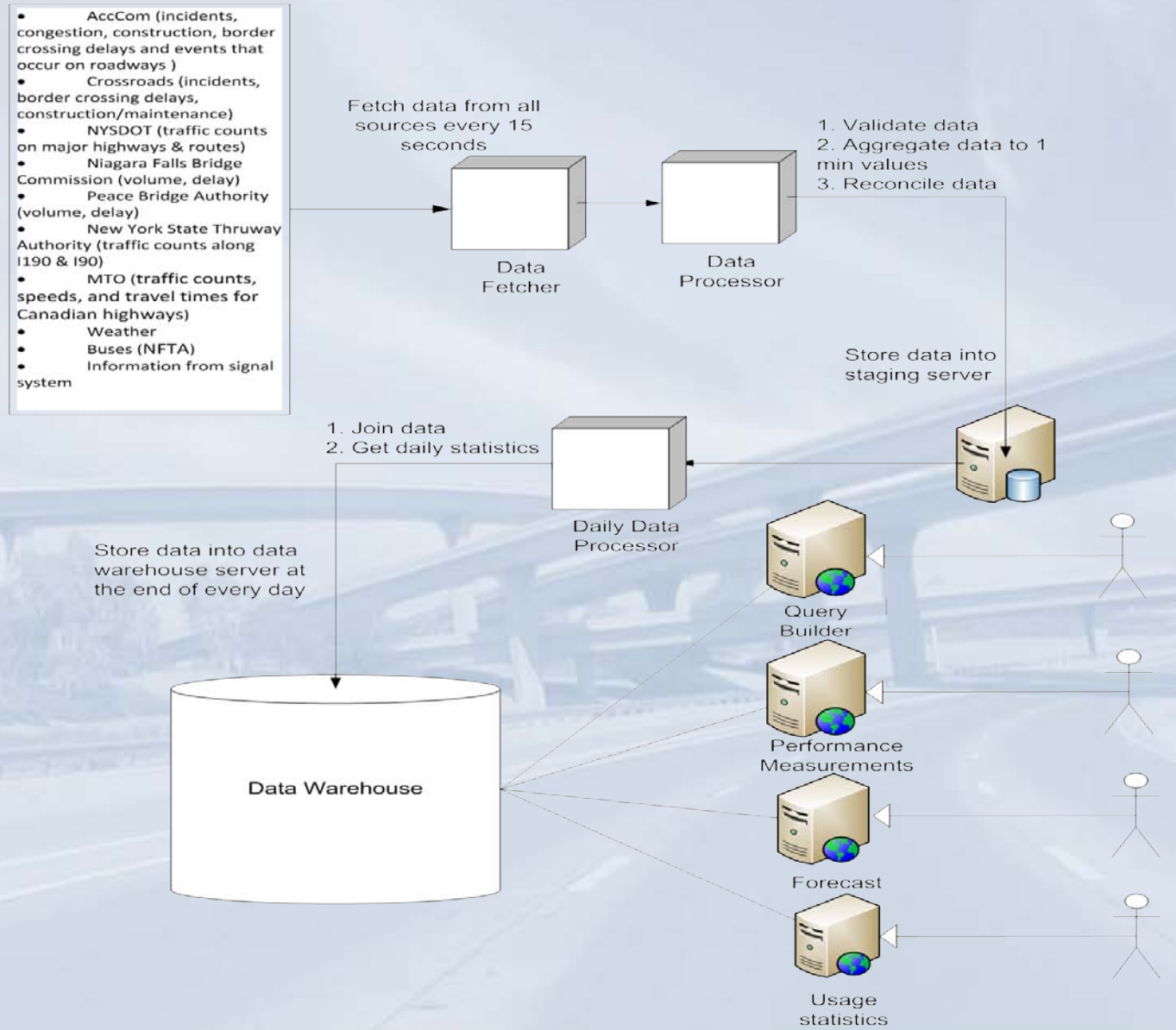
On-Road Data Collection

- Trip Analysis #1 (Route 1 – I-990) – G-G Diagrams





Data warehouse



Task 4 – Modeling New Behavior in TRANSIMS

- Modifications for snow events:
  - Changes to TRANSIMS CA traffic model in terms of reduced speeds & longer headways during snow events
  - Activity generation pattern of travelers to reflect the lower-than-normal volumes
- Wide-area network disruption:
  - Activity generation pattern to reflect simultaneous initiation of new trips
  - Drivers' behavior to become more aggressive

Task 5: Evaluate likely emergencies

- Three scenarios defined:
  - ***Scenario 1:*** a traffic accident involving a vehicle carrying HAZMAT, which closes a major thoroughfare such as I-190, I-290 or I-90.
  - ***Scenario 2*** will try to measure the impact that locally intense winter squalls have on the WNY area. Parameters include: area affected; reductions in travel speeds; network closures in extreme circumstances; and the time needed to remove snow
  - ***Scenario 3:*** a broad scale winter ice storm. Parameters include impact of reduced speed, number of obstructions, malfunctioning signals, increased accident frequency & time to clear snow

Human-in-the-Loop Simulation

Simulator Operation Monitor

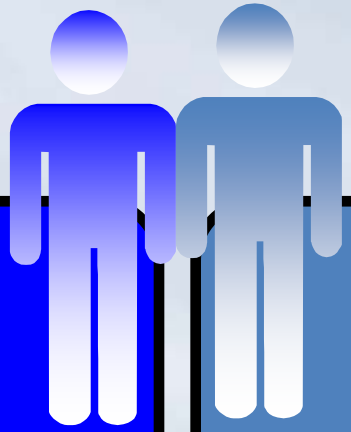
6 D.O.F Motion Platform

2-Seat Cabin

4-Screen VR Envi (3D Video & S. Audio)

On-board Reconfigurable Control

Introduction



Driving Simulator

- Realistic driving behavior
- Good for human factors & driver behavior research
- Lacks network realism & static background traffic

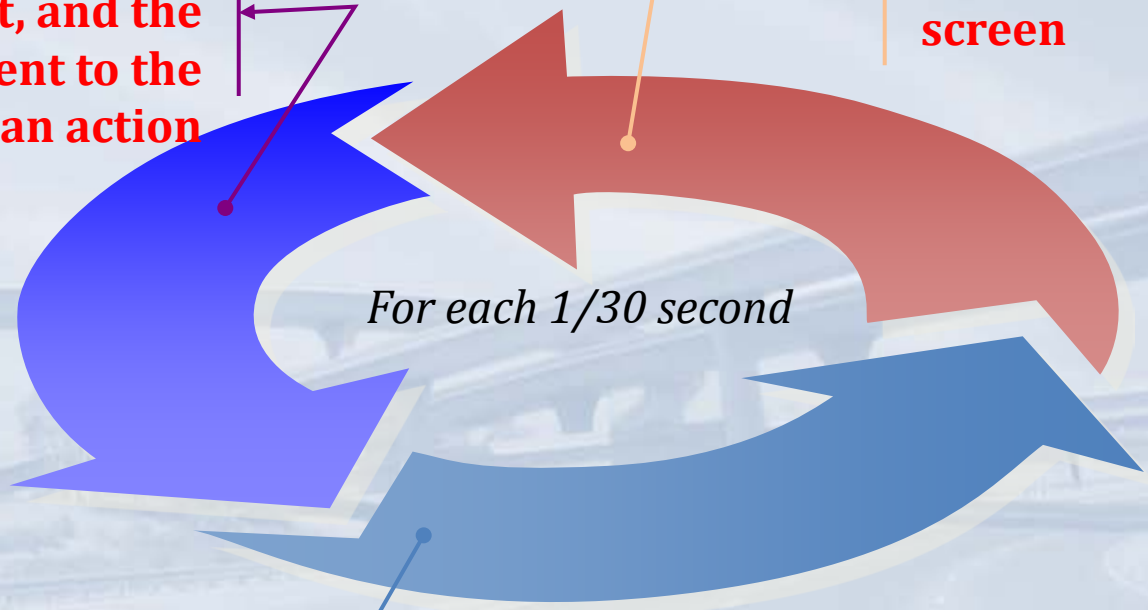
Traffic Simulator

- Realistic road traffic and network elements
- Does not account for human response time and errors

TS+DS Integration

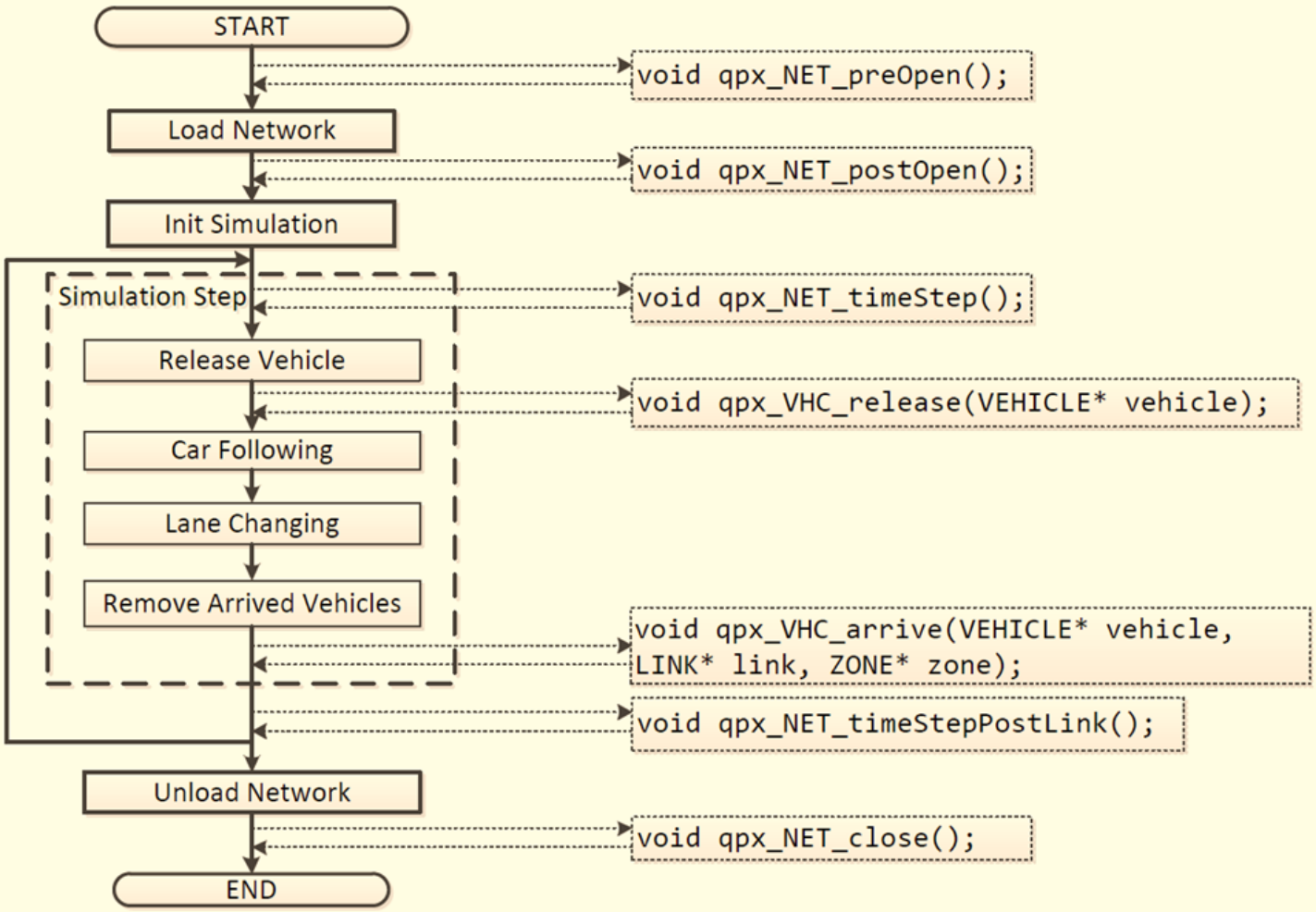
The driver controls the DS according to the screen output, and the behavior is sent to the TS as an action

A visual output is generated on the DS screen



TS gets an action and use it to overwrite current vehicle's behavior, and simulates other vehicles' movements

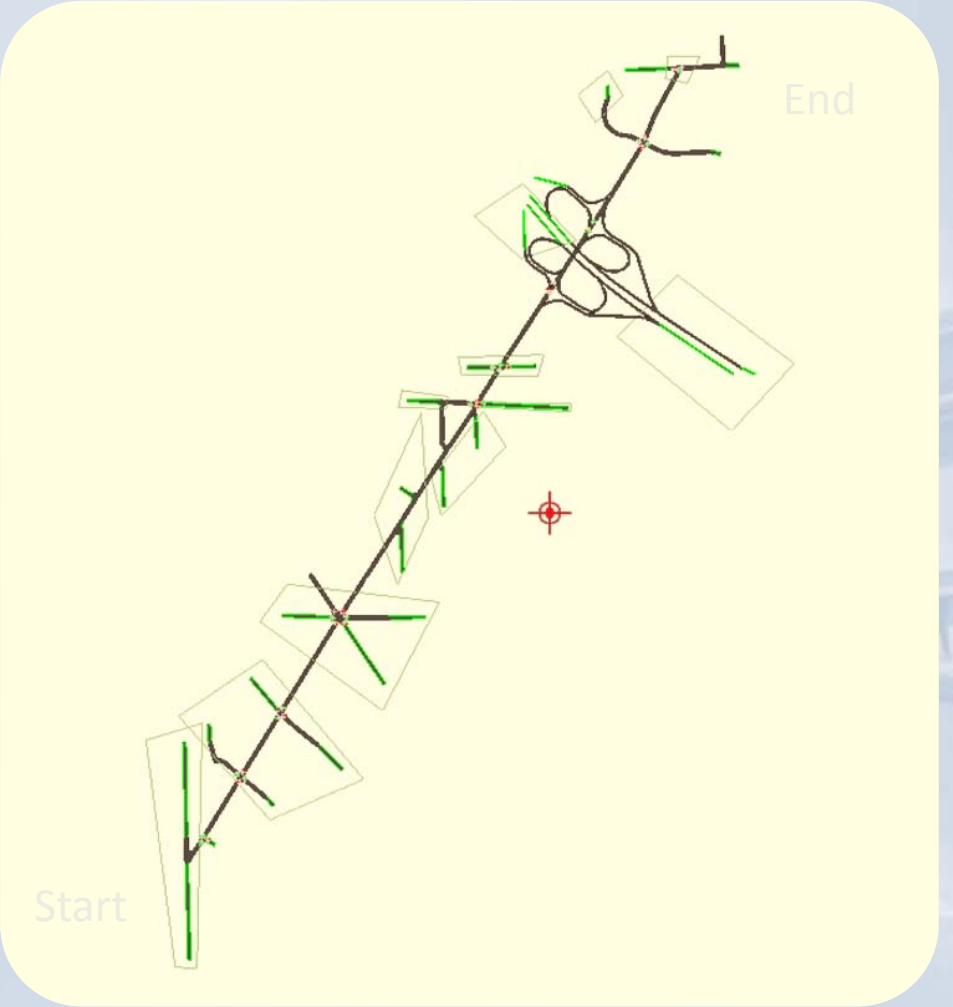
Technical Details



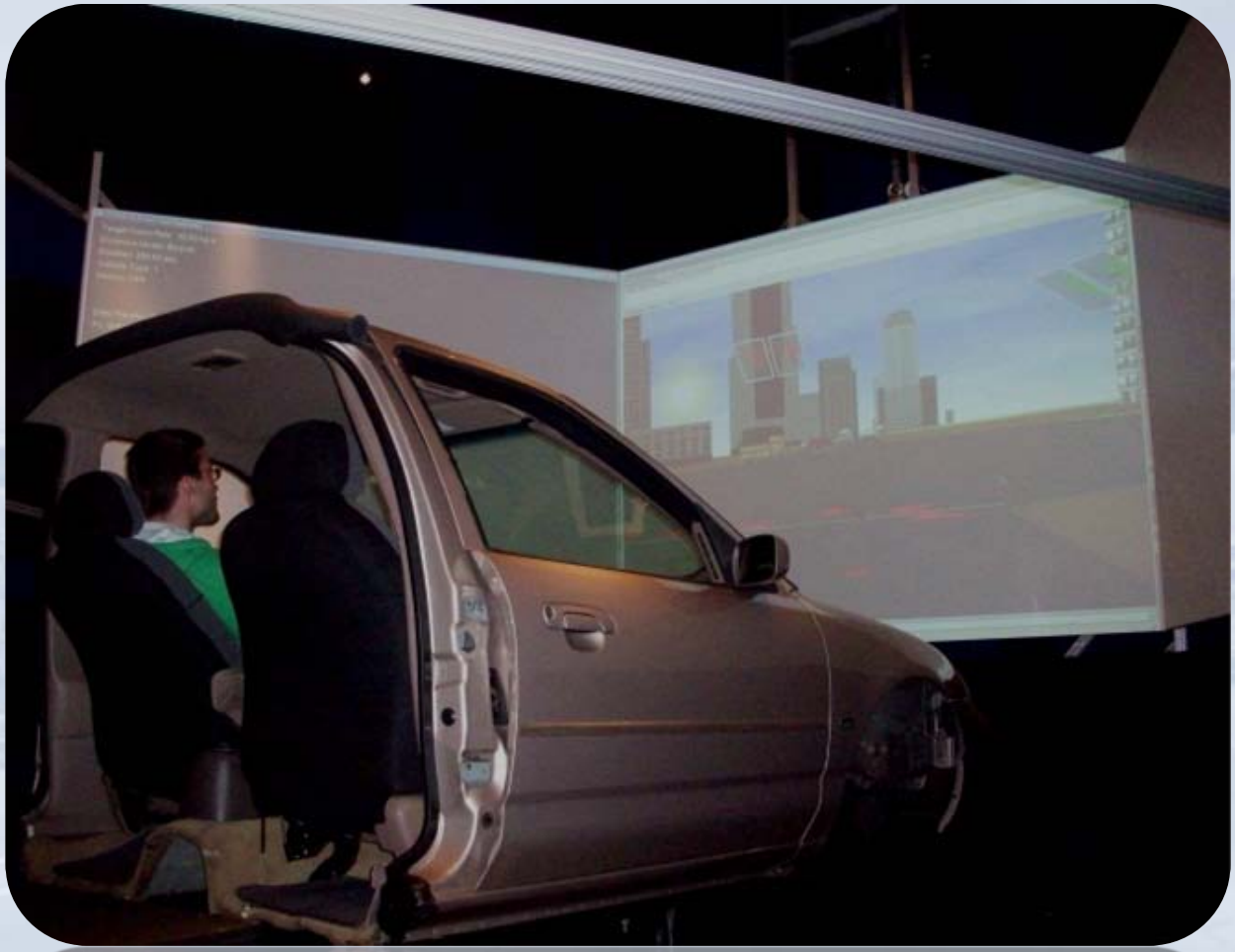
Experimental Setup

- 16 different drivers (14 M + 2 F)
- 0.75-mile roadway segment close to UB
- Two scenarios
  - Free flow
  - Slightly congested
- Emission: CMEM by UC Riverside
  - Fuel consumption rate
  - Tailpipe emissions rate

The Network

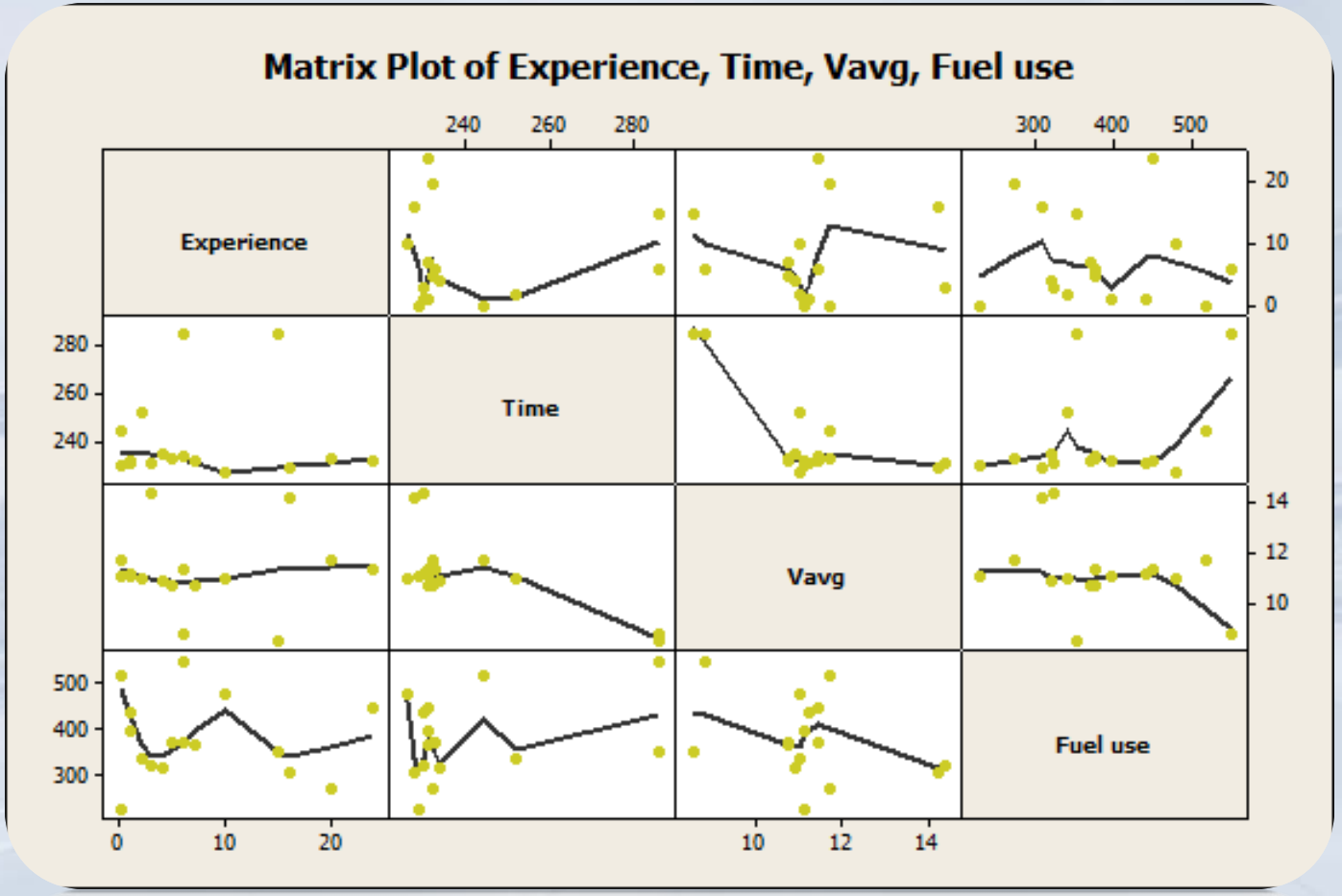


In The DS

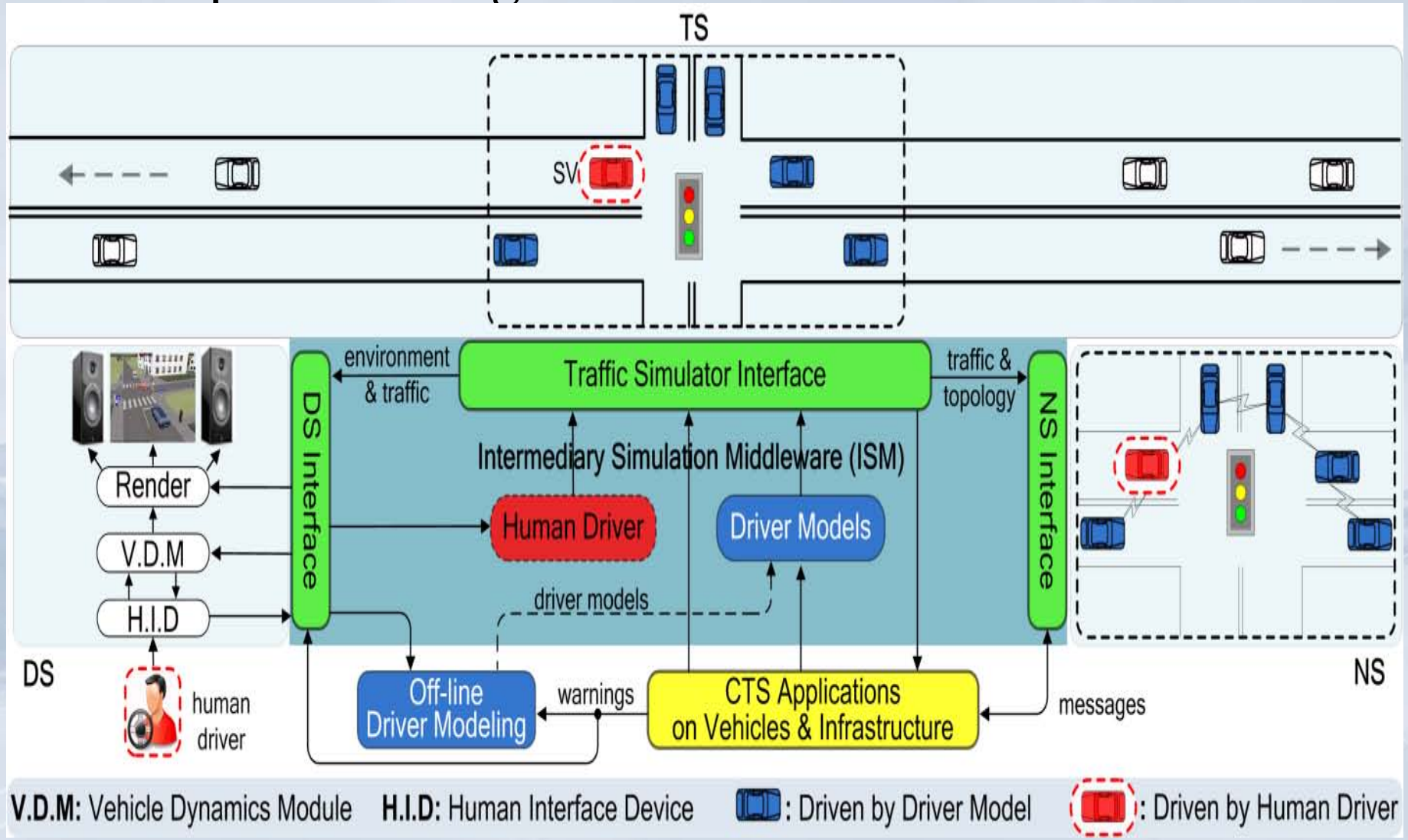


3D View in the TS

Results – Slight Congestion



Proposed Integrated DS-TS-NS Simulator



Conclusions

- Limitations of state-of-the-practice
- Two initiatives
  - Large-scale ABM for transportation system management during emergencies
  - Human-in-the-loop simulation
- 21st century transportation problems demand 21st century models

Acknowledgement

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GBNRTC
GREATER BUFFALO-NIAGARA
REGIONAL TRANSPORTATION COUNCIL

NITTEC
Niagara International Transportation Technology Coalition

Questions & Thank you !