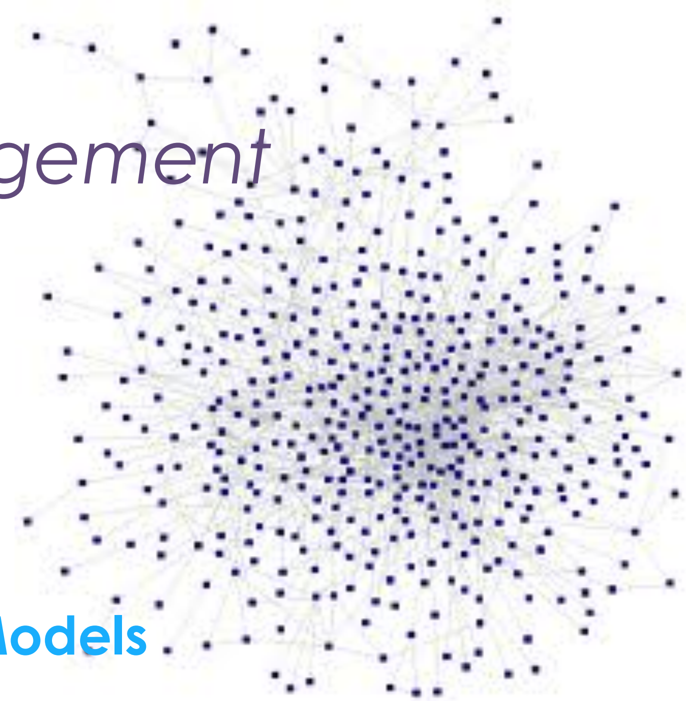
McCormick

Northwestern Engineering

Northwestern University Transportation Center

# Modeling Behavior -- *Expanding boundaries and Implications for System Management*



Hani S. Mahmassani

**Masterclass: Human Behavior in Traffic Models**
**Delft, NL. July 4 2012**

NORTHWESTERN UNIVERSITY

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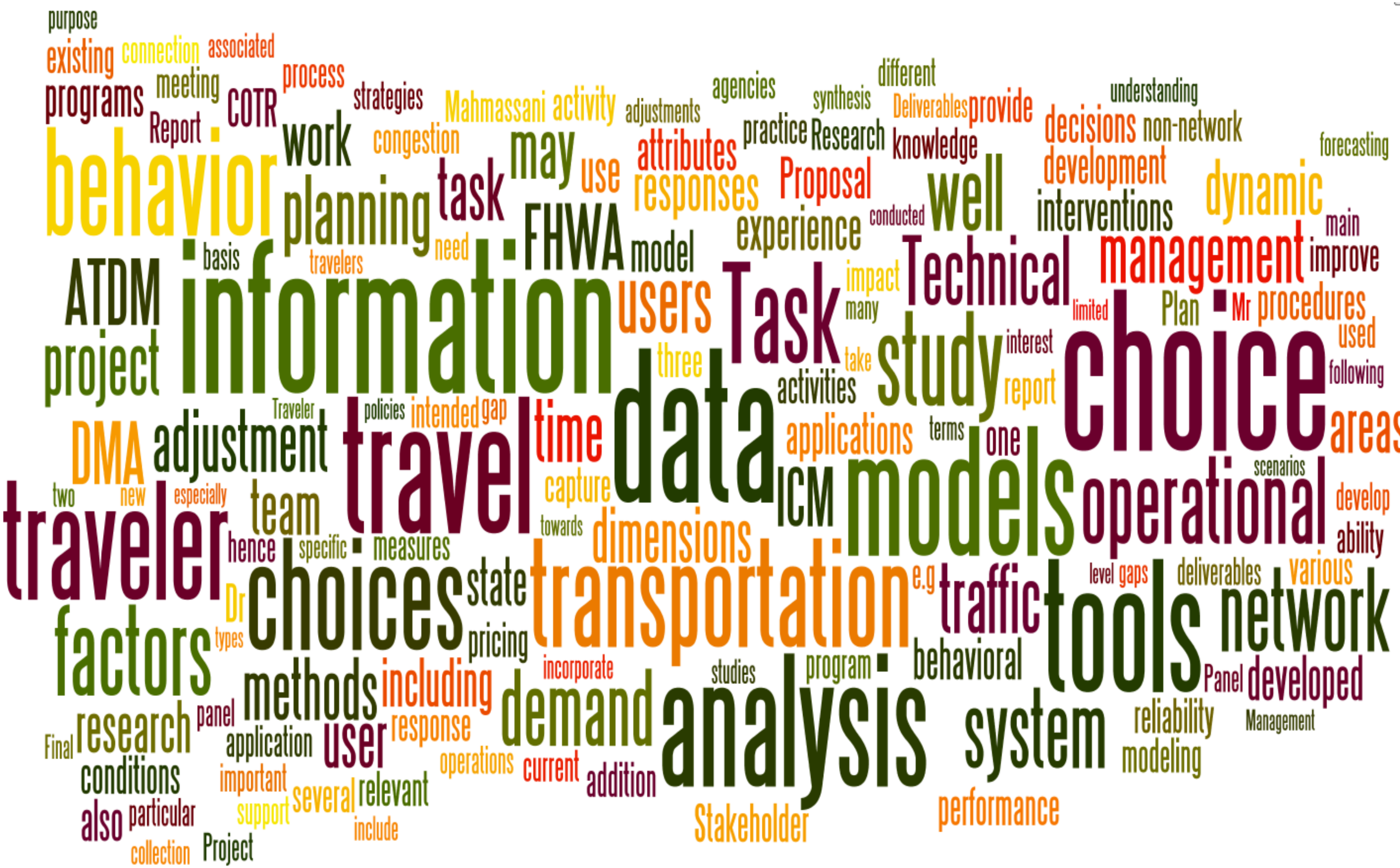

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COTR
strategies
Mahmassani
activity
adjustments
agencies
synthesis
different
Deliverables
provide
understanding
decisions
non-network
forecasting
Report
work
congestion
may
use
attributes
practice
Research
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Proposal
well
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application
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response
Final
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current
modeling
important
addition
relevant
several
also
particular
support
performance
Stakeholder
include
collection
Project

# OUTLINE

1. Simulation and Connection to Behavior: Practice and Research Perspectives
2. User Behavior: Expanding dimensions, Key Phenomena
3. The Case for Understanding and Modeling Behavior in Transportation System Management
4. Information– Still the Next Big Thing: Mobile, Social and Slippery
5. Concluding Remarks: the Sweet Spot for System Management

# Tighter coupling between traffic theories (including behavior models) and simulation

- TRAFFIC SIMULATION has evolved to become the primary
  - methodological framework and
  - computational platform

for *implementing* theories and models of traffic processes

and *delivering* analysis capabilities to users

# Where we are

- Engineers have powerful toolkit of traffic simulation packages that serve wide variety of application needs.
- Several models reasonably well-established and exhibit robust and reliable performance for many application needs.
- However, representation of several important traffic phenomena remains lacking– mirroring gaps in underlying theories and models.
- *Growing gap between existing packages and underlying traffic science and theories.*
- Emerging uses/applications bring new challenges for research and application communities.

# EMERGING FOCUS

Main focus of research and simulation community to date

**HOW** TO SIMULATE

Greater focus is needed on

**WHAT** WE SIMULATE

- Scenarios
- Space and time: Loads (DEMAND)

# WHAT DECISIONS IS SIMULATION INTENDED TO SUPPORT?

More interaction

UPSTREAM: operational planning, with planning tools, activity-based models…

DOWNSTREAM: control, on-line systems, real-time data feeds, microdata, personalized mobile information…

# WHAT DECISIONS IS SIMULATION INTENDED TO SUPPORT?

Broader set of questions

SAFETY: hazard risk, collision involvement and severity…

RELIABILITY: flow breakdown, phase transitions, speed harmonization, INFLO strategies, Connected Vehicle approaches

SUSTAINABILITY: traffic calming, pedestrian environments, eco-driving, demand management

**NOT JUST ABOUT PRODUCING THE MOE's BUT ABOUT REPRESENTING AND MODELING THE UNDERLYING BEHAVIOR**

# Some trends…

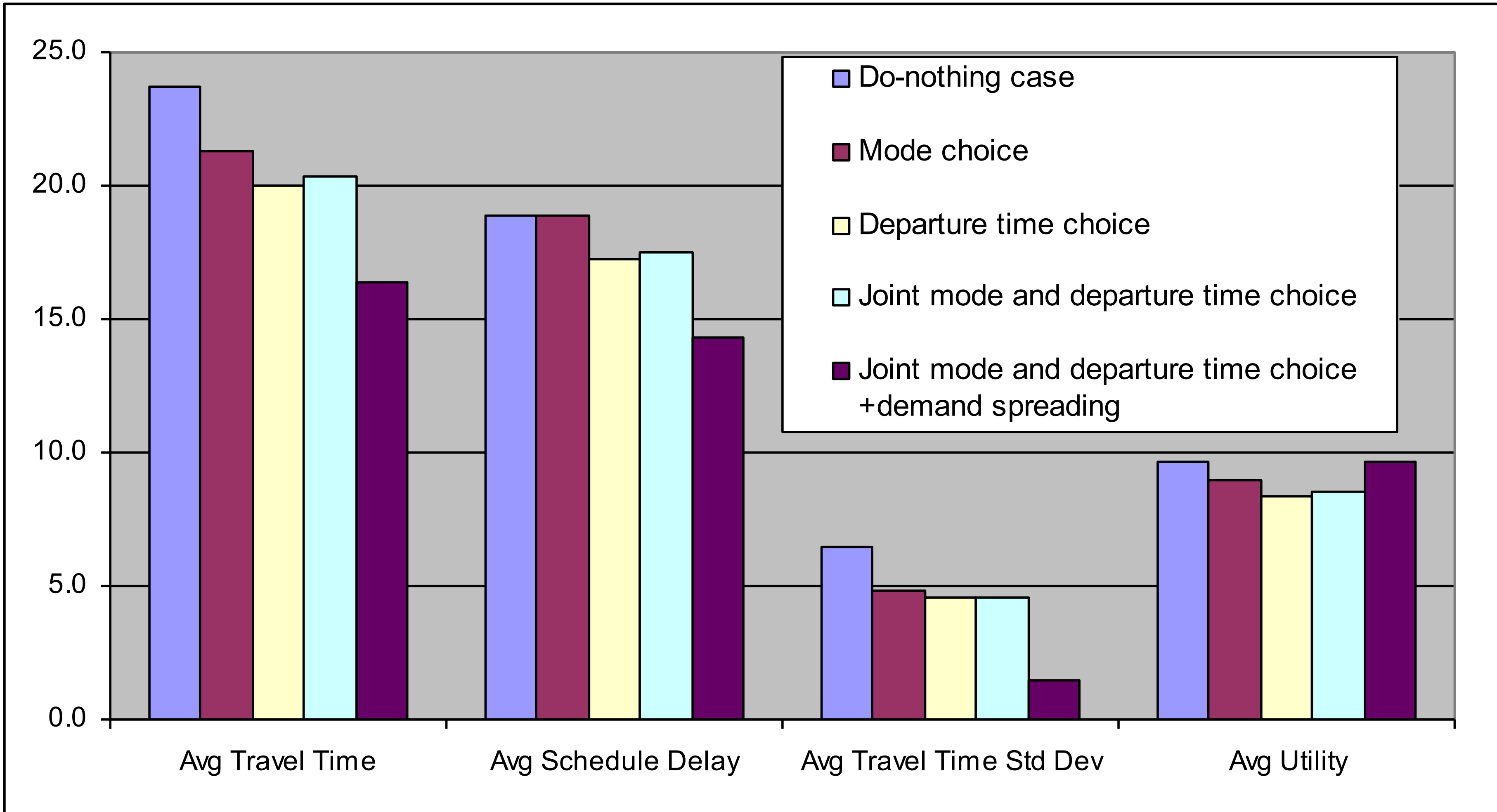
- 2010's– Maturation of network-level simulation-based assignment applications and market
- More aggressive penetration of simulation in planning: integration of activity-based models and network models through microsimulation-based platforms
- Blurring line between micro and meso simulation: PARTICLE-BASED SIMULATION– TRAJECTORIES as unifying observational unit

- Emerging applications:
  - Pedestrian and crowd models
  - Mixed flow, disordered traffic, different contexts
  - Connected Vehicles and active demand management
  - Stronger coupling with design/optimization
  - Real-time application/integration with control

# User Behavior

- Critical and MISSING link in many system management applications:
  - At MICRO LEVEL: User as driver and tripmaker
  - COLLECTIVE effects resulting from interactions of individual behaviors (e.g. flow breakdown)
- KEY QUESTION: Which behaviors or choice dimensions are “essential” in any given application situation?
  - Fuzzy boundary
  - Expanding Sphere

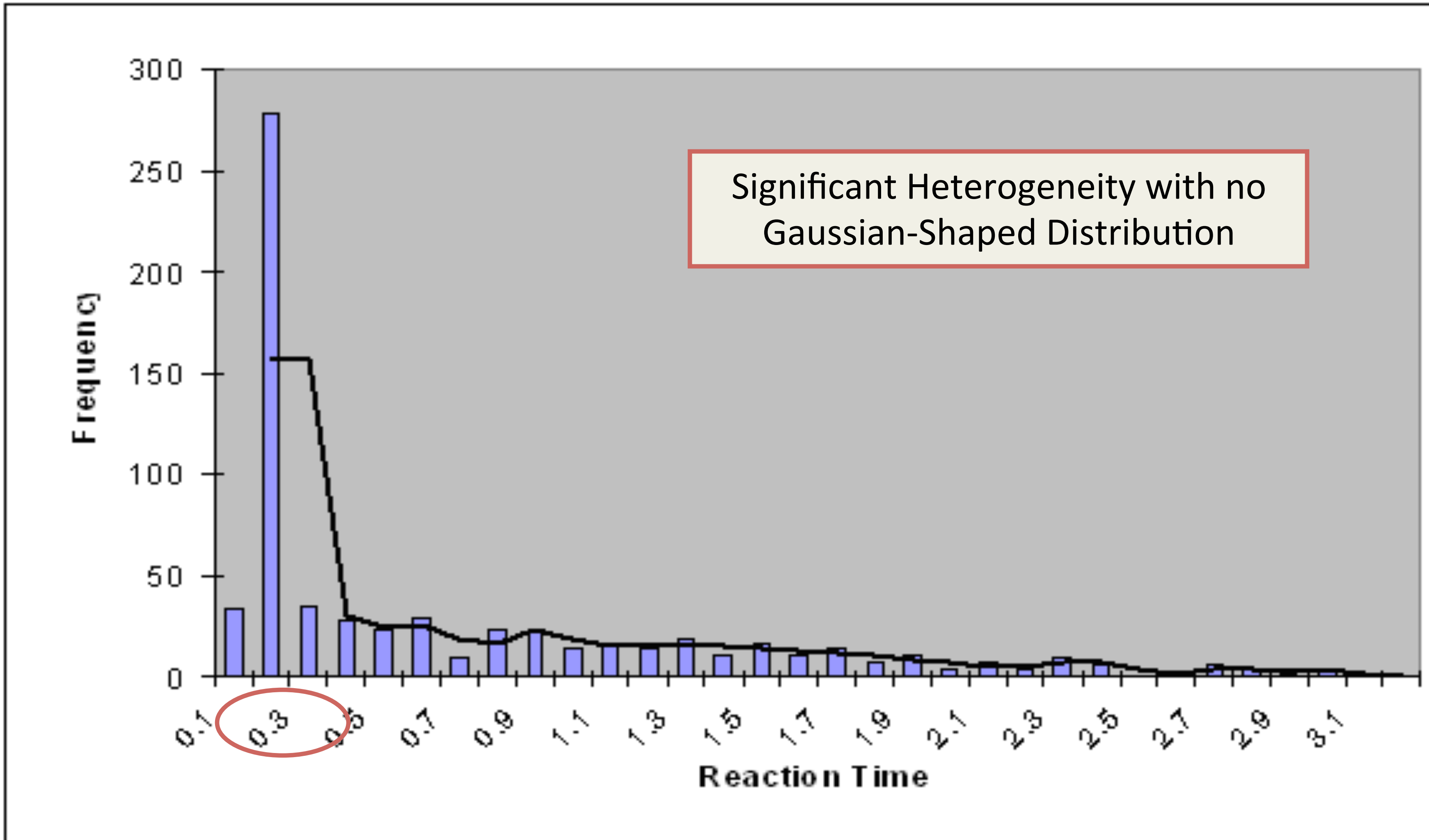
# Network-Wide MOE Comparison for ICM Response Scenarios: CHART Network



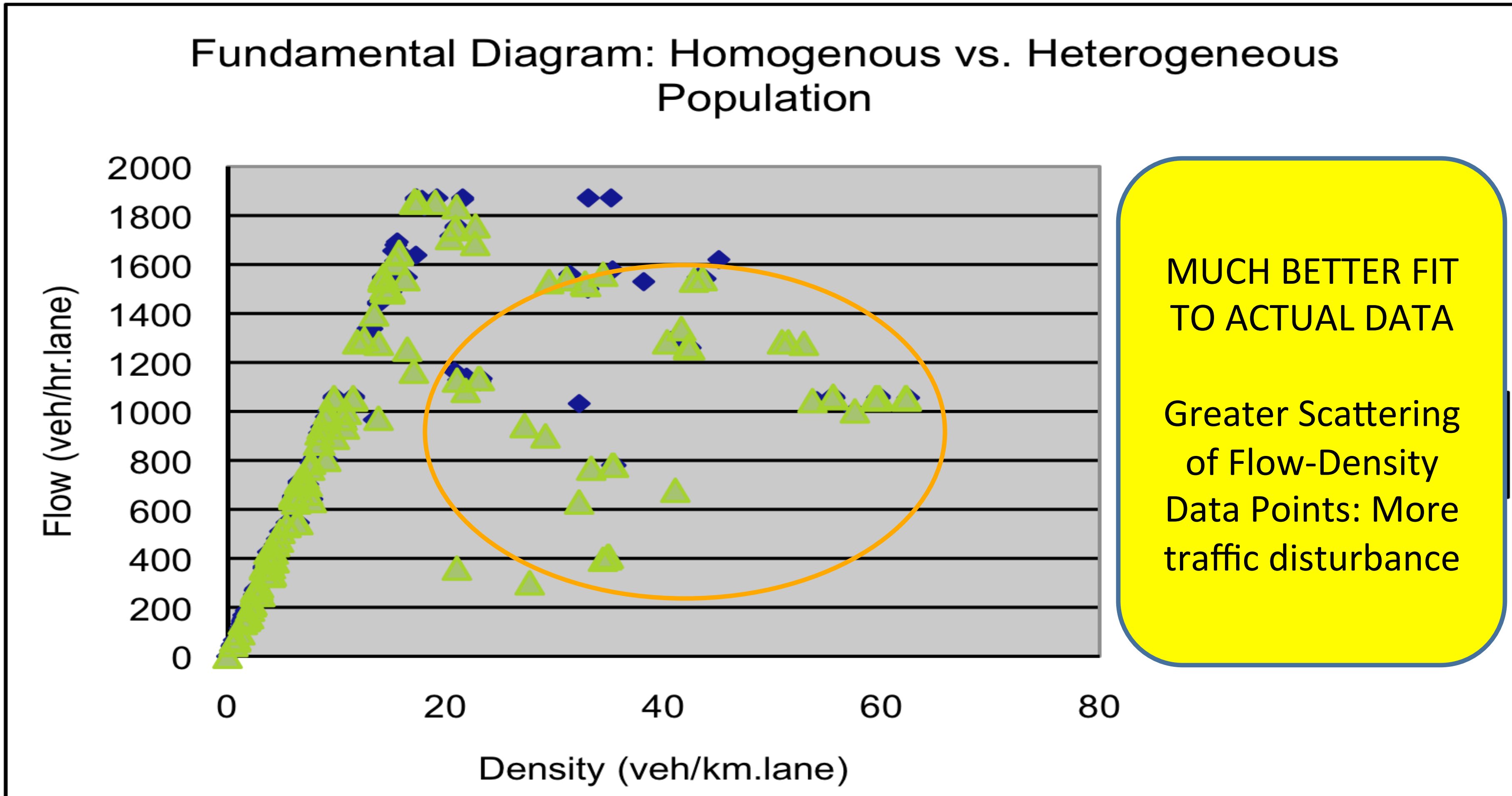
# Behavioral Phenomena/Features

- **Heterogeneity**
- Bounded rationality
- Inertia
- Compliance
- Time lags
- Thresholds
- Biases
- Heuristics
- Risk aversion/seeking
- Role of attitudes and beliefs in forming preferences
- Aggressiveness
- Situational awareness
- Attention
- Learning
- Role of experience and information in learning

# Parameter Distribution for GA Calibration– Prospect Theory Car Following Model (Hamdar and Mahmassani, 2009, 2010)



# Simulation: Fundamental Diagram: Homogenous vs. Heterogeneous Population




MUCH BETTER FIT TO ACTUAL DATA

Greater Scattering of Flow-Density Data Points: More traffic disturbance

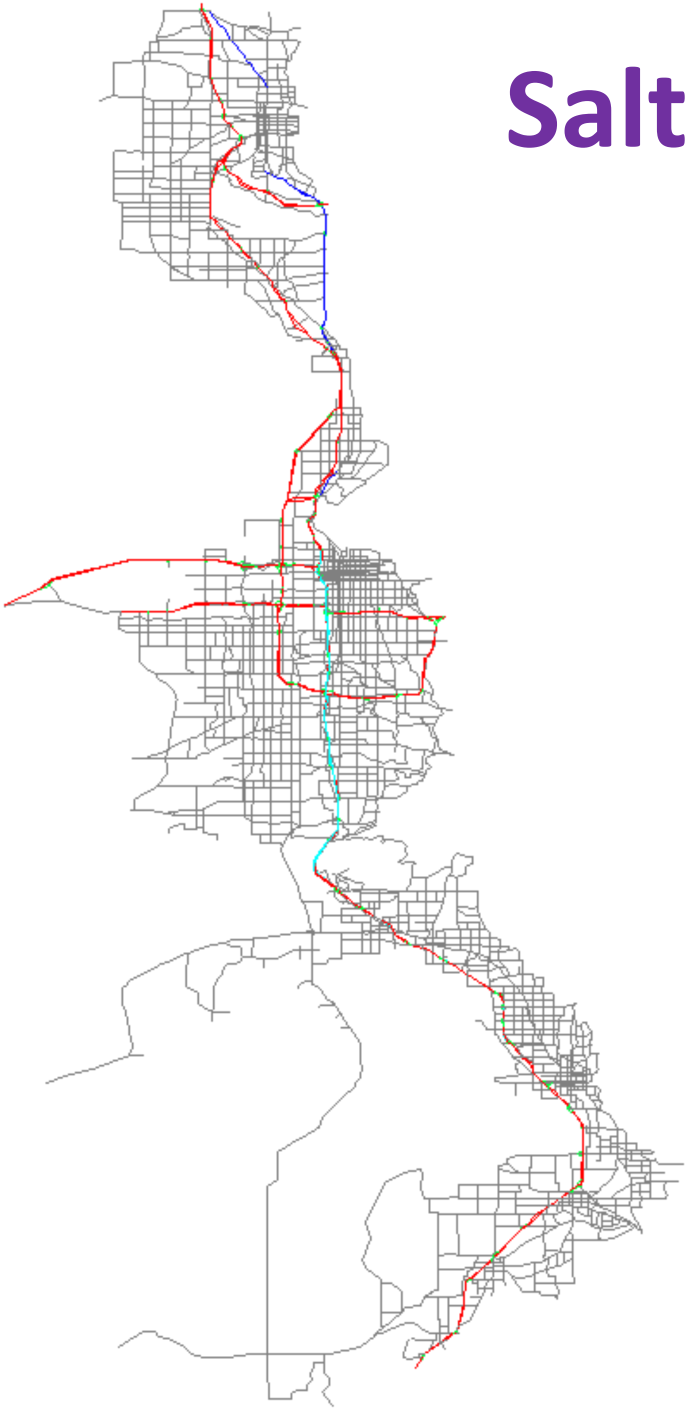
# THE CASE FOR UNDERSTANDING AND MODELING BEHAVIOR IN TRANSPORTATION SYSTEM MANAGEMENT

## Demonstration of Benefits of WRTM Strategies

Evaluating effectiveness of VMS Strategies during adverse weather events

using DYNASMART

# Salt Lake City

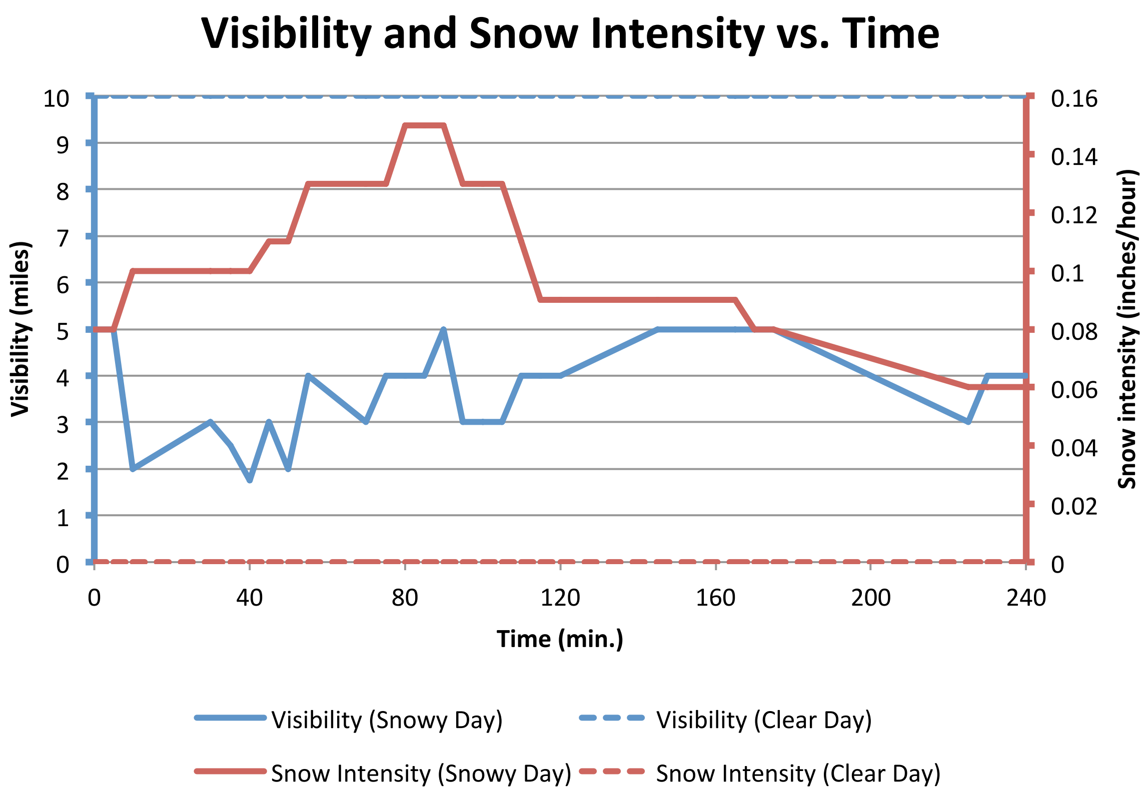


- 2,250 zones
- 17,947 links
  - 16,293 arterials
  - 576 ramps
  - 136 highways
  - 791 freeways
  - 151 HOV lanes
- 8,309 nodes
  - 1,134 signalized intersections
- Demand horizon
  - 6am – 9am
- Simulation horizon
  - 6am – 10am

# Description of 4 Scenarios

1. Clear Day: Maximum visibility with zero precipitation.
2. Heavy Snow: Visibility ranges from 5 to 1.75 miles, snow intensity ranges from 0.06 to 0.15 inches per hour network-wide.
3. Heavy Snow with VMS – Detour: 50 % of vehicles are detoured from some heavily impacted links to alternative routes.
4. Heavy Snow with VMS – Variable Speed Limit: Speed reduction strategies are implemented on heavily impacted corridors.

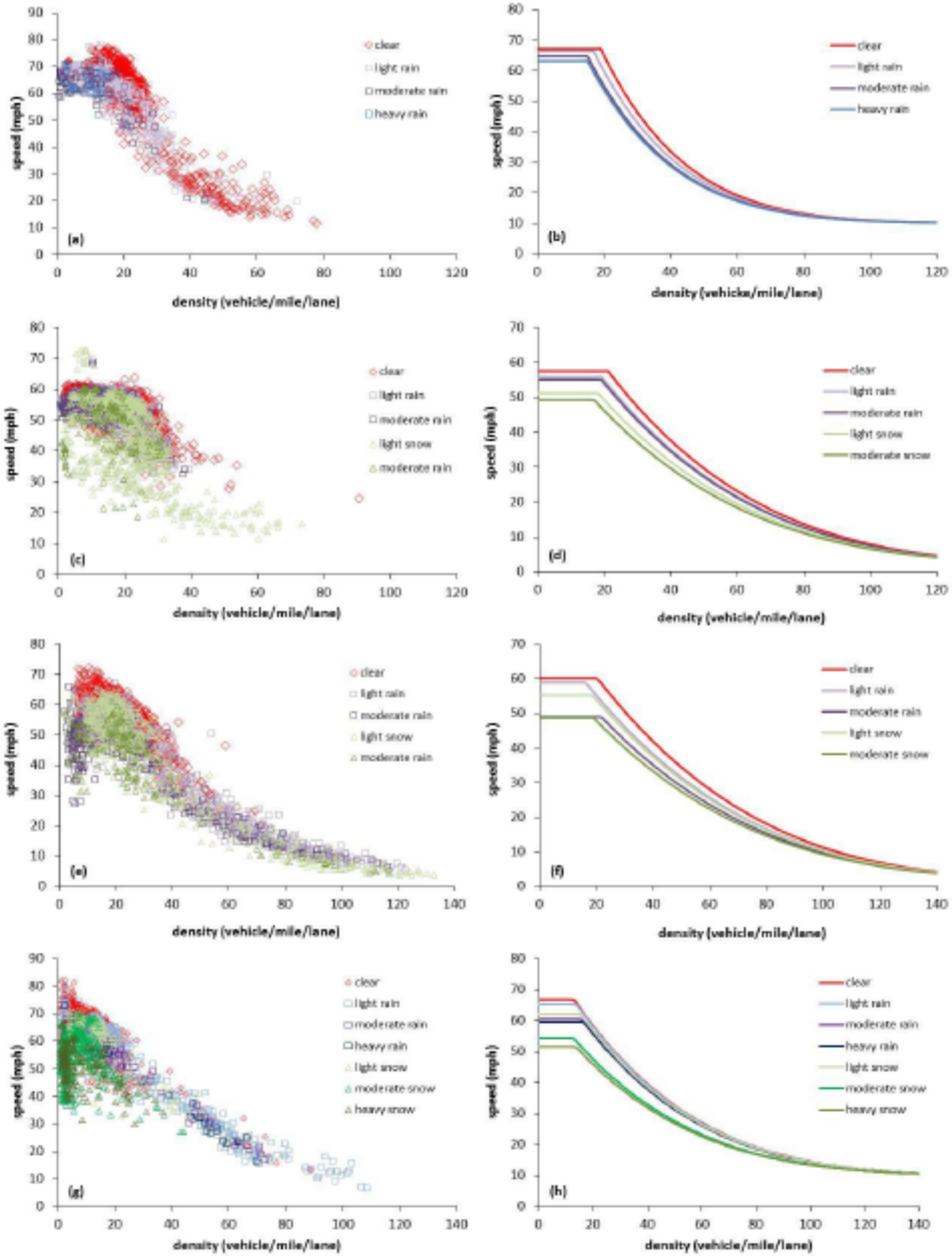
# Weather Scenario (Heavy Snow)




- Snow intensity ranges:
  - Light snow: < 0.05 inches/hour
  - Medium snow: 0.05 – 0.1 inches/ hour
  - Heavy snow: > 0.1 inches/hour
- Visibility ranges:
  - Max. 10 miles
  - Min. 0 miles

**Collective Effects:**

Capturing weather impact on speed-density relations



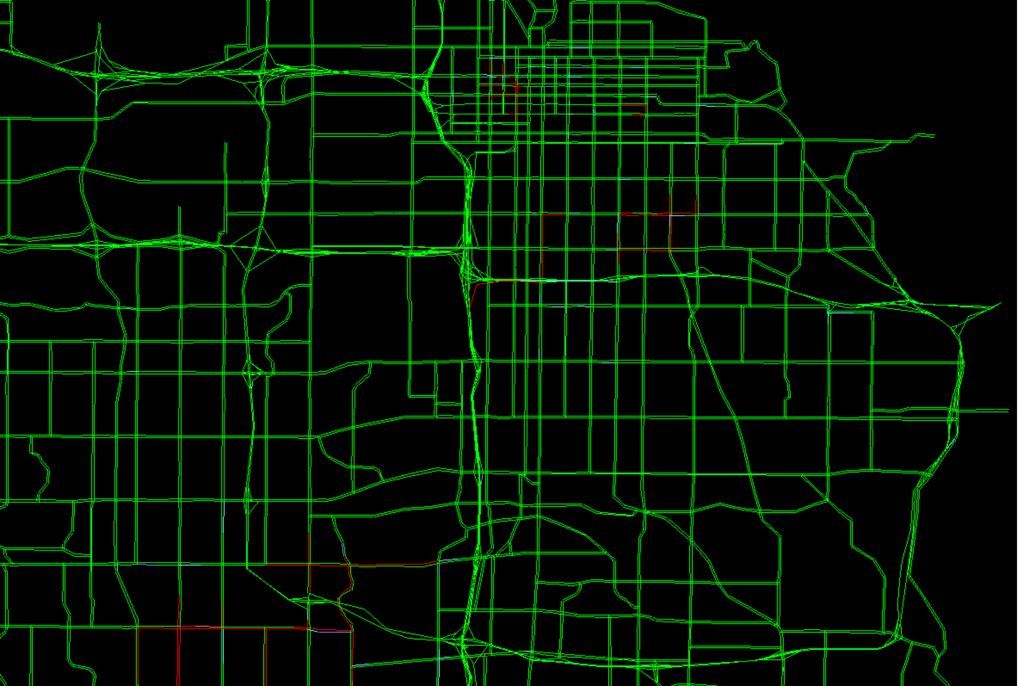

**Irvine, CA**

**Salt Lake City, UT**

**Chicago, IL**

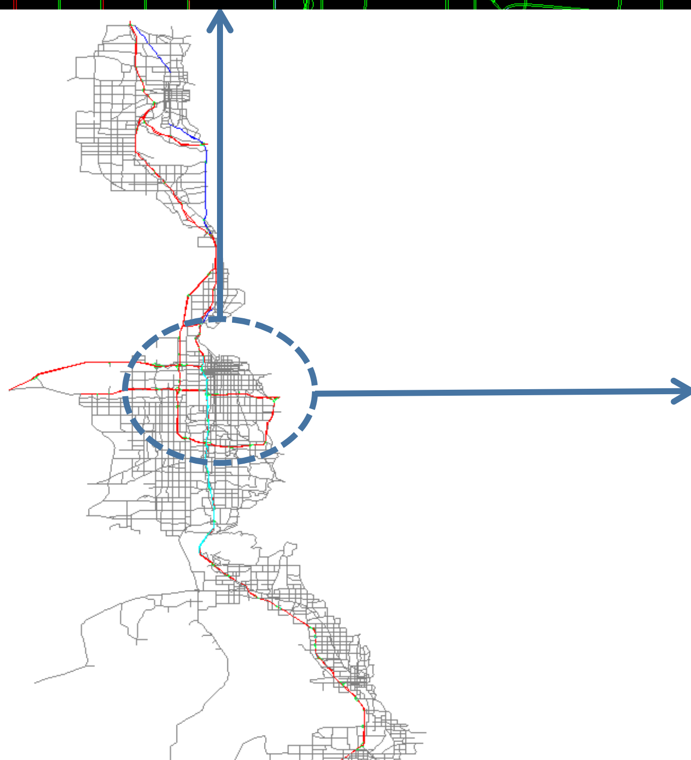
**Baltimore, MD**

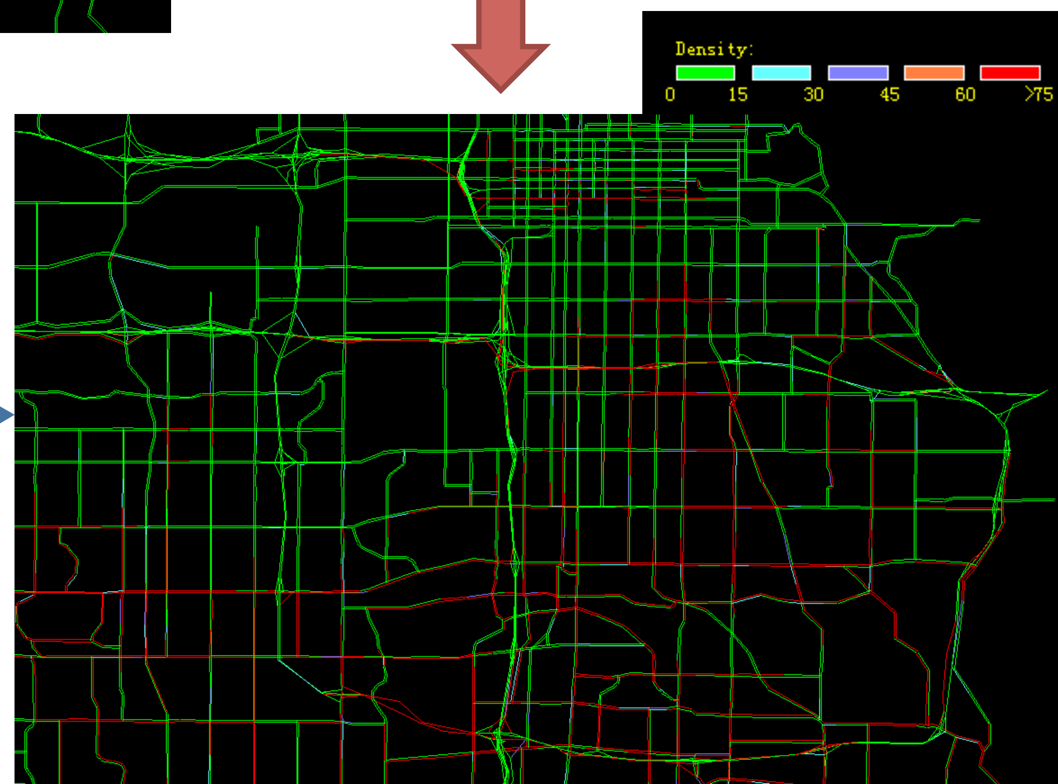
# Weather Impact



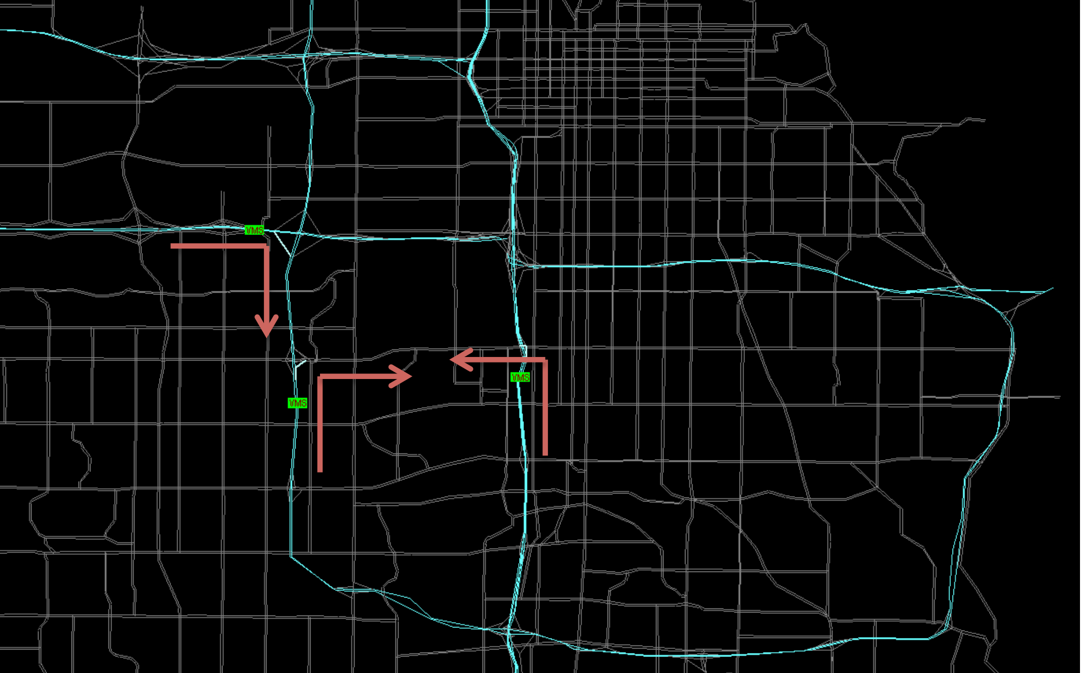
Clear Day

Heavy Snow



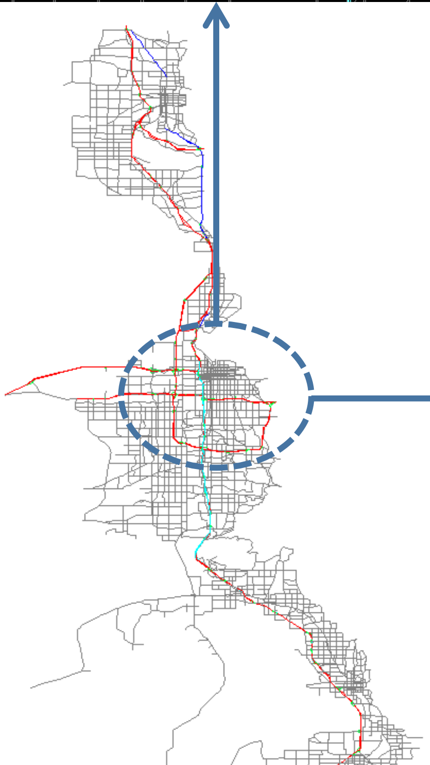


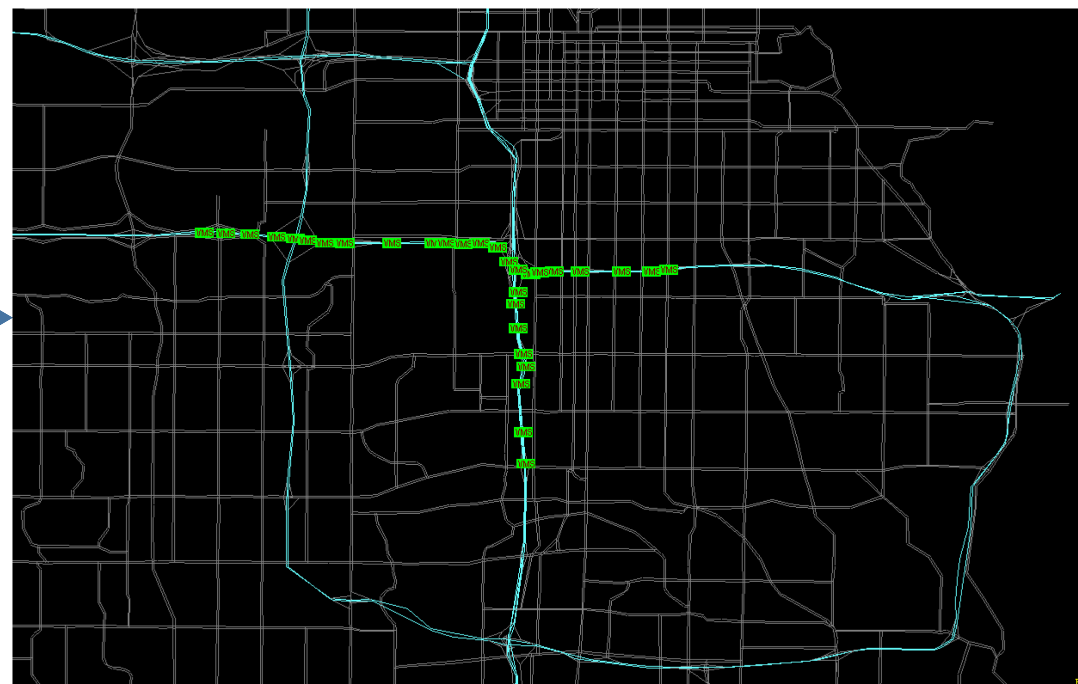
# Management Strategies

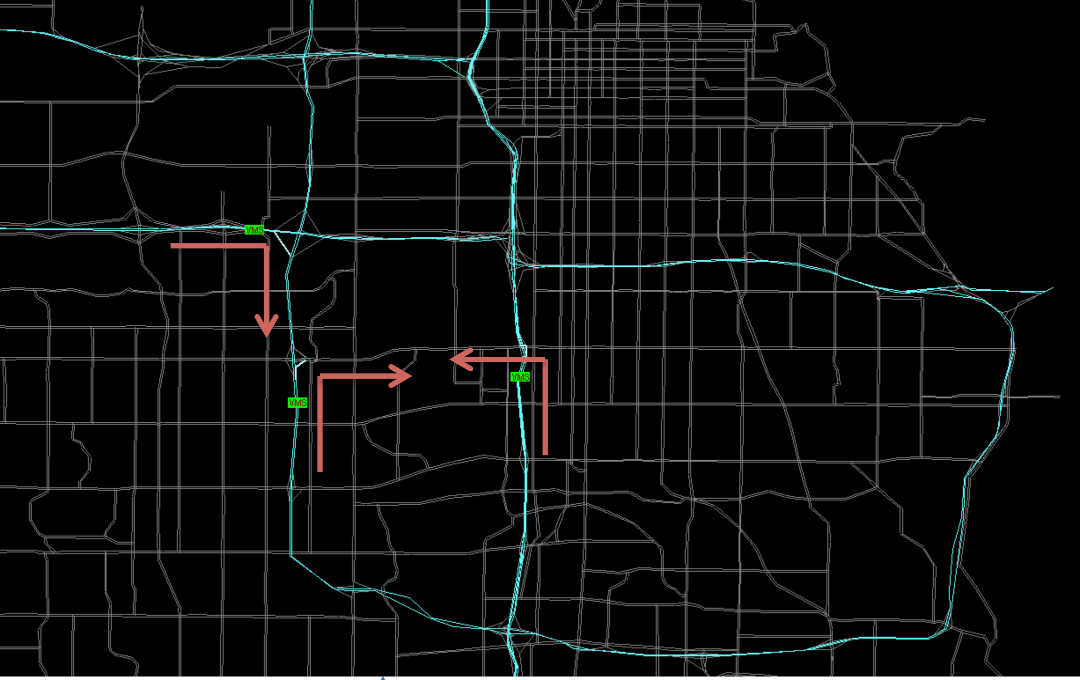


**VMS – Detour**

**VMS - VSL**



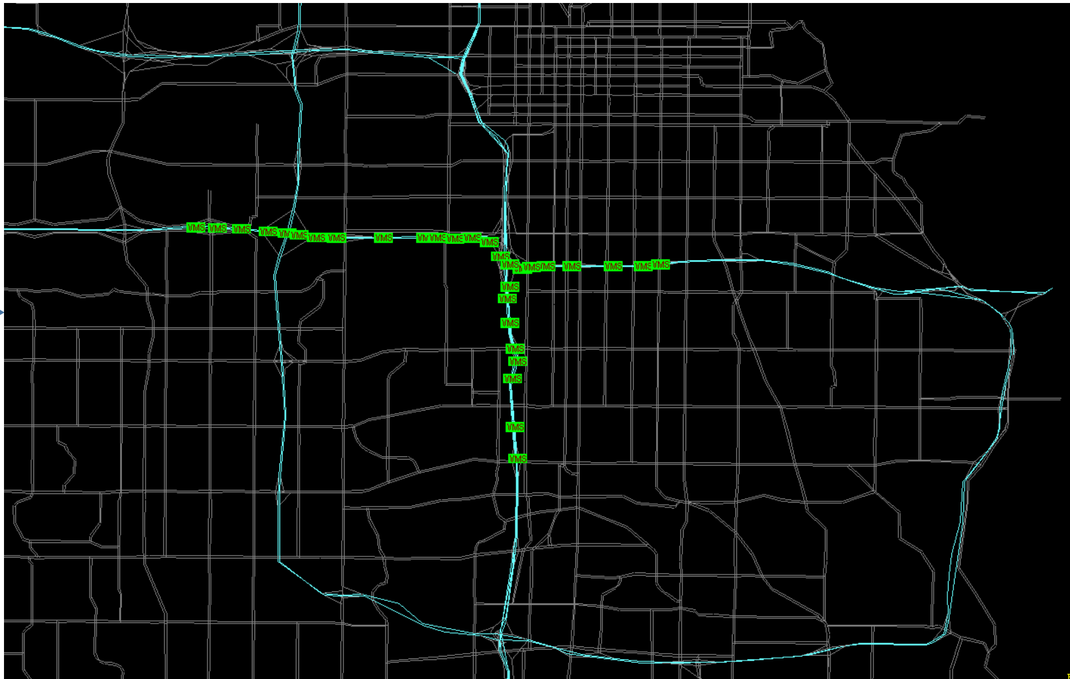




# Management Strategies

**VMS – Detour**

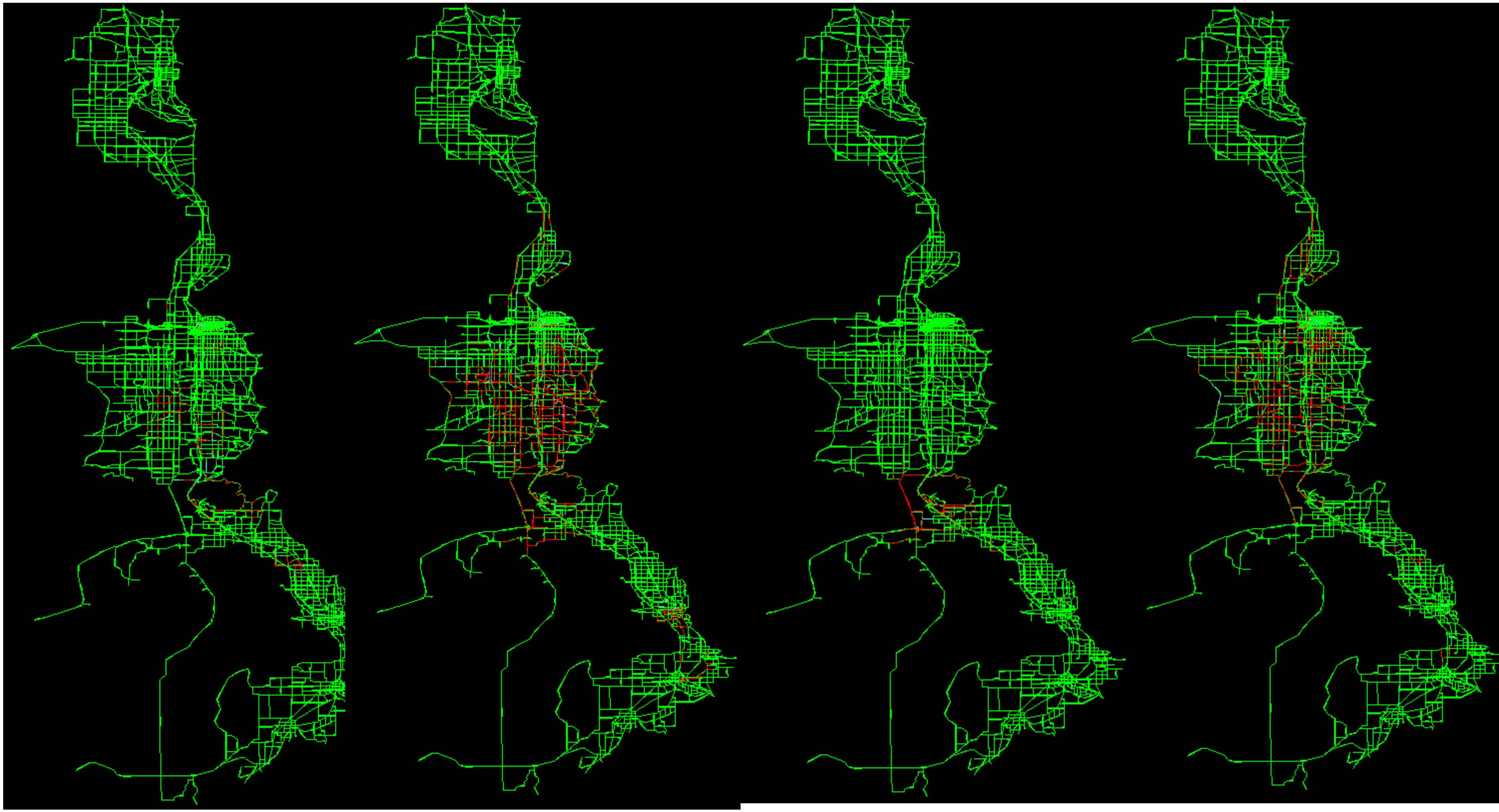
**VMS - VSL**



USER RESPONSE

Captured using micro-level probabilistic decision process models

# Overview of the 4 Scenarios

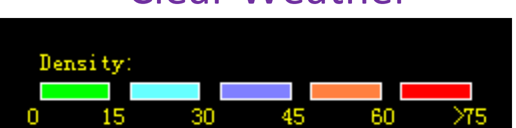


Clear Weather

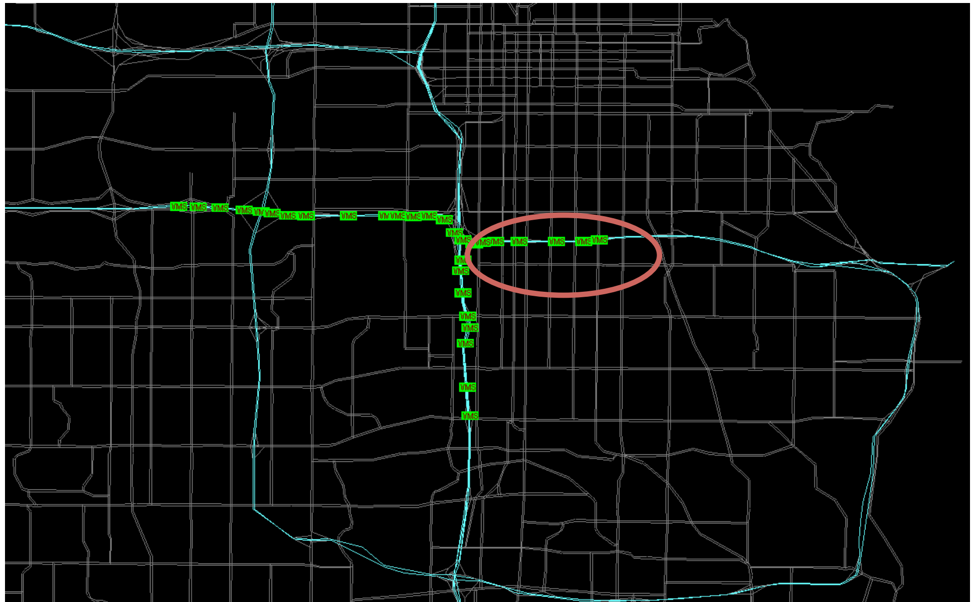
Heavy Snow

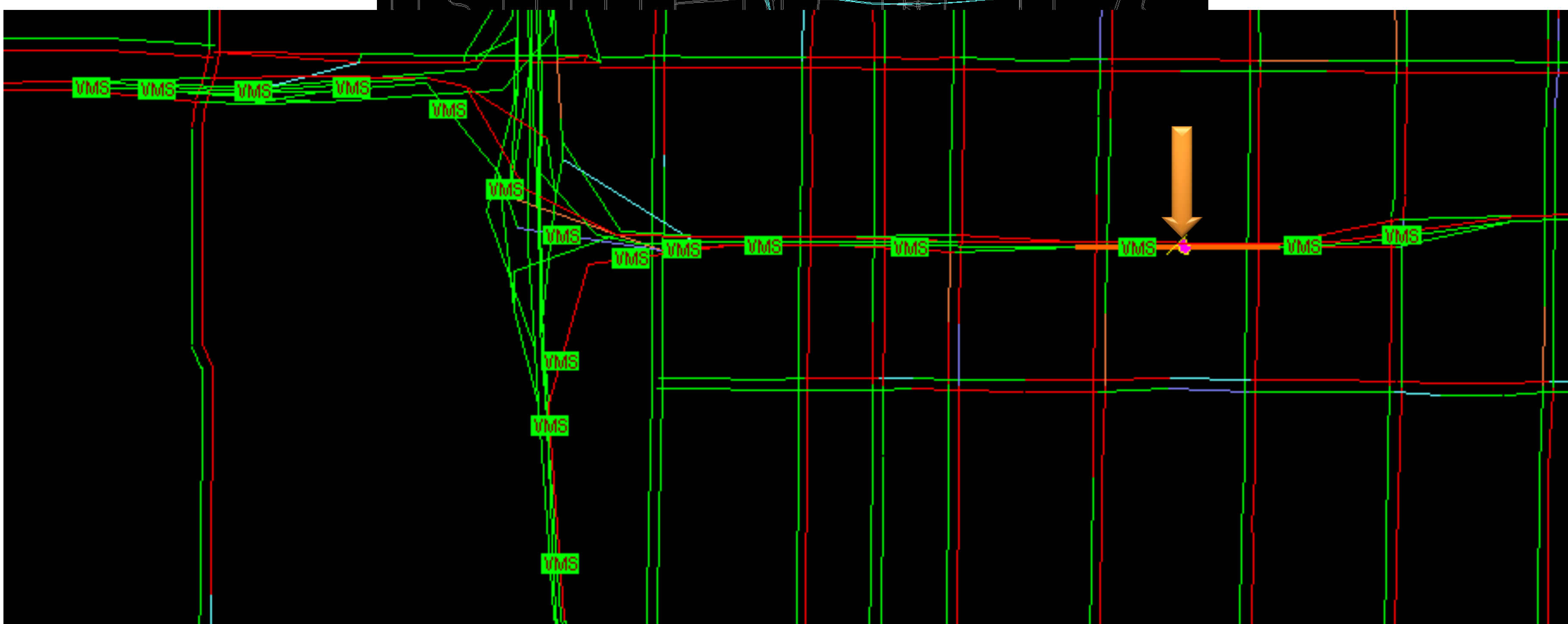
Heavy Snow with VMS – Detour

Heavy Snow with VMS – Variable Speed Limit



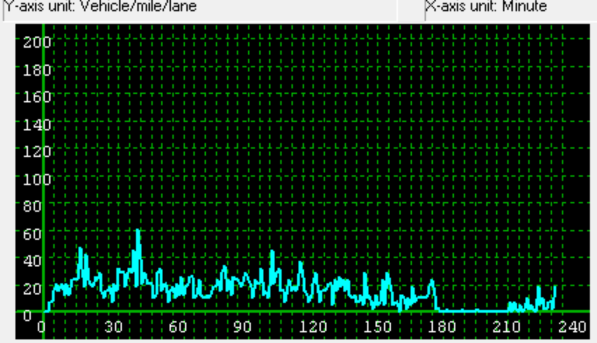
# A Closer Look: Link Densities and Speeds

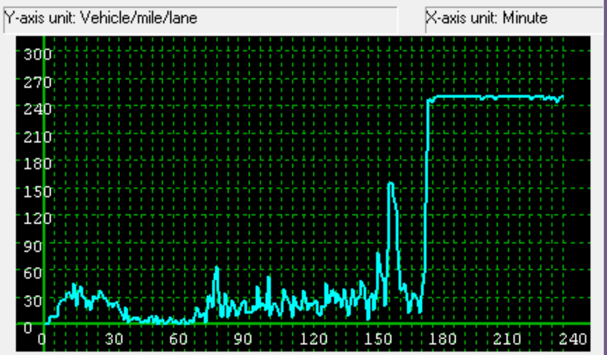


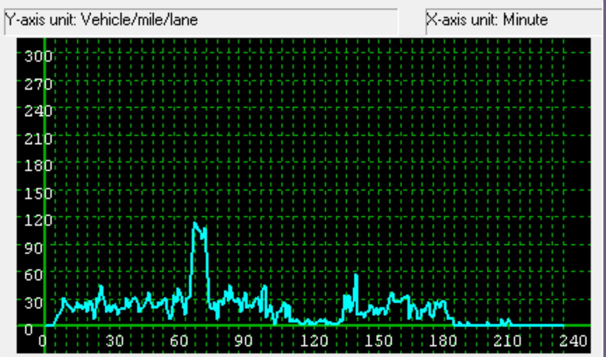


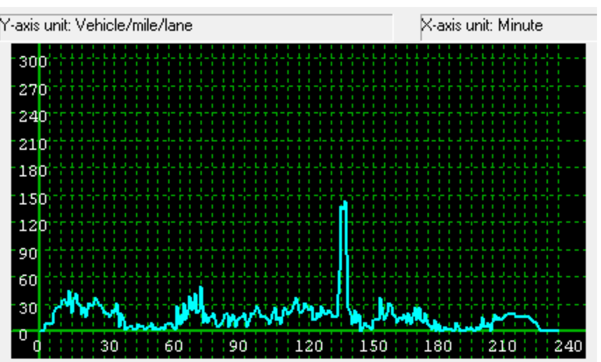
# Scenarios

**Densities**



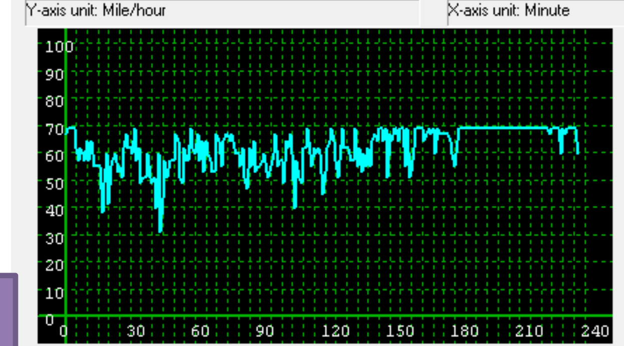

**Clear Day**

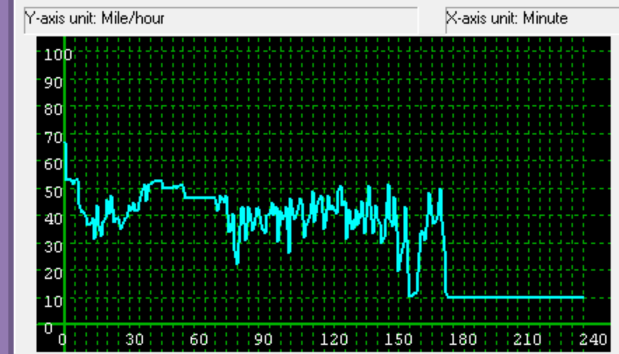
**Heavy Snow**

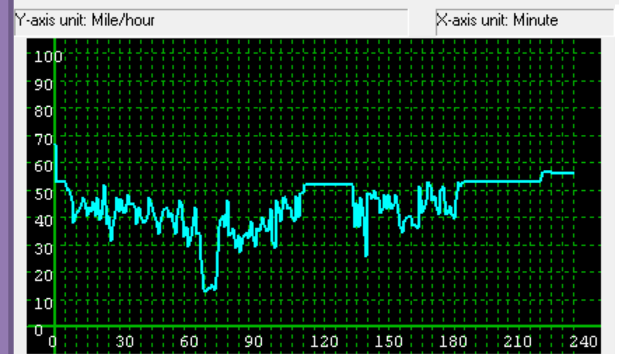
**VMS – Detour**

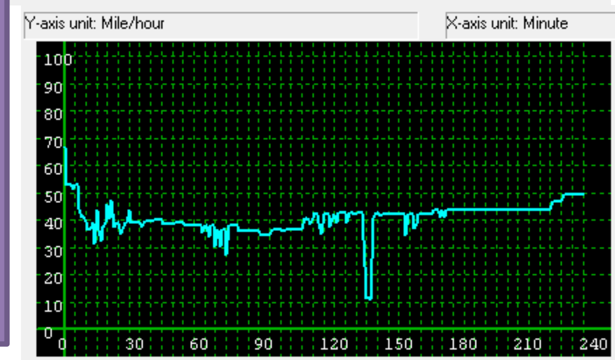
**VMS - VSL**

**Speeds**

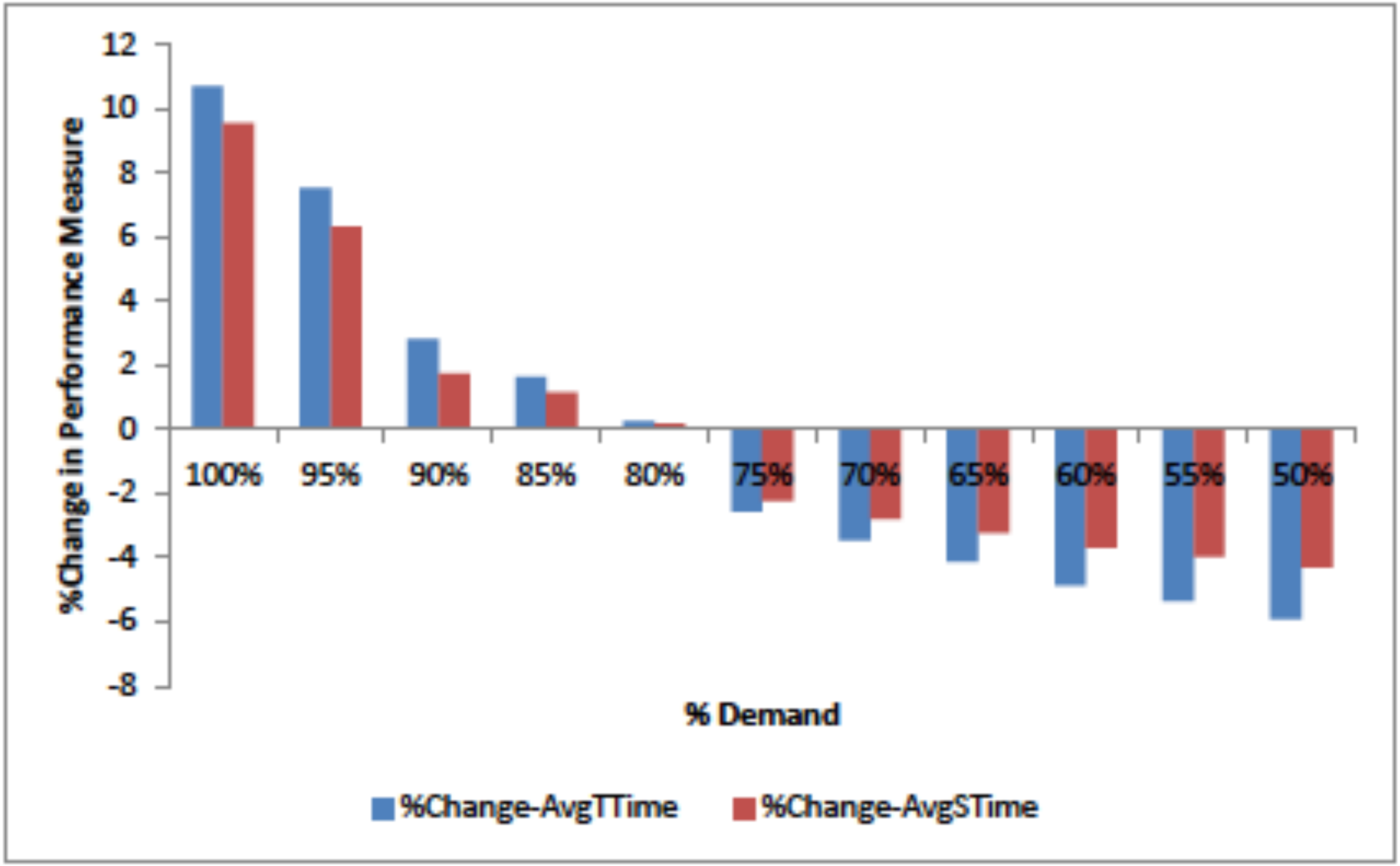


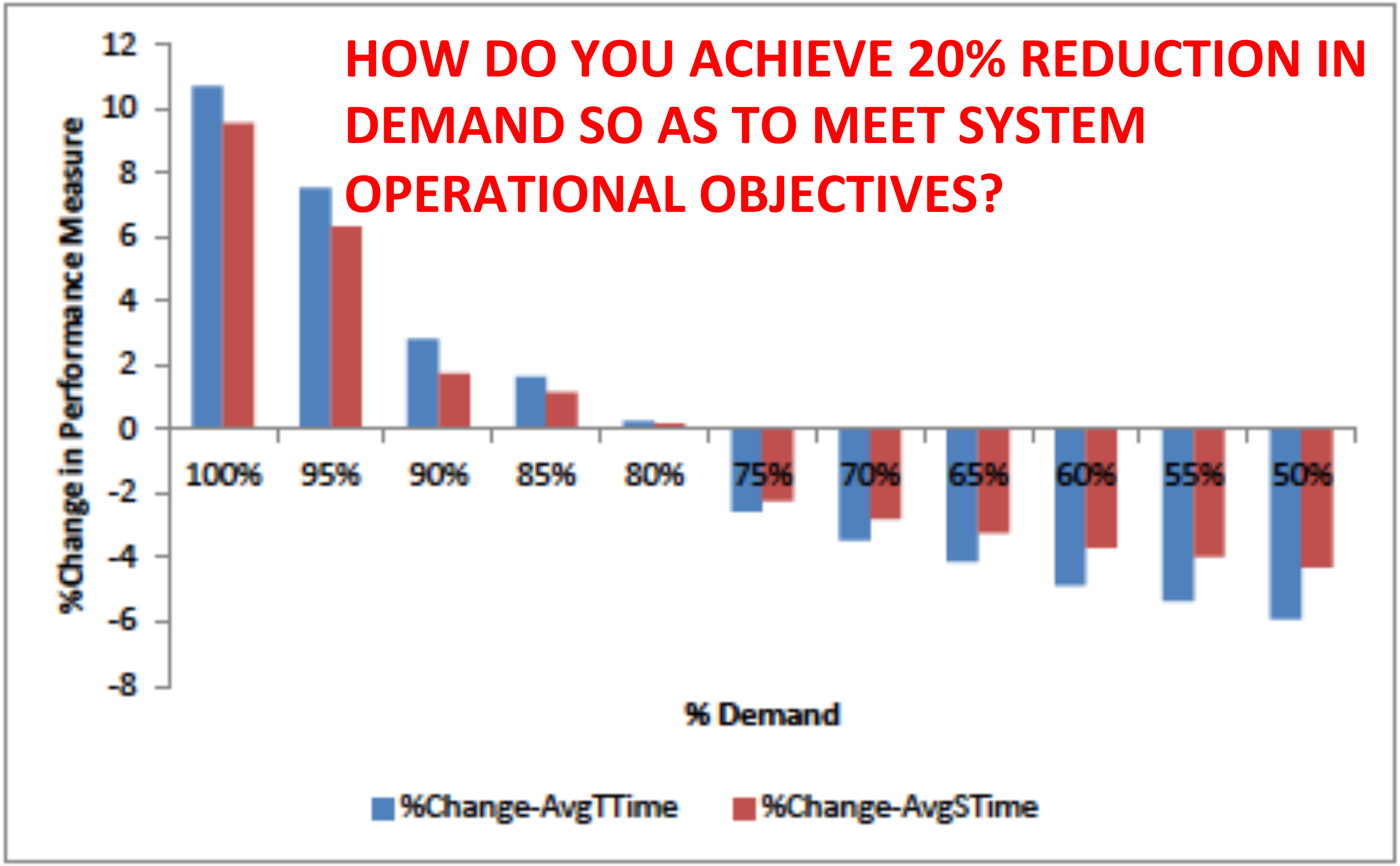



# SALT LAKE CITY: IMPACT OF PREDICTIVE WRTM DEMAND MANAGEMENT STRATEGIES DURING HEAVY SNOW DAY



# THE CASE FOR MODELING AND UNDERSTANDING BEHAVIOR IN TRAFFIC SYSTEM MANAGEMENT



# TWO BIG TRENDS IN INFORMATION SUPPLY

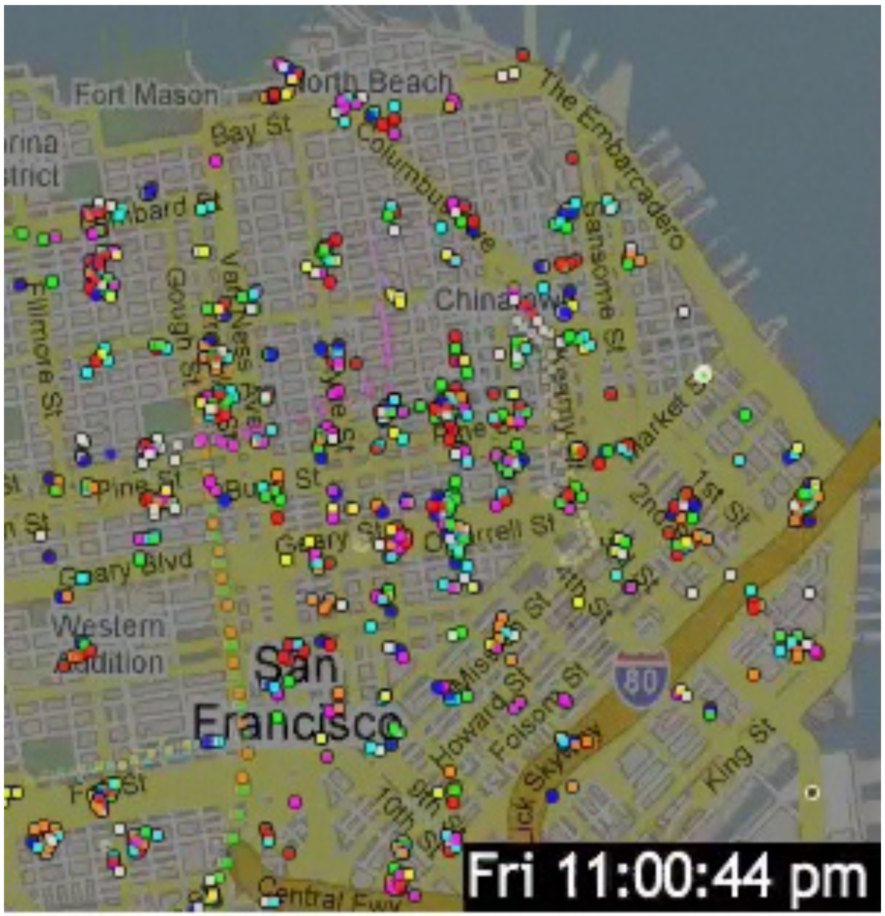
- PERSONALIZATION/CUSTOMIZATION:
  - Customized information specifically for user location and preferences ("*where is my bus?*")
  - *My* information, *My* preferences, *My* route, *My* location…
  - *My* experience, tracked for me
  - Special offers, just for *me* and *my friends*
- SOCIALIZATION:
  - Growing role of social media, and location-based apps (e.g. Google Latitude) (*"Where are my friends"?)*
  - I trust information I receive from my friends
  - I go where my friends are (or tell me to go)
  - Peer-to-peer and system connectivity will accelerate trend, and possibilities (M2M; "THE INTERNET OF THINGS")

**Major impacts on travel behavior beyond short-term route and departure time, still largely undocumented though evolving fast.**

Example: Sense Networks Inc.

## *Citysense*

Tracking cell phone signals
for social networking






Example: Google Inc.

## *Google Latitude*

Share your location with friends

# KEY DEVELOPMENT
# Handset Capabilities, Wireless Internet


**e-logistics**
**m-logistics**

**m-commerce**

# PERSONAL INFORMATION FOR GREEN TRAVEL CHOICES

COMMUTE GREENER!™
powered by Volvo

I-Phone App

Personalized information on handset

to assist commuters in understanding implications of different travel choices and provide advice for greener choices

The Home Screen

# USER RESPONSES TO REAL-TIME MULTIMODAL INFORMATON AND INTERVENTIONS

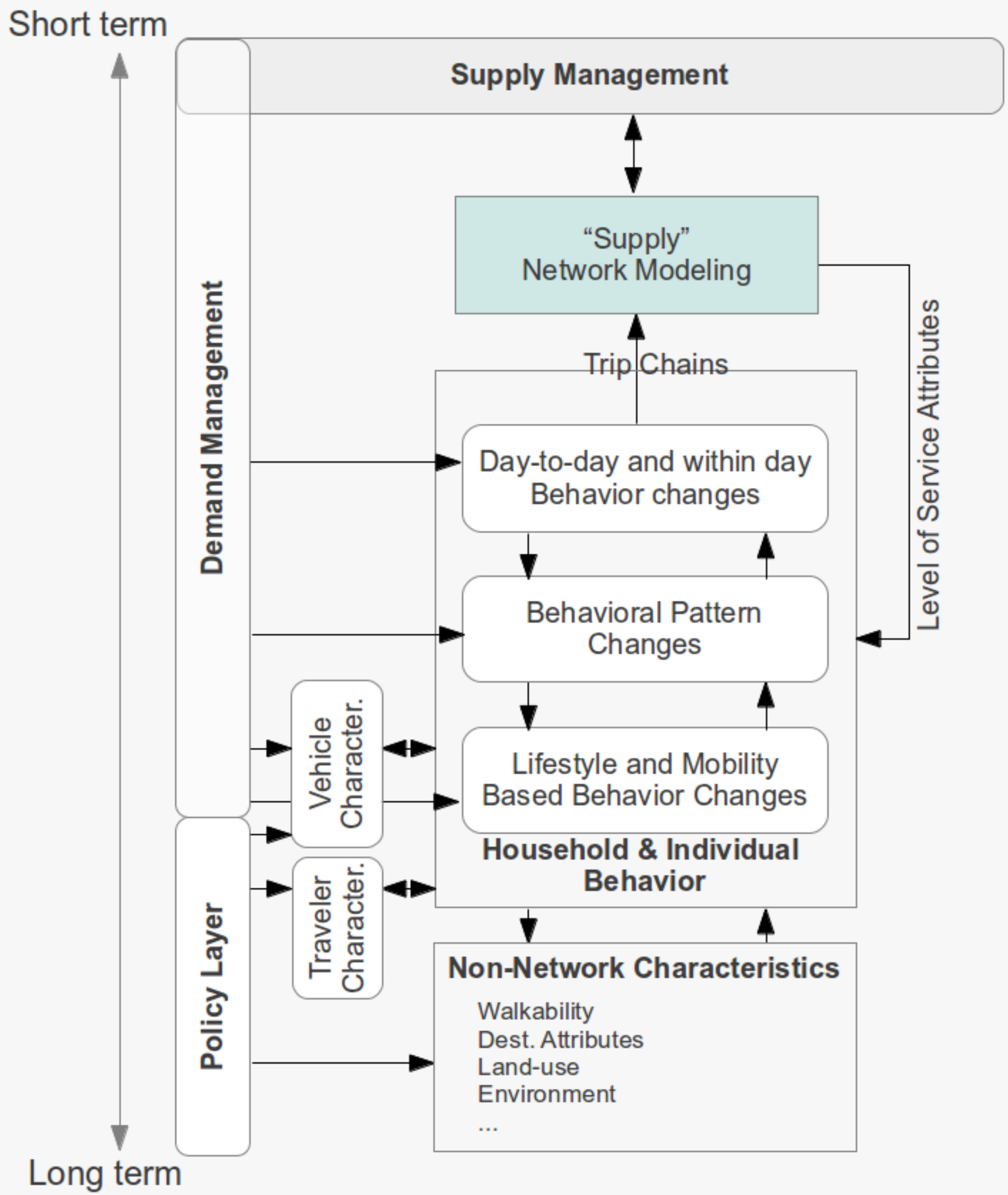
- **SHORT-TERM** (*Trip decisions*: within day and day-to-day)
  - Route changes
  - Departure times (advance, delay or postpone trip)
  - Destination (for non-work trips, e.g. shopping)
  - Mode
  - Chain activities
  - Cancel activity
- **MEDIUM TERM** (*Activity decisions*)
  - Route changes
  - Departure times
  - Destinations
  - Mode shifts and travel blending (includes carpooling)
  - Activity changes
- **LONG TERM** (*Mobility decisions*)
  - Mode shifts
  - Auto ownership
  - Location changes

# INTEGRATED USER RESPONSES IN A GENERAL FRAMEWORK

- Highly connected decisions, factors and attributes
- Complex system, integrated modeling and planning
  - Operational Interventions (dynamic, predictive, static)
  - Factors Affecting Behavior
    - Demographics & Household, Car availability, Transit pass, Alternative Mobility, Personal Networks, Network characteristics (LOS), Non-Network characteristics
- User responses:
  - Feedback effects
  - Different time frames
  - Endogenous “sphere” expands with time horizon and interventions

# Conceptual Framework

- Supply and Demand Management
- Linkage of Behavioral Influences



Day-to-day and Within Day Behavior/
Choices:
Route
Departure Time
Destination Choice
Mode Choice
Chain Activities
Cancel Activities

Behavioral Pattern Changes:
Mode Shifts
Travel blending
Activity Changes

Lifestyle and Mobility Decision based Behavior
Changes:
Trip Frequency
Trip Length
Mobility Tool Ownership
Location changes

+ information =

+ (compliance)
+ (inertia)

Decisions become more dynamic and have to be treated as endogenous in the model

Day-to-day and Within Day Behavior/
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# Key Questions for Modeling Community

- What is this “core”? What belongs inside?
  - How do daily behaviors become patterns and patterns become lifestyle choices?
- Where are the boundaries?
- Which factors and decisions interact to change these boundaries
- Which ones are worth studying, and how could they be observed?

# DOMAIN OVERVIEW

- Considerable research on short term responses, especially route, in both en-route and pre-trip settings
  - Much more on commuter work trips by auto than other trip purposes
  - Very little in-field research with advanced forms of information provision (which are only now in early stages of deployment, e.g. predictive information)
- Some work, on departure time and mode choice
  - Most based on stated preference
  - A couple of studies on destination adjustment in response to real-time information for discretionary (shopping) travel
- Response to traffic control information– VMS, weather-related management– limited to aggregate observation
- Much less research on impact of travel information on activity engagement on long-term mobility and location choices
- Even less research on how dynamic factors (information, control) interact with non-network factors (walkability, transit accessibility…)

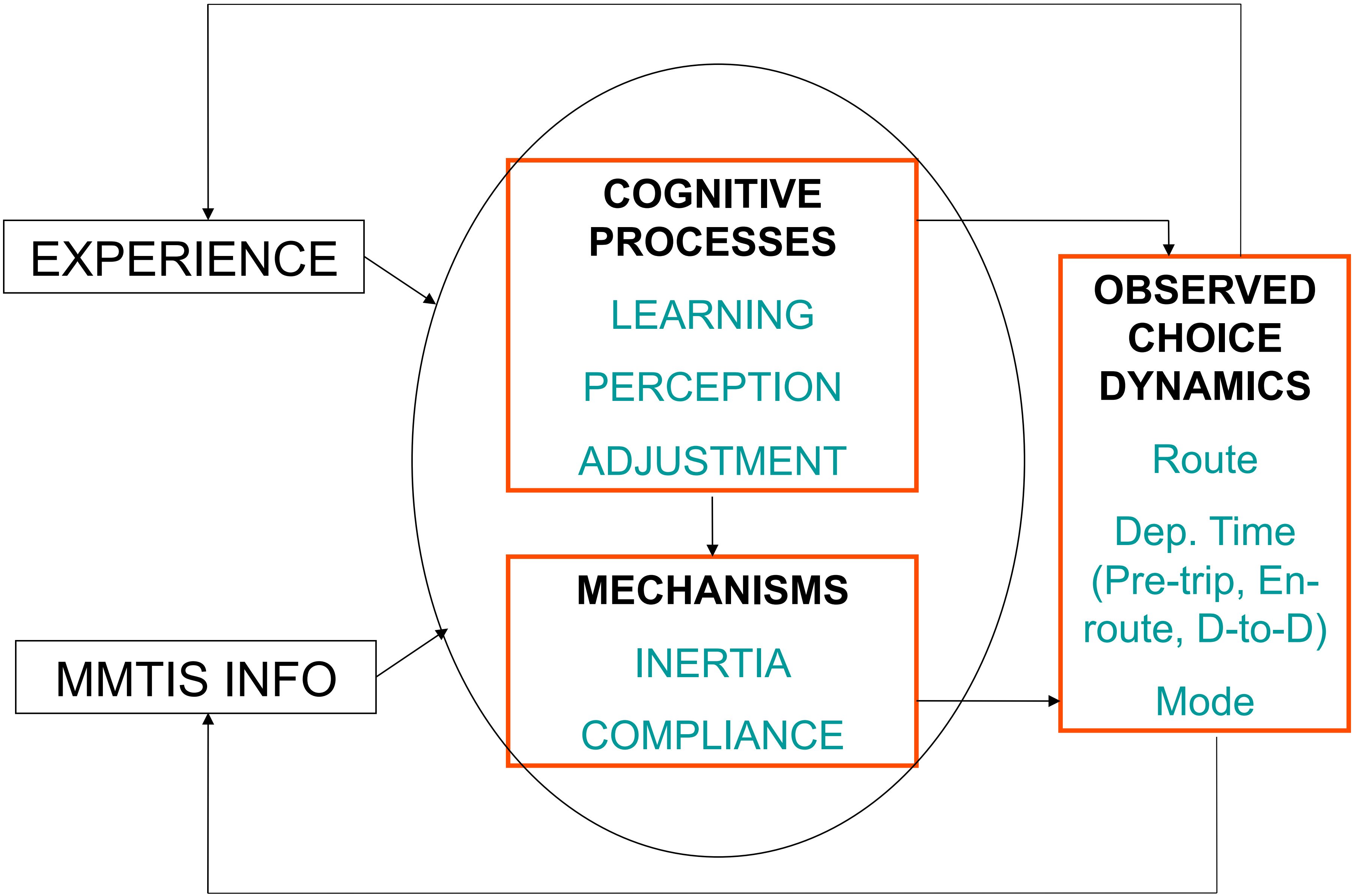
# METHODOLOGICAL CHALLENGES

- Impact of information on travel decisions poses considerable challenges in terms of measurement/ observation and modeling
  - Difficulty of measuring both traffic conditions, information actually supplied and consulted, and user responses
  - Learning effects and feedback:   adaptive behavior, moving target
  - Elusive steady-state: critical role of dynamics
- Revealed preferences vs. stated preferences
  - Difficult to obtain revealed preferences (*what people actually do*)
  - Several studies relied on recall (*what people say they did*)– do people really remember relevant details for such decision situations?
  - Stated preferences (*what people say they would do* under hypothetical scenarios) primary means for studying impact of information– concern about reliability of responses
- Role of laboratory and virtual experiments; experimental economics
- **Personal devices and GPS tracking to collect information**

# INFORMATION DIMENSIONS

- Recency
- Relevance
- "Accuracy"– objective vs. perceived
- Static vs. dynamically updated
- Generic vs. personalized
- Prevailing vs. predictive
- Action-oriented (guidance) vs. state-descriptive
- Mandatory vs. discretionary actions
- Final vs. amenable to query
- Free vs. paying (subscription vs. per-use)

# DYNAMIC PROCESSES IN USER BEHAVIOR



# COGNITIVE DECISION PROCESSES

# UNDERLYING COMMUTER BEHAVIOR DYNAMICS

- Learning
  - discriminative and trial and error learning
  - role of memory
- Perception and attitudinal factors
  - margin (12%) added to accommodate uncertainty
  - attitudes towards trip time savings and congestion affect choice
- Judgment of information quality
  - predicted - highest, random - lowest
- Updating perceptions
  - reported information weighted more than past perception in random treatment
  - weights: 2/3 (sequential case) to 8/9 (random evolution)

# MEDIUM AND LONG TERM ADJUSTMENTS

Studies of these traveler choice dimensions, in response to traffic information, are generally missing from literature, for both theoretical and applied aspects.

However, new social science and marketing contributions on role of mobile information (in general) and connectivity on various aspects of activity engagement.

# Telemobility and Activity Engagement

- Internet as *end activity* in its own right
- Internet with wireless as *enabler* of wide realm of activities and social engagement
- Internet + mobility → **TELEMOBILITY**

May entail changes in:

- Nature of the activities themselves (doing what?)
- Location/spatial characteristics of the activities
- Social dimensions of the activities (with whom and where they might be?)
- Process of activity generation and scheduling: more dynamic (real-time) activity generation and scheduling; less pre-planning, more spontaneous (e.g. through SMS)

# FROM STATUS INFORMATION TO TRAFFIC MANAGEMENT

- ROLE OF PREDICTION
  - Requires predictive capability for travel time information: Anticipatory information
- Provision of reliability information increases information effectiveness for both users and system management objectives
- Need to combine traffic prediction with forecasts of external factors (such as weather)
  - Primarily in response to unexpected disruptions
  - In case of severe weather, where trip may be altogether cancelled on given day
  - Studies based primarily on stated preferences

# THE SWEET SPOT FOR SYSTEM MANAGEMENT

- Leverage system state information and individual characteristics (and preferences) in generating interventions that are

  - dynamic (timely)
  - localized (consider network and non-network factors)
  - anticipatory (consider predicted events and system evolution)
  - adaptive (learn about individual responses and system impacts)
  - distributive (across modes, times of day, user groups)
  - economically efficient (e.g. consider value of time distribution)

Influencing Behavior

# Persuasive Technology

- Interactive computing products created for the purpose of changing people's behaviors
  - Goal setting
  - Feedback

- Exampe: Ubifit

Consolvo, et al., 2008

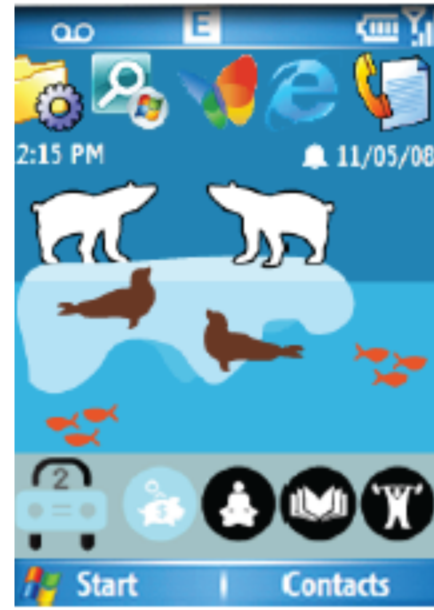

**Figure 2. Garden mappings and two sample gardens.**


**Figure 1. UbiFit Garden's Glanceable Display.** a) at the beginning of the week; b) after one cardio workout; c) a full garden with variety; and d) a full garden on the background screen of a mobile phone. Butterflies indicate met goals.

Slide courtesy of Joan Walker

## Influencing Behavior

# Persuasive Technology




- Ubigreen (Froehlich et al., 2009)
  - tracked $C0_2$ from transportation

Slide courtesy of Joan Walker

**Nudging Behavior**

# Quantified Self

- Applications that
  - Record behavior
  - Process data
  - Feed it back
- Goals
  - Better understand patterns
  - Adapt behavior more intelligently
- Examples
  - Fitness
  - Mood
  - Sleep
  - Spending habits




Slide courtesy of Joan Walker