Evaluation of Cooperative Adaptive Cruise Control (CACC) Vehicles on Managed Lanes Utilizing Macroscopic and Mesoscopic Simulation

(Recipient of Top Student Paper Award)

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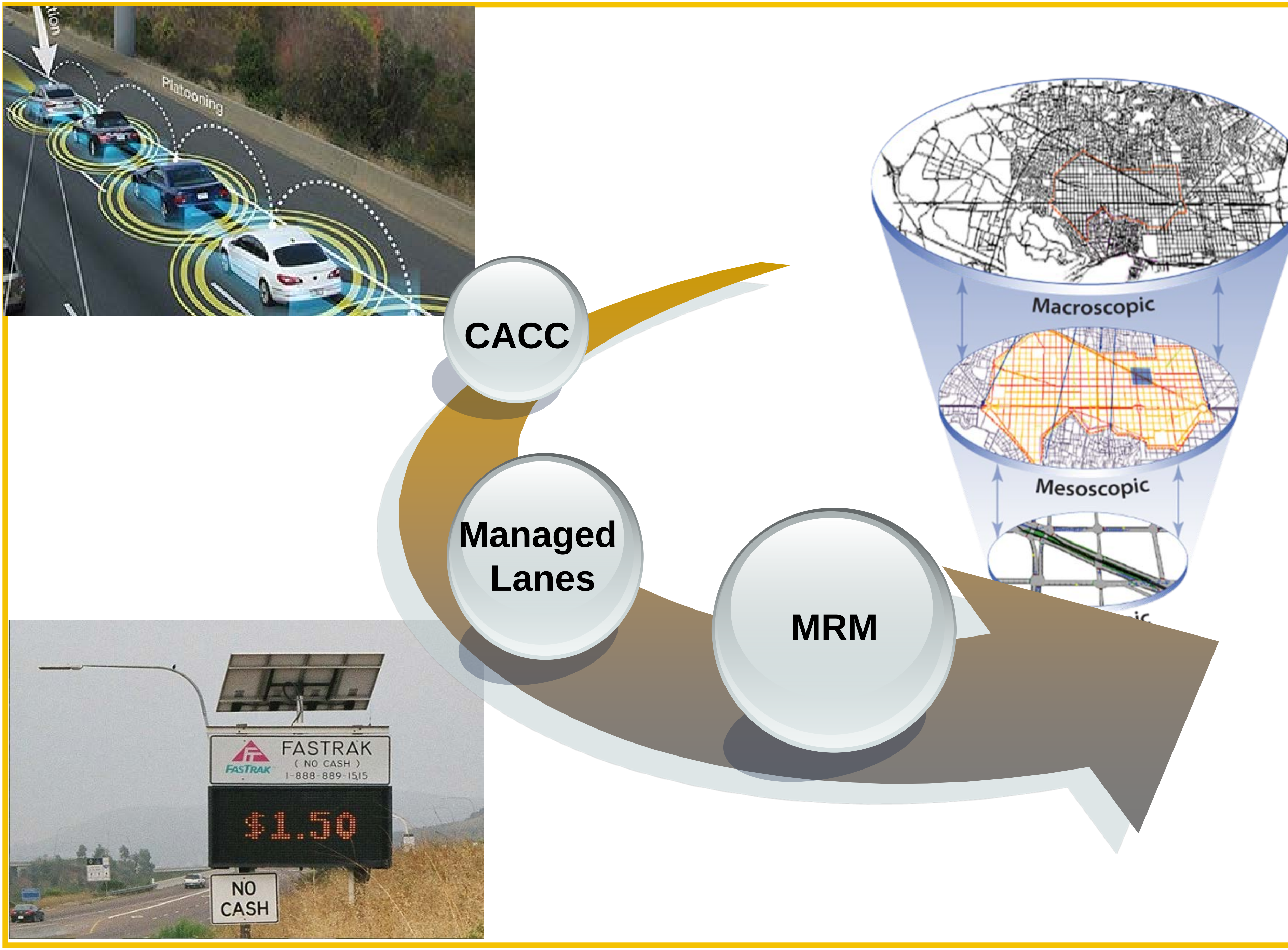
Research Contents



Platooning
CACC
Managed Lanes
MRM
Macroscopic
Mesoscopic
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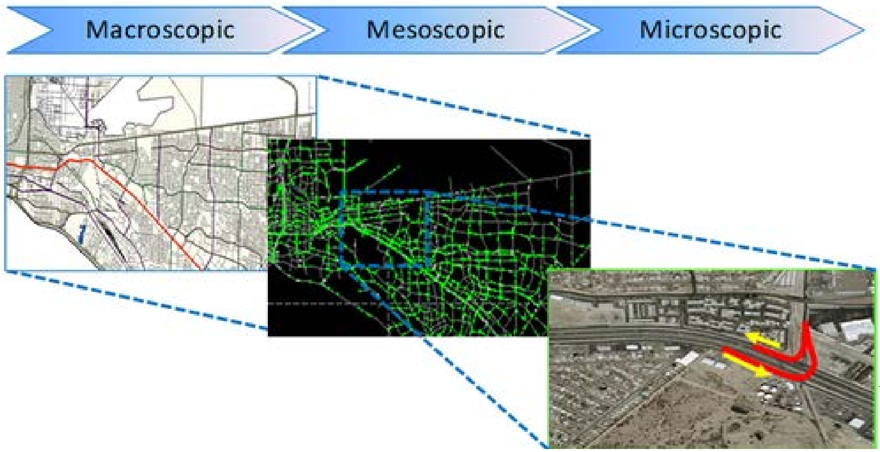
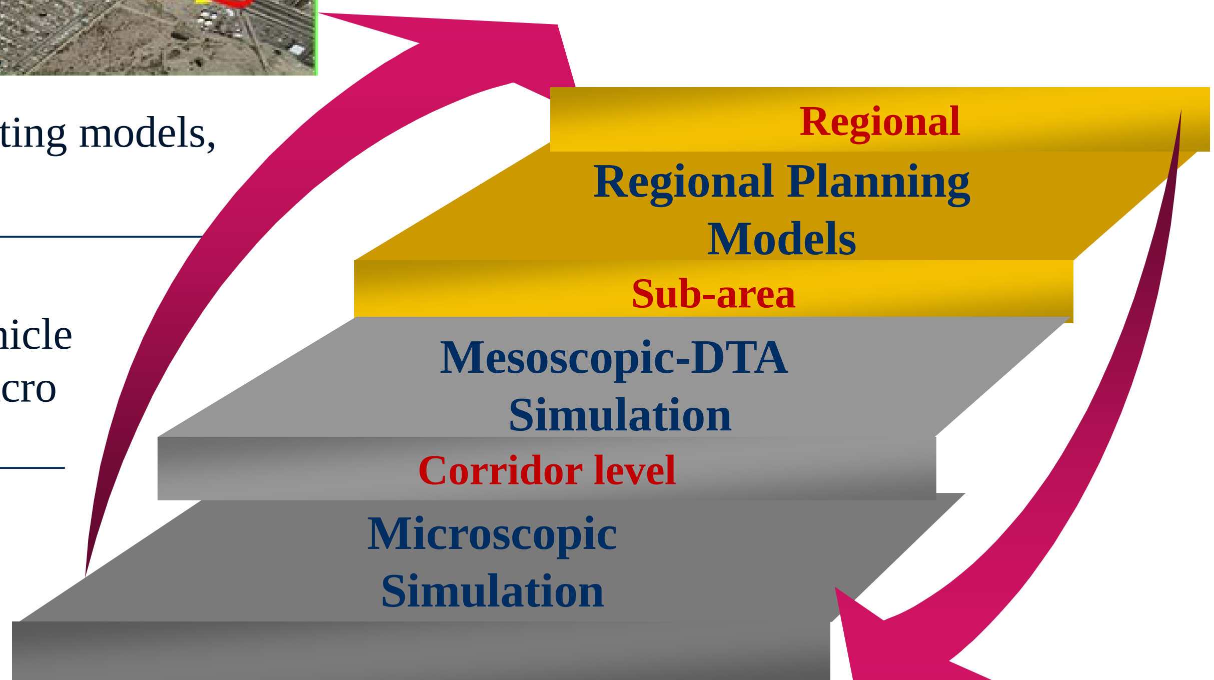
Multi-Resolution Modeling (MRM)



Static, initial demands, forecasting models, Traffic Flow Model (TFM)

Dynamic, Time varying paths, dynamic O-D or individual vehicle trips, dynamic equilibrium, macro TFM

Dynamic, individual vehicles car following, lane changing, gap acceptance



Multi-Resolution Modeling (MRM)

Definition:

- **Integrating different tools with different levels of modeling**
- **Maintaining the consistency between different levels of modeling**

Applications:

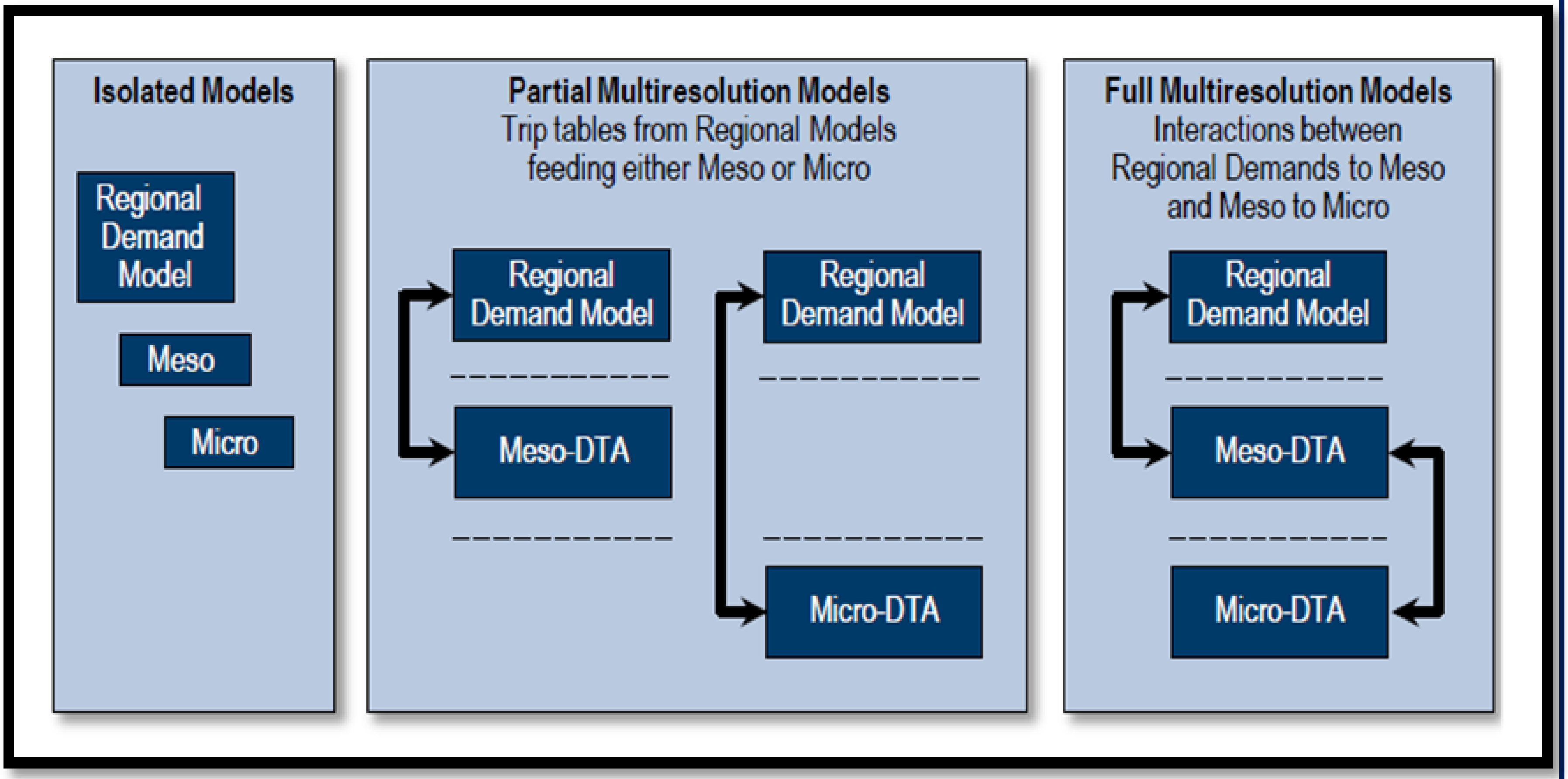
- **Advanced ITS strategies such as :**

Managed Lanes (ML), smart work zones, incident management, freight corridors, and integrated corridor management

Levels of Modeling:

- **Macroscopic simulation**
- **Mesoscopic simulation**
- **Microscopic simulation with or without DTA**

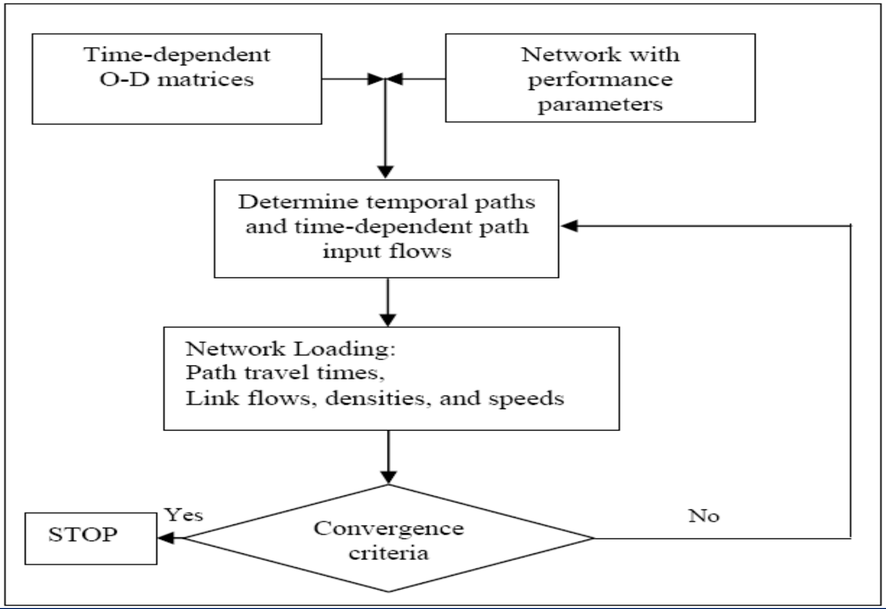
Multi-Resolution Modeling (MRM) Structure



(FHWA. 2012)

Utilizing of Static Traffic Assignment (STA) for Managed Lanes

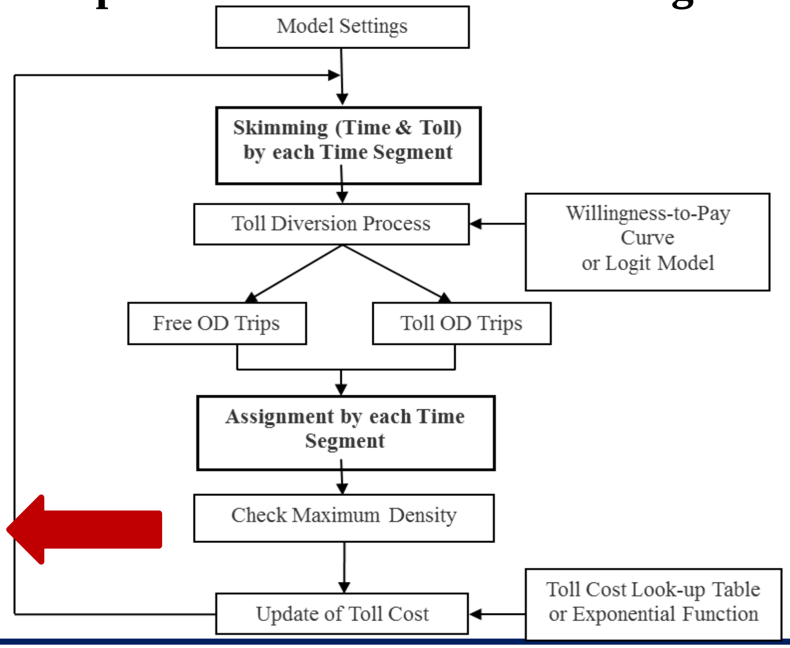
- **Time-fixed O-D matrices**
- **Analysis of advanced ITS strategies such as ML and fixed pricing require simulation based STA**
- **Fixed Value of Time (VOT) and generalized cost function for ML modeling**
- **Combination of macroscopic and microscopic simulation for CACC modeling**



Utilizing of Dynamic Traffic Assignment (DTA) for Managed Lanes

- **Time-dependent O-D matrices**
- **Analysis of advanced ITS strategies such as ML and dynamic pricing require simulation based DTA**
- **Need to consider dynamic pricing and associated traveler responses**
- **Dynamic density function and willingness to pay for different toll values**
- **Consideration of various capacity and queue spillback effects after each assignment iteration for different vehicle types**

Level of Service	Road Density (veh/mi/ln)		Toll Cost ($)	
	Minimum	Maximum	Minimum	Maximum
A	0	11	0.5	0.5
B	12	18	0.5	1.5
C	19	26	1.5	8.5
D	27	35	8.5	9.5
E	36	45	9.5	10.5
F	>45		10.5	10.5

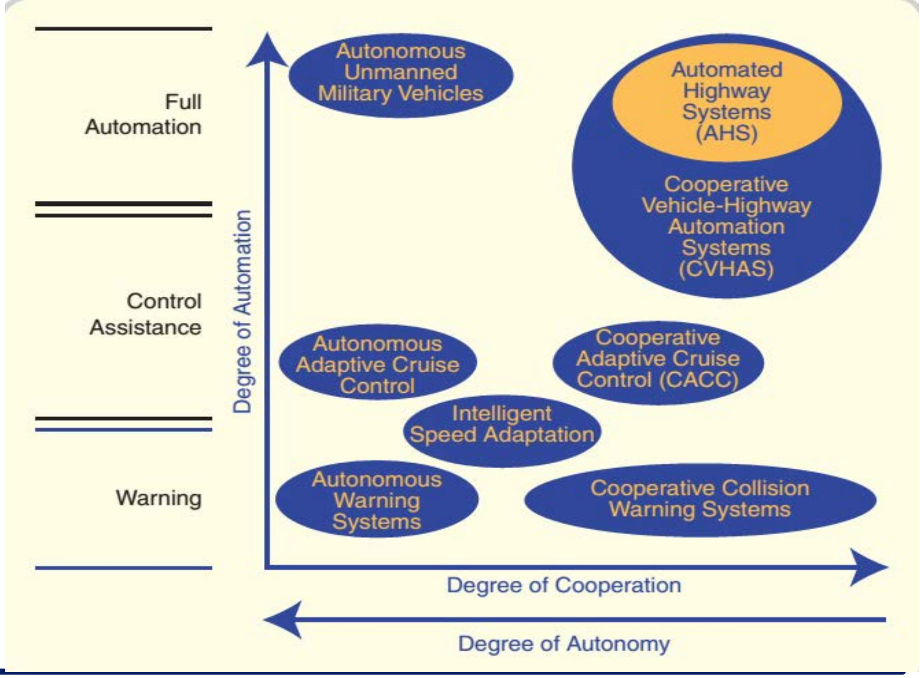


Cooperative Adaptive Cruise Control (CACC)

- **Examples of Connected Vehicle (CV) explored in this study**
- **ACC is Automotive feature that allows a vehicle′s cruise control system to adapt the vehicle′s speed to the traffic network.**
- **CACC involves Adding a wireless vehicle−vehicle Communication (V2V) to ACC.**
- **Gap size and impacts on capacity**

  ACC vs. CACC

  Size of platoon
- **Microscopic simulation**



Goals and Objectives

- **To estimate the mobility impacts of CACC vehicles on ML**
- **To apply different levels of modeling (Multi-Resolution Modeling) in ML facilitates**
- **To assess the different levels of modeling, separate or in combination in modeling of ML facilities**
- **To estimate the impacts of preferential treatment of CACC vehicles in setting ML pricing schedule**
- **To assess the different market penetrations of CACC on ML modeling**

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Methodology

TRB

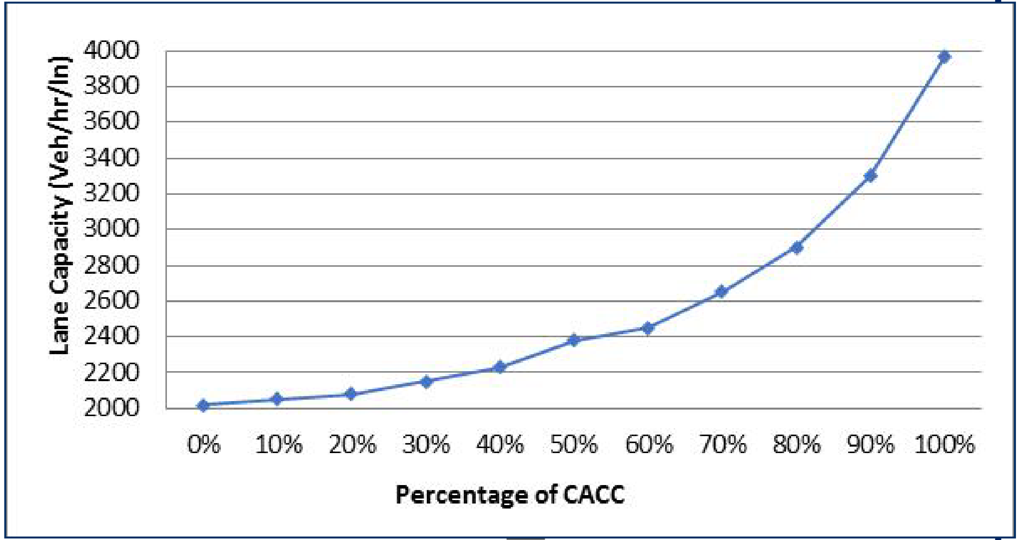
- **Application Multi-Resolution Modeling (MRM) on ML strategies**
- **Estimated capacity based on microscopic simulation for different market penetration of CACC from Shaladover et al (2012)**
- **Utilizing estimated capacity for different market penetration of CACC into static assignment and dynamic traffic assignment**
- **Utilizing Cube Voyager for macroscopic ML modeling and Cube Avenue for mesoscopic ML modeling**
- **Development of Cube script language for simulation of CACC based on macroscopic and mesoscopic simulation**
- **Analyzing of different schedule pricing for different market penetration of CACC.**

Microscopic Simulation

- **Capacity Estimation for freeway facilities**
- **Shladover et al (2012), Field data , size of platoon**
- **Car following, gap acceptance, acceleration, and deceleration**
- **Desired time gap selected by drivers:**
  - **CACC: 12% at 1.1 sec, 7% at 0.9 sec, 24% at 0.7 sec, and 57% at 0.6 sec.**

Data needed:

- Time gap
- Acceleration, deceleration
- Road capacity for 100% manually driven
- Different market penetration of CACC



Estimated Capacity for Different Market Penetration of CACC (Shladover et al, 2012)

Macroscopic Simulation

- **Static Assignment (STA)**
- **Time-Fixed demand matrices (factored OD matrices)**
- **Fixed toll cost and value of time**
- **The toll cents per minute saved:**

$$= \frac{\text{Total toll cost (cents) for toll route}}{\text{Free route time (min)} - \text{Toll route time (min)}}$$

- **Different capacity based on different percentage of CACC on ML**

Data needed:

- Fixed toll cost ($)
- Calibrated lane capacity based on ODME
- Capacity for different percentage of CACC based on microscopic simulation

Mesoscopic Simulation

- **Dynamic Traffic Assignment (DTA) based on time-dependent demand matrix (15 minutes time interval)**
- **Dynamic pricing schedule based on density Function**
- **Varying Capacity for different market penetration of CACC based on Microscopic Simulation**

Data needed:

- Toll policy for ML route
- Dynamic toll values based on different density
- Calibrated lane capacity based on ODME
- Capacity for different percentage of CACC based on microscopic simulation

Level of Service	Road Density		Toll Cost ($)	
	Minimum	Maximum	Minimum	Maximum
A	0	11	0.25	0.25
B	12	18	0.5	1.25
C	19	26	1.5	2.75
D	27	35	3	3.75
E	36	45	3.75	6
F	>45		6	7

Default Toll Values Based on the ML FDOT District 6 Policy

Performance Measurements

Percentage of ML Share

- **To calculate percentage of diverted volume to ML :**

$$= \frac{\text{Total volume entered to ML}}{\text{Total volume entered to ML+Total g volume enter to corresponding General urpose Lane(GPL)}}$$

Speed of Bottleneck

- **To calculate speed of bottleneck:**

$$= \frac{\text{Link Length (mi)}}{\text{Travel time at upstream of bottleneck (hr)}}$$

Toll Value

- **Model output function density and VOT depends of level of assignment**
- **Based on different discount scenarios for CACC vehicle n ML**

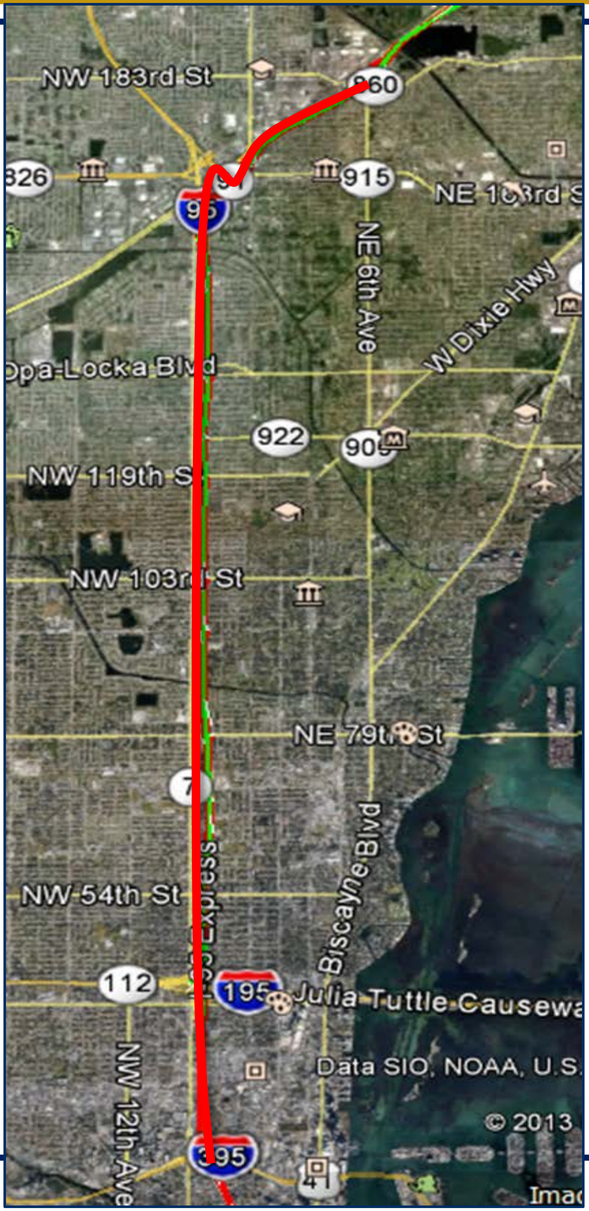
Levels of Simulation:

- Macroscopic(STA)
- Mesoscopic (DTA)

Case Study

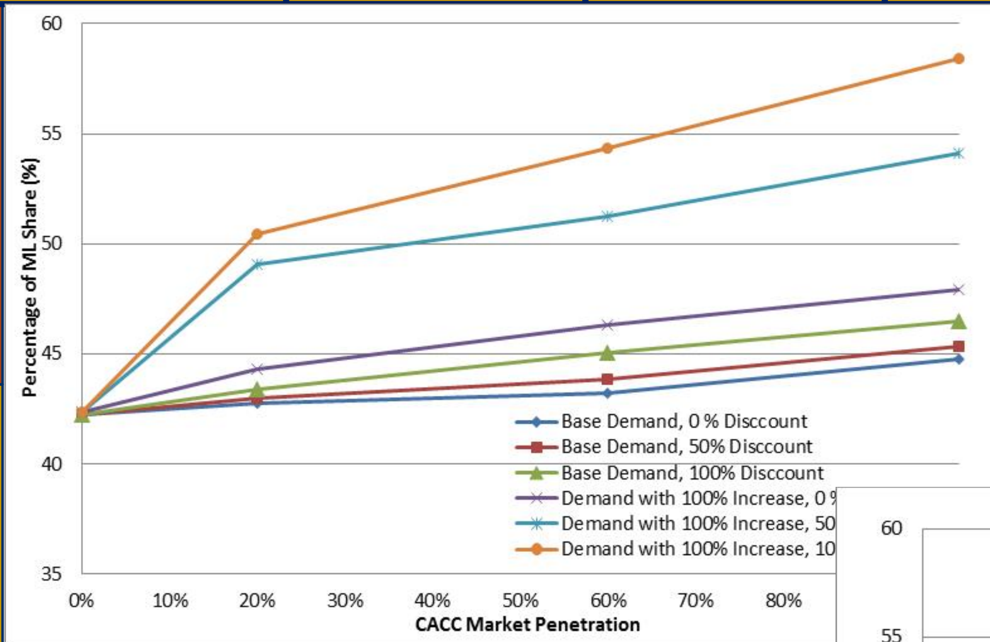
Exploration Network:

- Regional demand forecasting model, SERPM 6.5
- I-95 freeway corridor in Miami
- 288 nodes, 303 links and 57 zones
- 3 hours in the PM peak
- Calibrated by Hadi et al (2014)



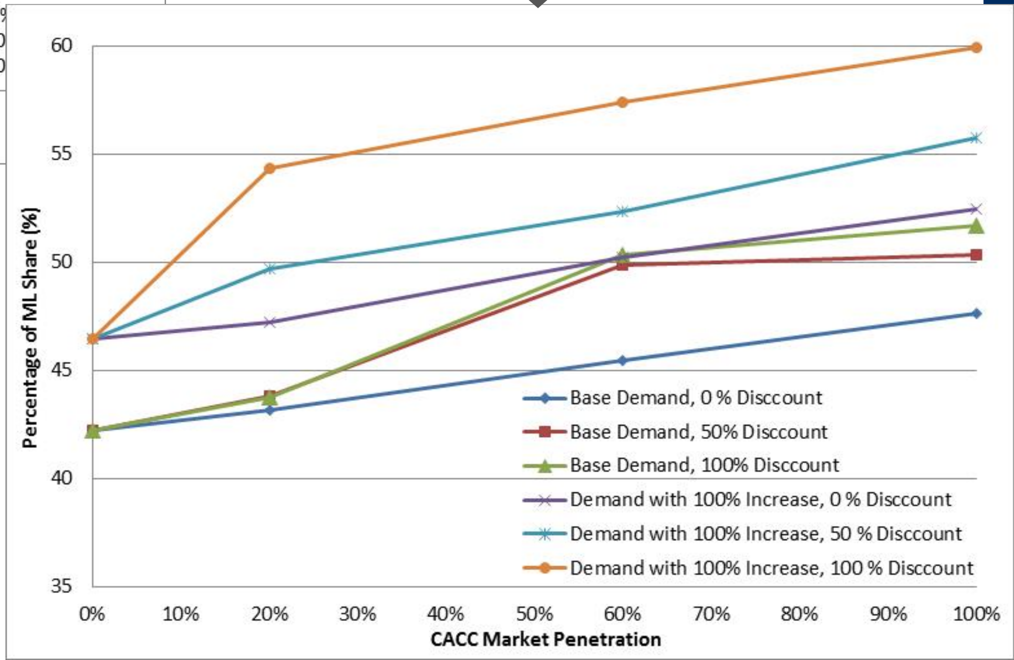
STA: Cube Voyager
DTA: Cube Avenue

Performance Measurements



Variation of percentage of ML share, STA

Variation of percentage of ML share, DTA



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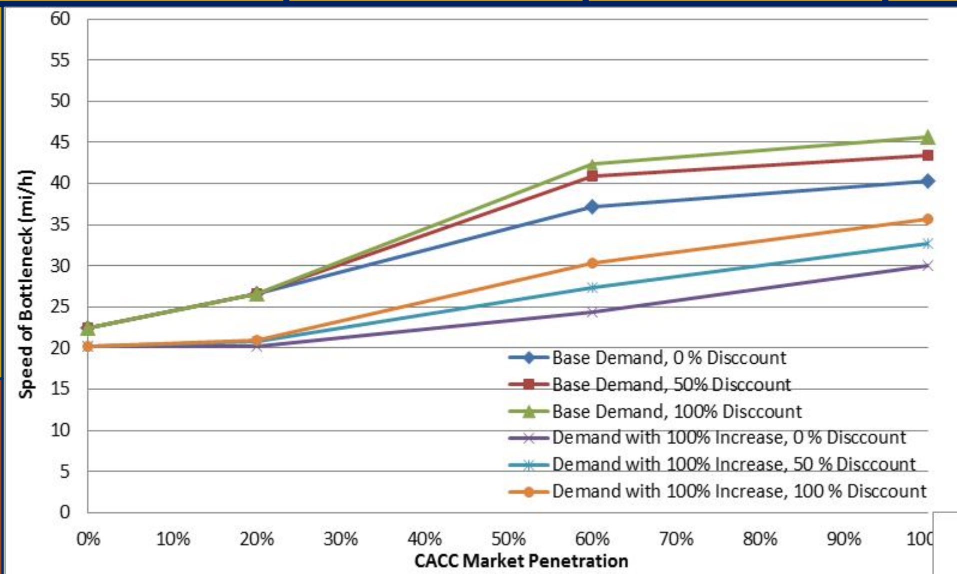
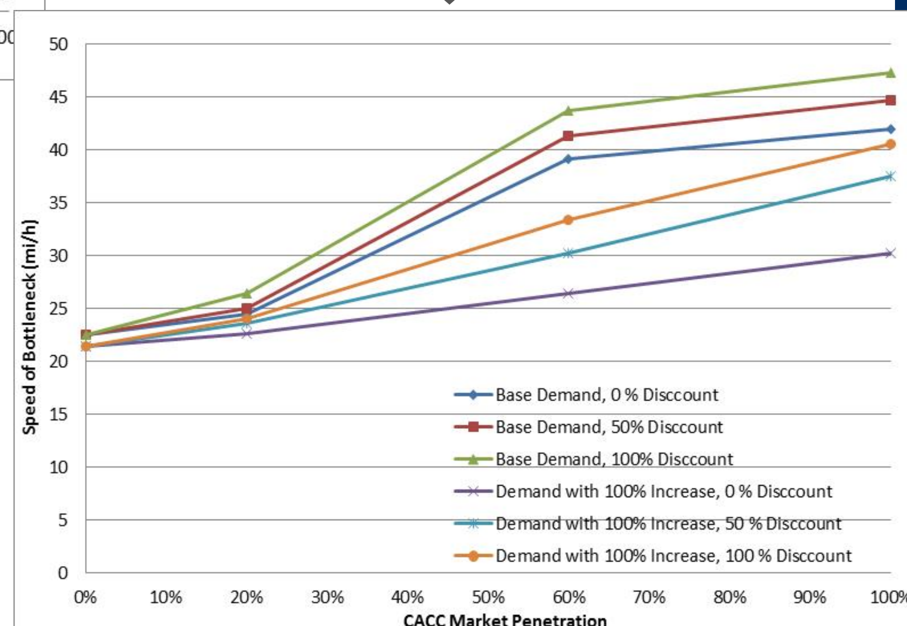
Performance Measurements



Variation of speed at bottleneck location , STA

Variation of speed at bottleneck location , DTA



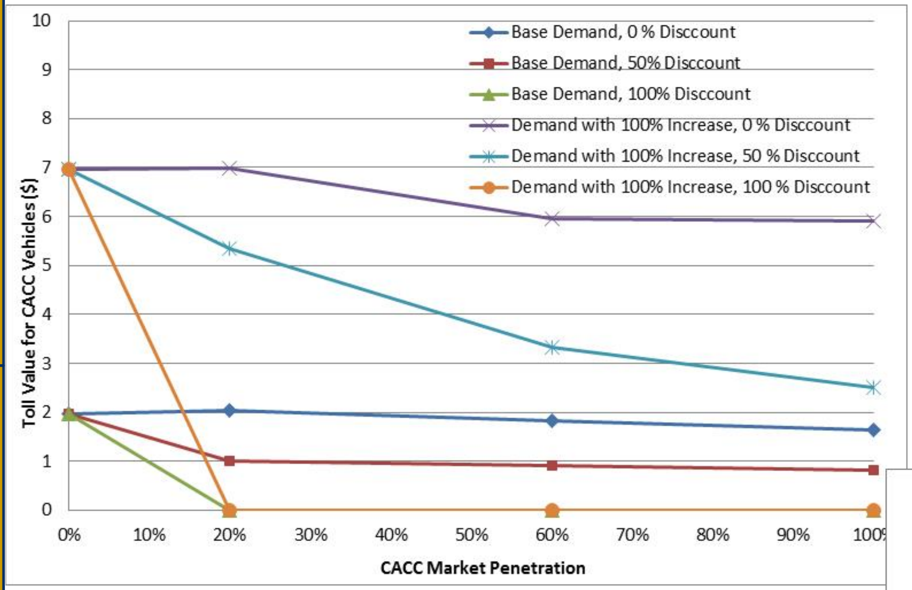
Performance Measurements

Introduction | Objectives | Methods & Tools | Case Study | Results | Conclusions

Diverted Volume ML

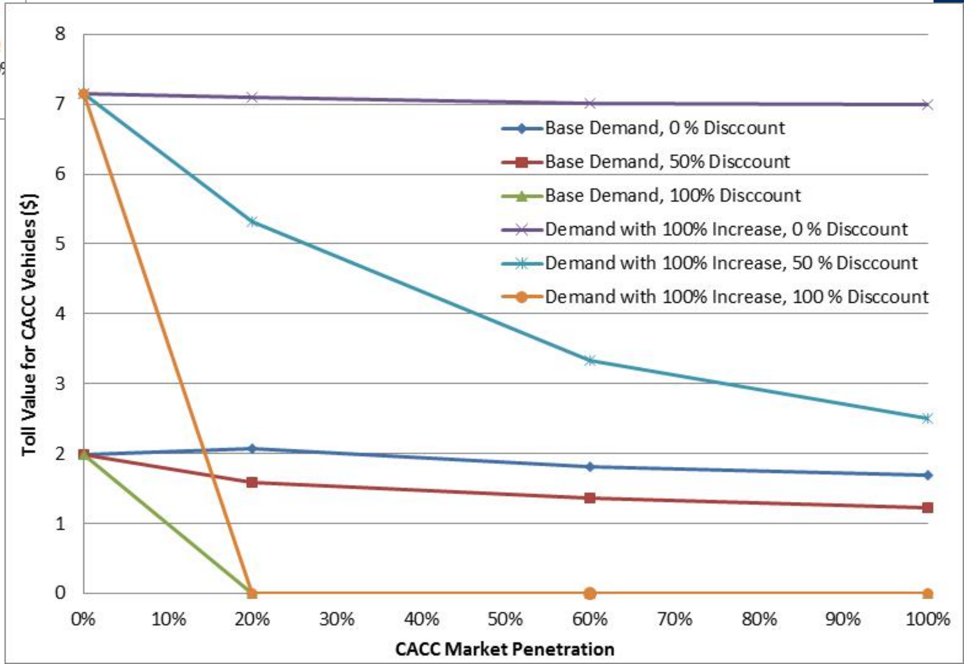
Speed of Bottleneck

Toll Value



Variation of toll values for CACC, STA

Variation of toll values for CACC, DTA



Conclusions

- **General trends of obtained based on results from the STA modeling of CACC in terms of the reduction in congestion on General Purpose Lanes (GPL) are consistent with those obtained from DTA**
- **DTA results show more significant shifts due to its better modeling of traffic congestion**
- **Toll incentives for Cooperative Adaptive Cruise Control (CACC)-equipped vehicles is not beneficial at lower market penetration due to the small increase in capacity**
- **Analysis of CACC on advanced ITS strategies such as ML and dynamic pricing require combination of different levels of modeling**

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Contributions

TRB

- **Explore the effectiveness of different resolutions of modeling when used separately and in combination**
- **Show how MRM can be used to answer questions related to existing and advanced strategies to improve system performance**
- **Utilizing different levels of modeling (STA and DTA) in ML modeling**
- **Apply an effective MRM approach to assess the operations of ACC and CACC on ML with different incentives (preferential treatments), pricing strategies, and access restrictions**

Thank You !