A Coordinated Control System for Emergency Evacuation

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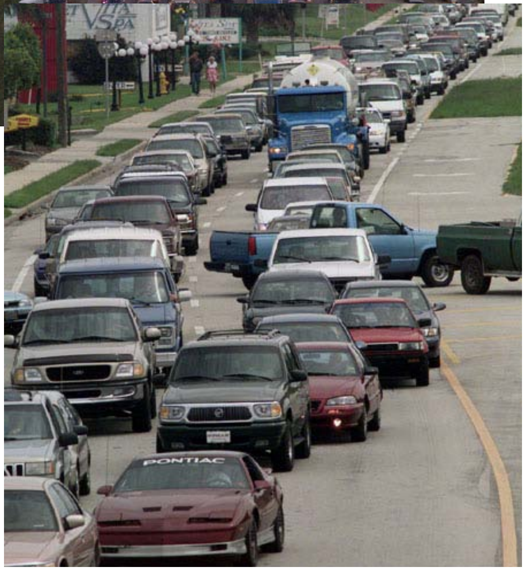
Introduction: Motivation/Objective/Approach

Framework:
- Extreme Conditions
- Multi-Level Modeling Prospect
- Modeling VS Execution

Formulation
- Control Strategies
- Coordination via Critical Path

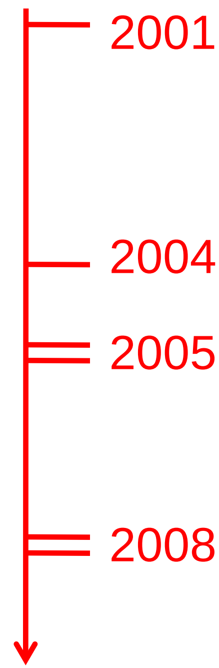


Case-Study:
- Evacuation VS Equilibrium
- Network Characteristics
- Exploration of Results

Conclusions and Future Research Needs

Motivation:

Some Recent Extreme Condition	Date	Countries Affected
New York September Attack	September the 11th, 2001	United States
Indian Ocean Earthquake/Tsunami	December the 26th, 2004	Indonesia
		Sri Lanka
		India
		Thailand
		Somalia
		Myanmar
		Malaysia
London Bombing	July the 7th, 2005	England
Hurricane Katrina	August the 29th, 2005	United States
2008 New York Explosion	March the 6th, 2008	United States
Iowa/Wisconsin Flooding	June, 2008	United States



Motivation:

By definition, traffic engineers can contribute effectively by providing effective control strategies for a safe arrival of individuals to destination zones:

- Practical (easy to implement/build and use)
- Dynamic
- Coordinated

Objective:

To offer a dynamic integrated control strategy that can respond in real-time to changes in demand and supply flows during extreme conditions.

Approach:

- Modeling
- Calibration (corresponding case-study)
- Simulation → Implementation

Framework

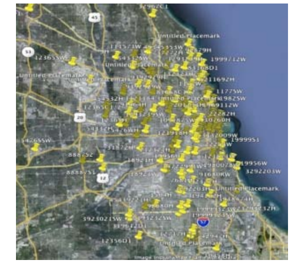
Hamdar and Mahmassani, 2008

Extreme Conditions

Extreme Condition	Urgency of Evacuation	Control Measures	Predictability
Extreme Heat	Low	Moderate	Moderate
Extreme Cold	Low	Moderate	Moderate
Heavy Rain	Low	Moderate	Moderate
Heavy Snow	Moderate	Moderate	Moderate
Floods	High	Low	Low
Hurricanes	High	Low	High
Tornados	High	Low	Low
Typhoons	High	Low	High
Fires	High	Moderate	Low
Earthquakes	Moderate	Low	Low
Volcano Eruptions	High	Low	Low
Tsunami Waves	High	Low	Low
Meteorites	High	Low	Low
Accidents	Low	High	Low
Hazardous Spills (Physical)	Low	High	Low
Hazardous Spills (Biological)	High	Low	Low
Hazardous Spills (Chemical)	High	Low	Low
Hazardous Spills (Nuclear)	High	Low	Low
Terrorist (Bombing)	High	High	Low
War	High	Moderate	Moderate

Multi-Level Evacuation Framework

Demand/Network Supply
Method by which demand loaded on a network (scheduling) and OD matrix dynamics (destinations choice)



Multi-Level

Route Assignment (Strategic Behavior)
Optimal Evacuation Routes - Network Flow Optimization (Dynamically)

Integrated

Control
Traffic controls + Strategies allowing greater number of people to leave the "impacted" area in the shortest period of time

Multi-Level

Behavioral (Operational/Tactical)
changes in behavior if any during extreme conditions

Modeling VS Execution

Modeling:

- Dynamic
- Real-Time
- Straightforward Implementation

Execution:

- Dynamic traffic route assignment + dynamic change in control coordination scheme
- Existing readily available control logics and technologies (on the ground)
- Easily used by transportation agencies/traffic engineers

Formulation

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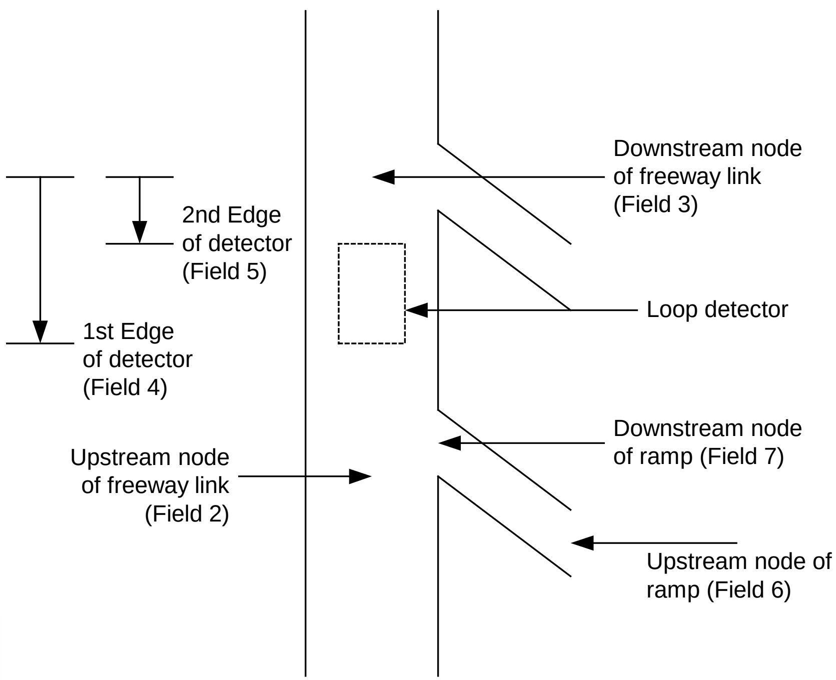
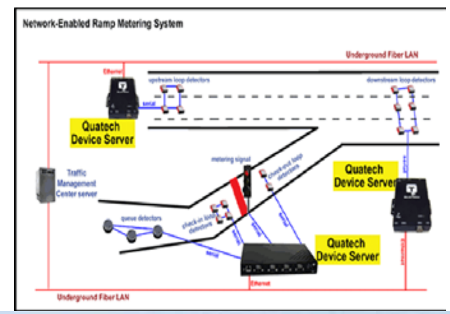
Control Logics (1): Freeway & Arterial Control

- Ramp Metering (Freeway Control - Dynamic):
  - Widely used feedback control ALINEA mechanism (Papageorgiou, 1998)
  - Adjust ramp metering based on the existing flow-occupancy to maximum desired flow-rate occupancy on downstream freeway segment
  - Two detectors





Control Logics (2): Freeway & Arterial Control

- Signalization (Arterial - Dynamic):
  - o Need of dynamic logic with simple required changes →
  - o Actuated control with provision of maximum max/min allowable greens (159 seconds, 59 seconds) along critical evacuation routes
  - o Possibility of using pre-timed signalization while increasing green times along critical paths with dynamic progression bandwidth activation

- Sto ble):
  - o conflicting ngular co

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Control Logics (3): Freeway & Arterial Control

- Variable Message Signs – VMS (Freeways & Arterials – Dynamic):
  - Driver responsiveness dependent
  - (Congestion) Warning VMS, (Mandatory/Optional) Detour VMS, Speed Advisory VMS → Utilized for demand control and flow diversion
  - Put at entrances of impacted areas (high risk areas) and serving as warning and detour VMS
  - Dependent on driver responsiveness: driver education + flow of info

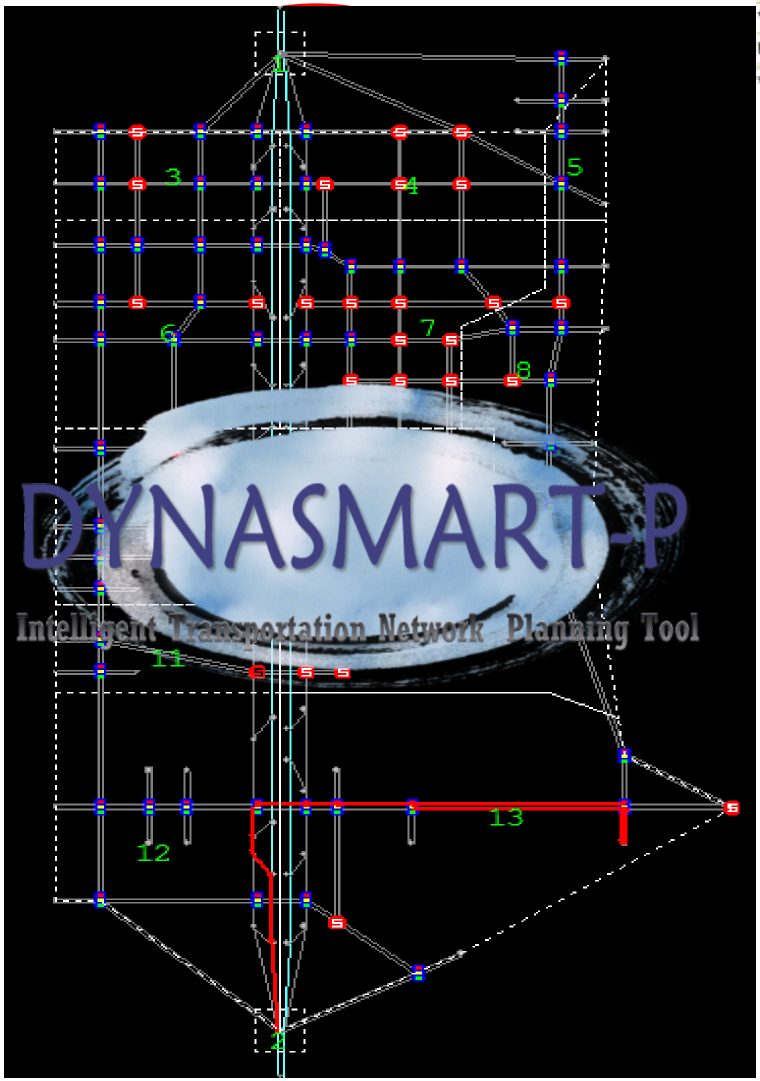
Control Logics (4): Freeway & Arterial Control

- Contra-Flow (Focus on Freeway Control and Main Arterial – Lesser Dynamicity ~ Hourly):
  - Reversing the direction of inbound lanes to the impacted areas to outbound lanes to the safe areas (Williams, 2005).
  - Use of existing U-turns and interchanges with soft barriers
  - Converge all lanes but one along critical paths

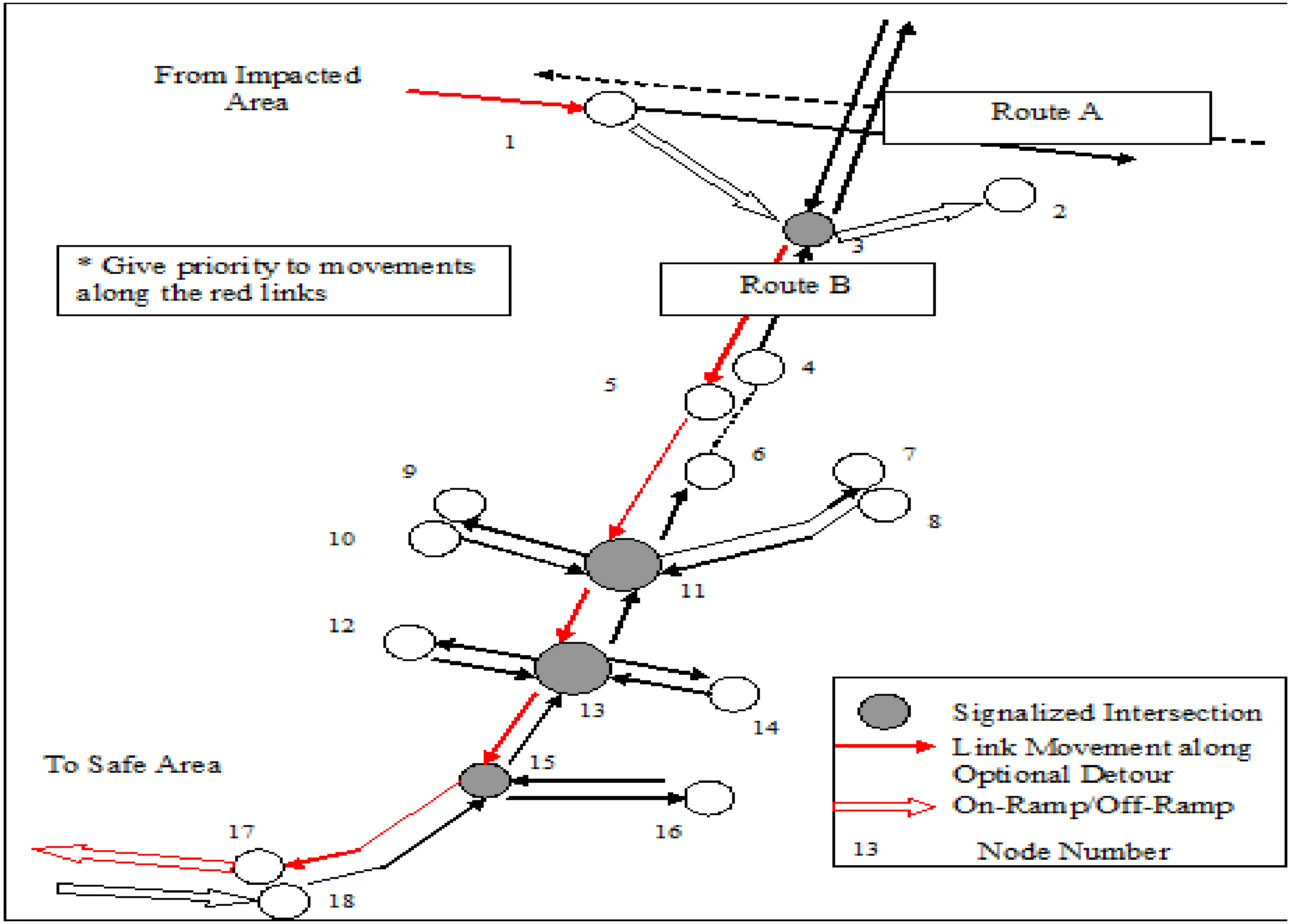
Coordination Scheme: Impacted Vehicles / Critical Path Logic

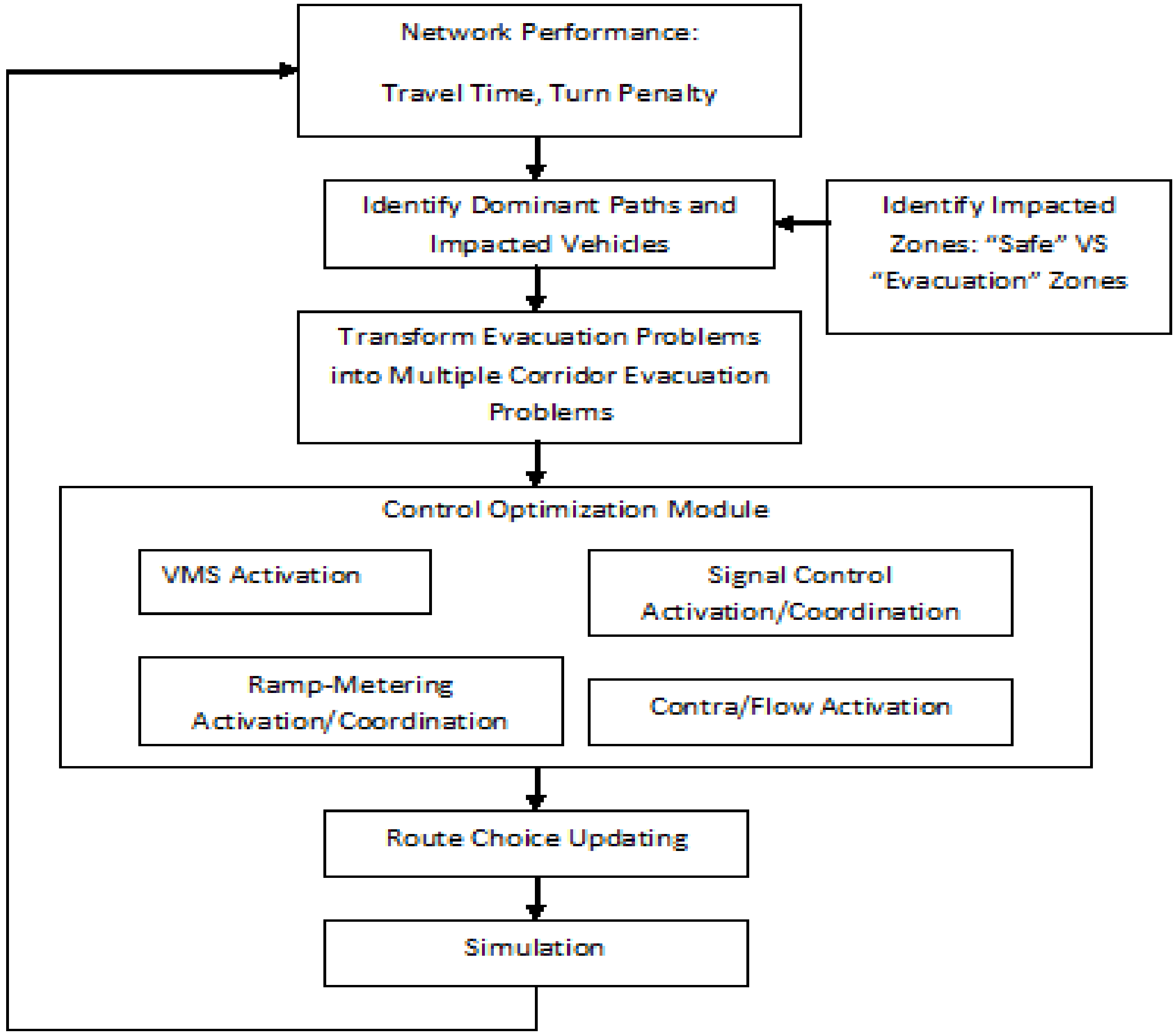
- Use of a dynamic traffic assignment logic/no equilibrium (run time)
- Specify impacted area VS safe area so that to direct evacuees – switch demand (VMS)
- Specify Critical OD pairs with highest number of impacted vehicles:
  - o Passing through …
  - o Origin at …
  - o Destination at …

    impacted area
- Paths attracting highest number of impacted vehicles approaching capacity flows → Critical Paths



Coordination Scheme




Network Performance:
Travel Time, Turn Penalty
Identify Dominant Paths and Impacted Vehicles
Identify Impacted Zones: "Safe" VS "Evacuation" Zones
Transform Evacuation Problems into Multiple Corridor Evacuation Problems
Control Optimization Module
VMS Activation
Signal Control Activation/Coordination
Ramp-Metering Activation/Coordination
Contra/Flow Activation
Route Choice Updating
Simulation

Illustrative Study

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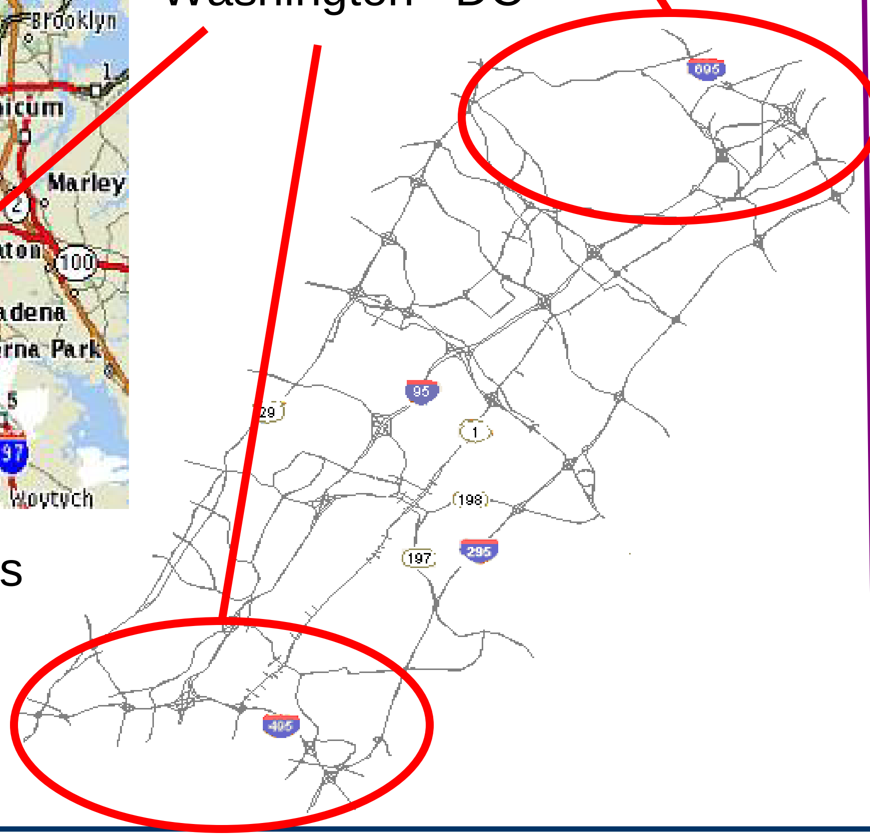
Network: Maryland – Chart Network

- 2182 nodes, 3387 links, 111 zones
- US-29, Route 1 Arterials
- I95-I295 N-S Freeways
- I495 and I695 Beltways

- 345720 responsive vehicles
- 8 AM - 2 PM 6 hrs Study Time
- Calibrated: Detector Flow/Density Data and OD Data, 2005

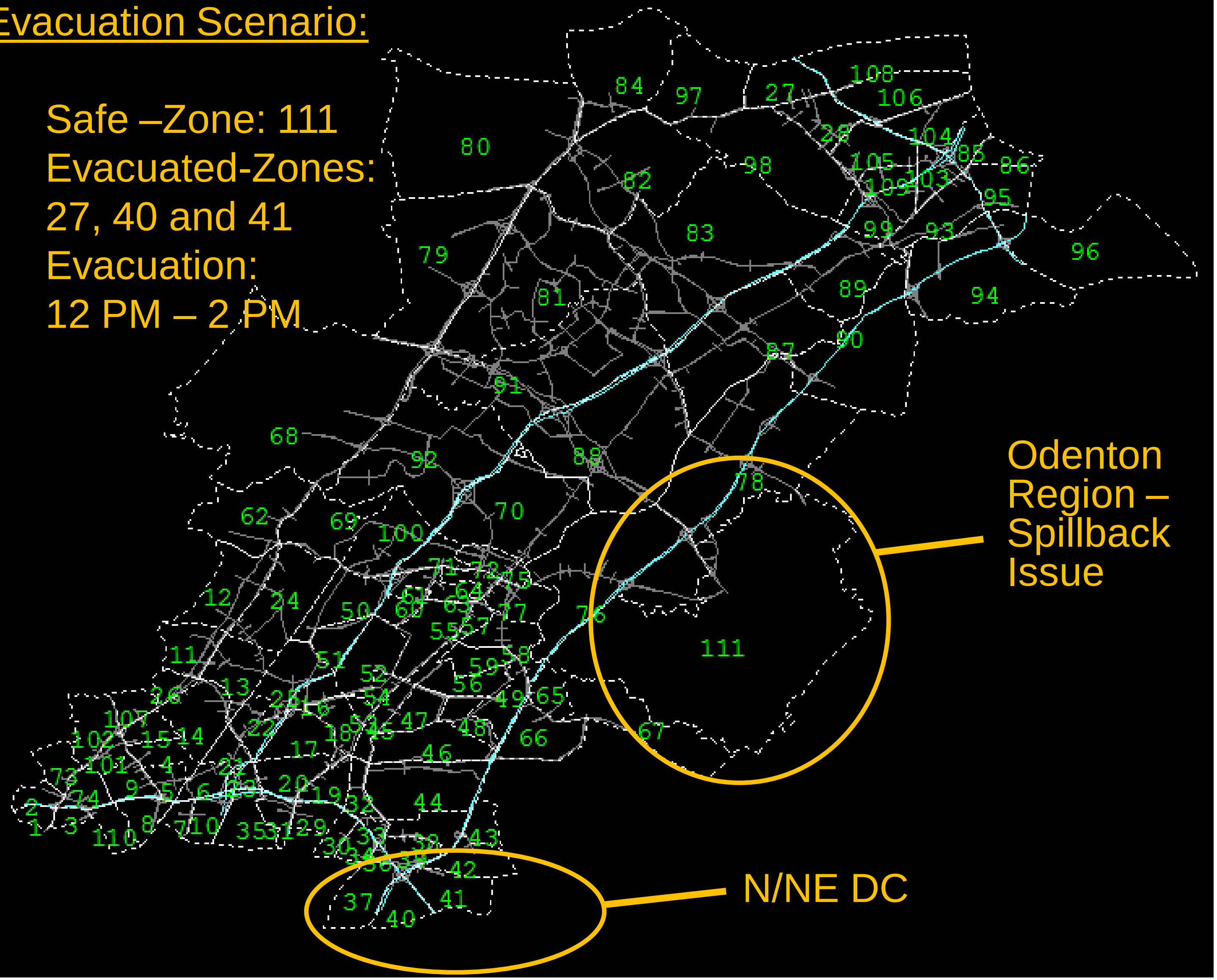
Baltimore

Washington - DC



Evacuation Scenario:

- Safe –Zone: 111
- Evacuated-Zones: 27, 40 and 41
- Evacuation: 12 PM – 2 PM



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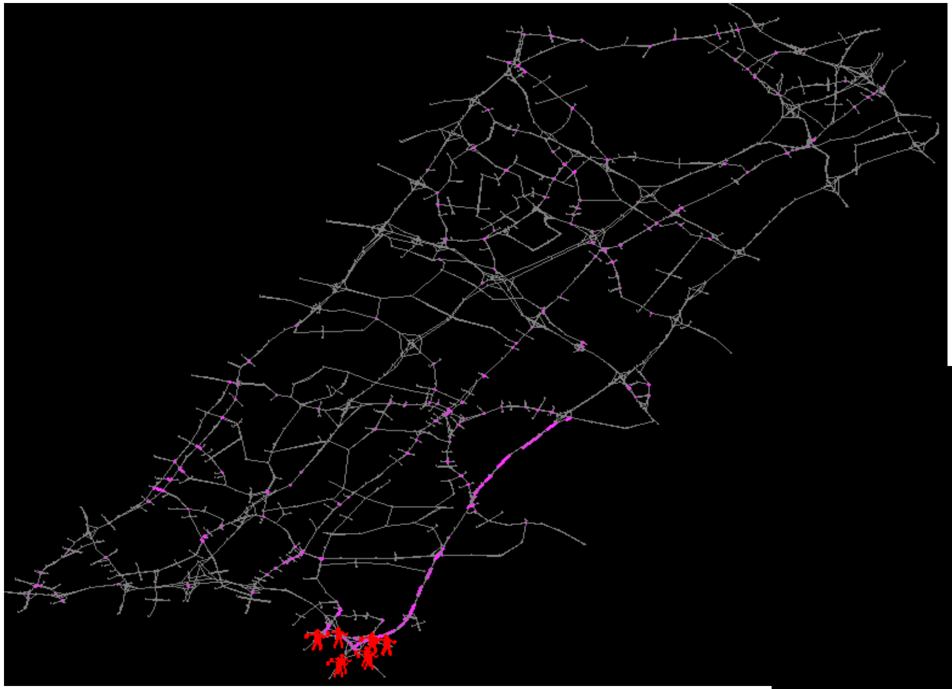
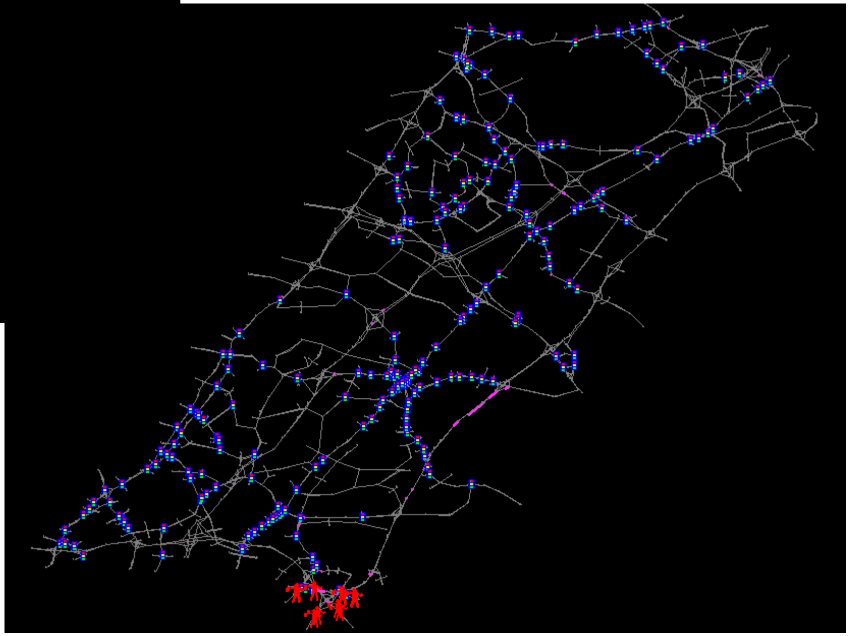
Comparative Videos

No Control



Integrated System



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Sample MOEs

Aggregate Comparison	No Coordination	Coordination
Average Trip Time (mins)	15.8323	16.119
Average Stop Time (mins)	1.7723	1.8761
Impacted Sample (vehs)	4108	2858
Average Trip Time (mins)	42.364	20.435
Average Stop Time (mins)	8.602	0.545

Conclusions & Future Research Needs

Conclusions:

- This research aims at coordinating control strategies via integration with route choice/traffic assignment for evacuation purposes.
- The proposed system is ready executable with existing control equipments/facilities and is to be implemented in real-time
- The system was illustrated using the Maryland Chart-Network Corridor between Washington DC and Baltimore City
- Even though network wide clearance and trip times are slightly increased, significant improvement is recorded for impacted vehicles

Future Research Needs

- Integrate demand and behavior levels in the system:
  - Driver behavior under extreme conditions
  - Dynamic location choice for safe destinations and storage
- Alternative Control Strategies (Adaptive Control …etc)
- Further illustrative studies with multiple scenarios (urban networks, larger scale networks …etc)

Questions?

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