Scenario-Driven and Real-Time Information based Evacuation Planning

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NYS RISE
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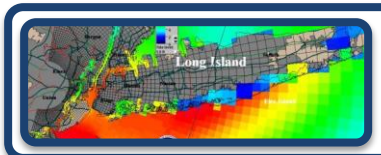
Overview

- Objective
  - Build simulation scenarios for simulating evacuations under different storm conditions
  - Quasi-dynamic approach with modified Origin-Destination (OD) matrices to reflect 1-hr temporal resolution (Hourly Incremental Assignment)
  - Compare simulation scenarios with empirical data
- Study Area
  - New York Metropolitan Area
    - New York City (5 Boroughs)
    - Eastern Long Island (Nassau and Suffolk County)

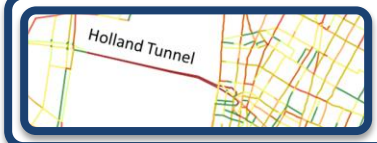
Steps of Evacuation Modeling



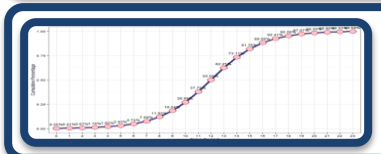
SLOSH maps and existing NYC evacuation zones (June 2013) are used

TransCAD
Transportation GIS Software

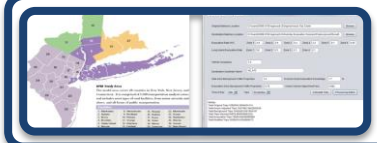
A network assignment model is used to estimate evacuation times for Sandy case study



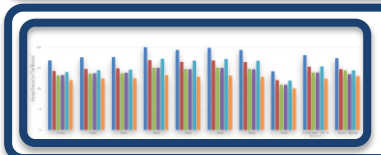
Non-viable links are identified and model parameters adjusted accordingly



Hourly distribution of demand is modeled systematically using theoretical S-Curves and observed demand curves during Sandy from TRANSCOM data



Different Demand Scenarios are developed and evacuation model runs are conducted for different demand assumptions and link performance



Comparison of evacuation times with actual taxi data during Sandy

Visualization of evacuation time results

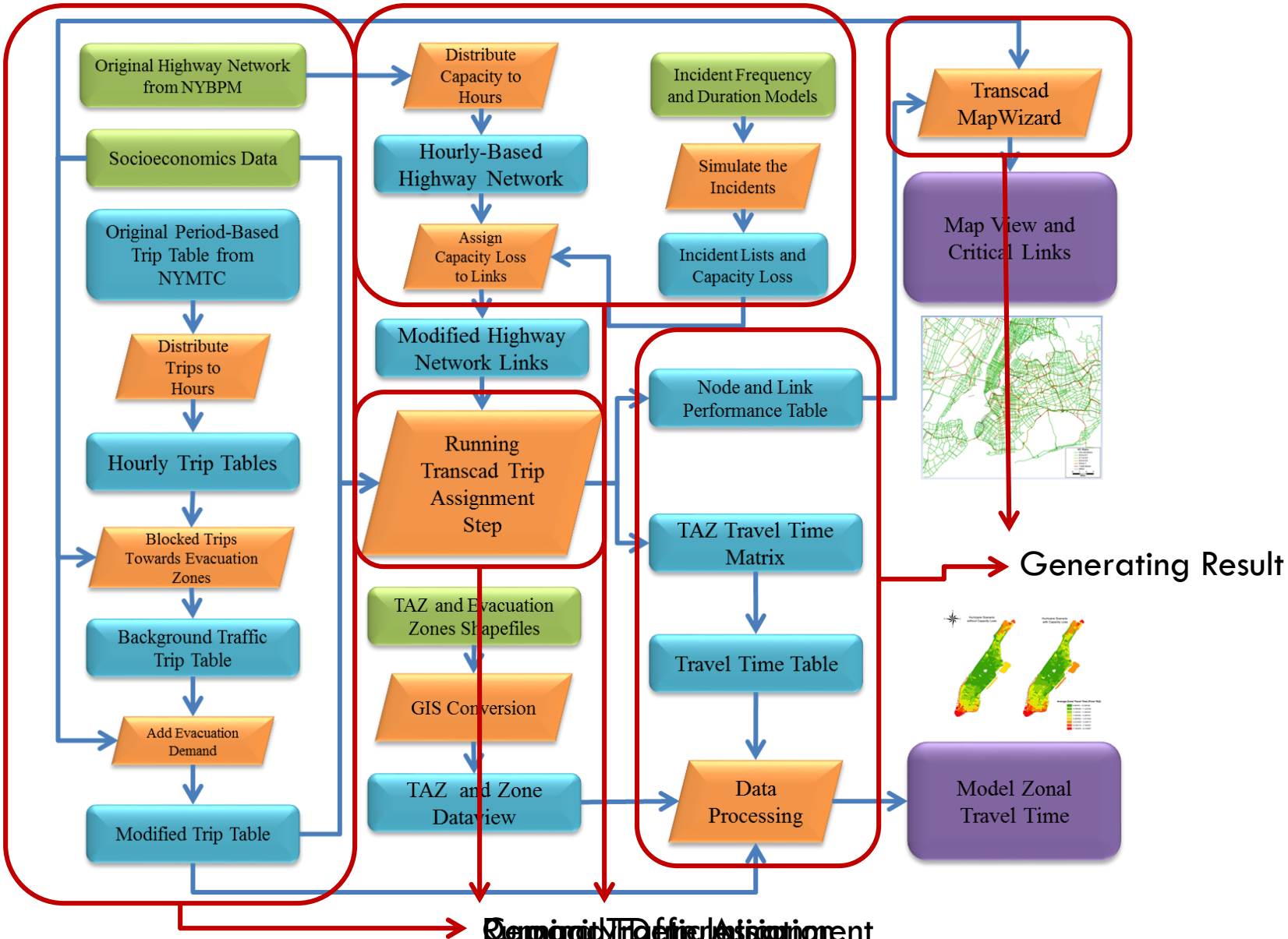
Methodology For Demand Estimation

- Background Traffic
  - Assume 100% background traffic for trips within safe inter-zonal trips
  - Assume 75% background traffic for trips between safe and evacuation zones
  - Set 0% background traffic for evacuation zones
- Evacuation Traffic
  - Zonal Population: Based on 2010 Census Data
  - Evacuation Rate: Differs in terms of Zone Categories
  - Vehicle Occupancy: 2.2 for moderate scenario, 1 for worst case scenario
  - Generating Evacuation Trips:

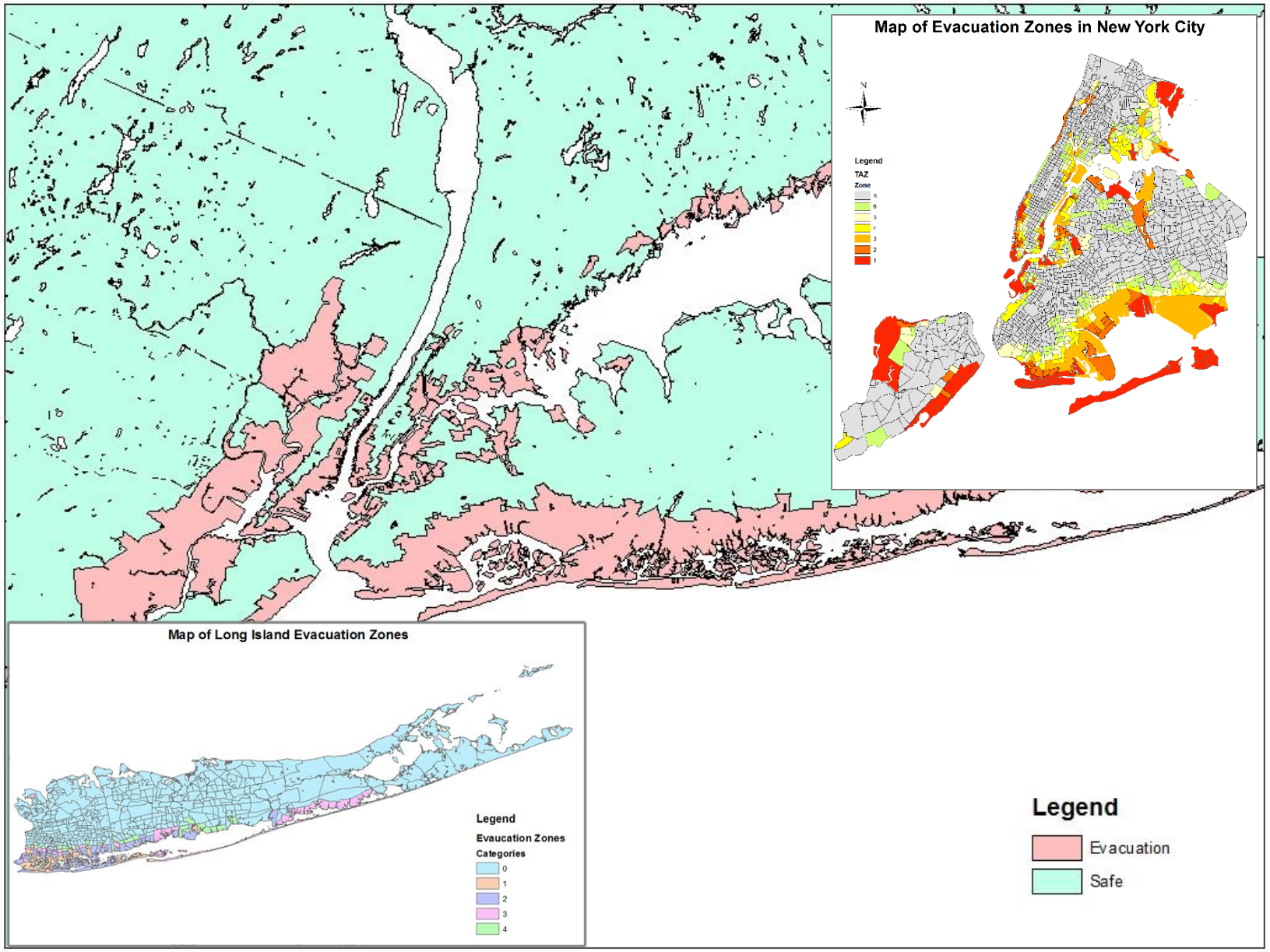
    Zonal Evacuation Trip Demand = Zonal Population * Evacuation Rate * Vehicle Occupancy
- Consideration of Transit Demand
  - Transit Network
    - Entire subway system were shutdown at 7pm on Sunday, October 28th[1], one day before Hurricane Sandy made landfall
    - Buses were the primary public transit method for evacuation
    - In the model, bus volume is integrated in the highway assignment and converted to Passenger Car Equivalents(PCE), and included in total link flow

1. http://www.huffingtonpost.com/2012/10/28/mta-shutdown-hurricane-sandy-subway-cuomo_n_2034337.html

Data Processing Procedure



Assumption of Evacuation and Safe Zones



Traffic Assignment

- Use TransCAD Highway Assignment Module
- User Equilibrium[1]
  - Objective: Minimize Travel Time
  - Functions :

$$\min \sum_a \int_0^{v_a} s_a(x)dx$$

Generalized Cost Function

$$s.t. v_a = \sum_i \sum_j \sum_r \delta_{ij}^{ar} x_{ij}^{r} \quad for\ all\ links\ a\ in\ the\ network$$

Dummy Variable

$$\sum_r x_{ij}^{r} = T_{ij}$$

Number of Vehicles from i to j

$$v_a \geq 0$$

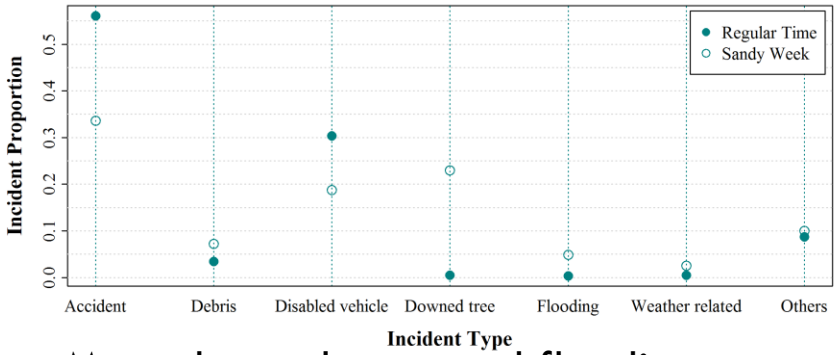
$$x_{ij}^{r} \geq 0$$

  - Methodology
    - Origin User Equilibrium: Compute solution for each origin in addition to overall link flow equilibrium, which is fast but take more physical memory
    - Bus Preload
    - Consolidated HCM 2000 Turning Delay Model
- Incremental Hourly Assignment
  - For hourly assignment of time period n, a_n is the demand of hour *n*, *t* (in minute)is hourly travel time. If *t* is greater than 60, for the next hour *n+1*, the original demand is d_{n+1} , the incremental demand for period a_{n+1} is:

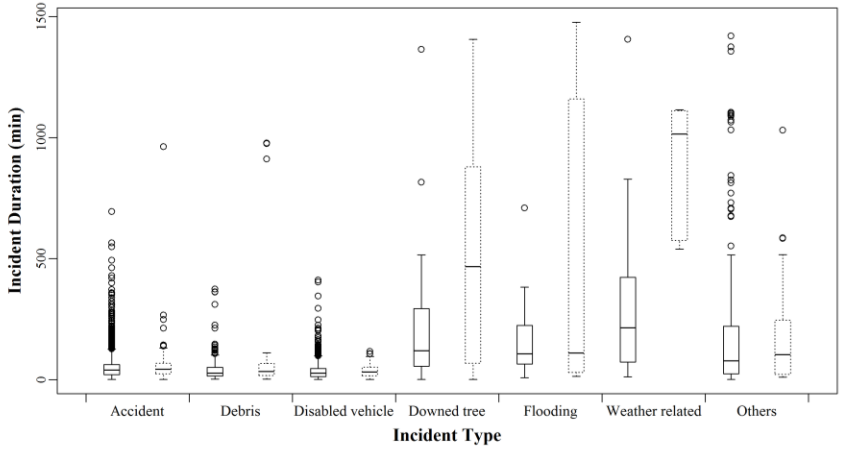
$$a_{n+1} = \begin{cases} d_{n+1} & ,if\ t \leq 60 \\ d_{n+1} + a_n * \dfrac{t-60}{t} & ,if\ t > 60 \end{cases}$$

1. Y. **Sheffi** (1980)

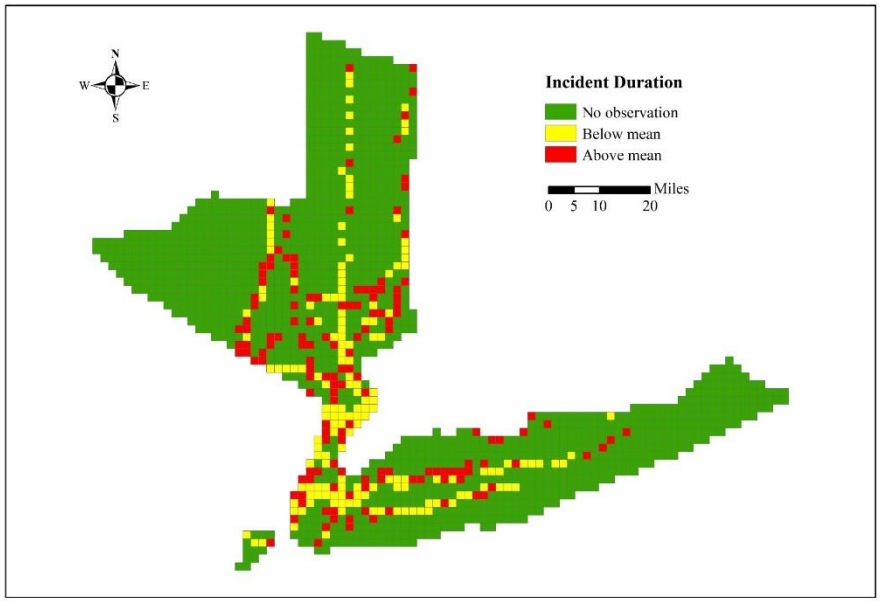
Analysis of Sandy Related Accidents



More downed trees and flooding events occurred during Sandy



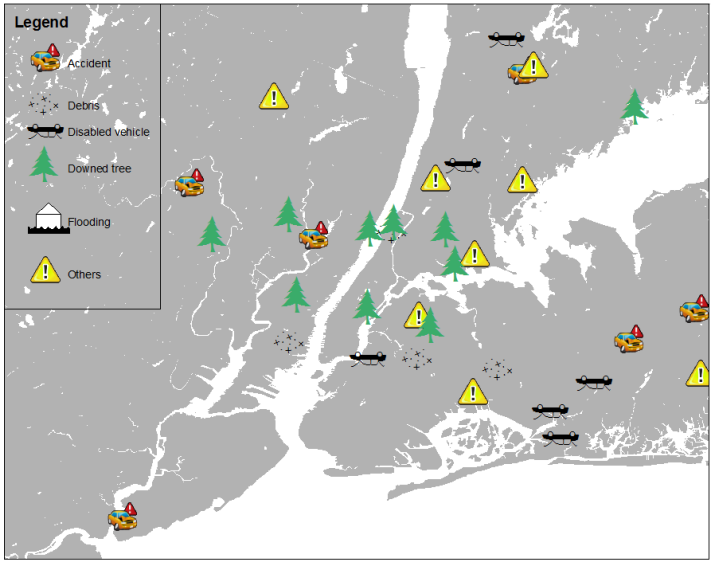
Incident duration got extended during Sandy

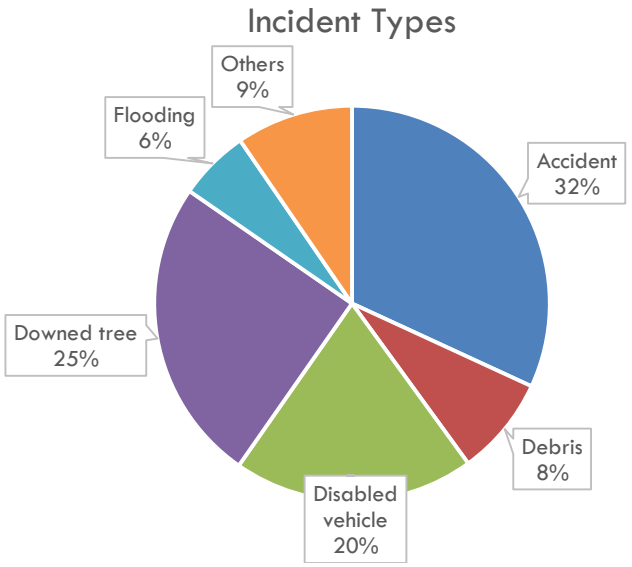


Spatial clustering of areas with high incident duration

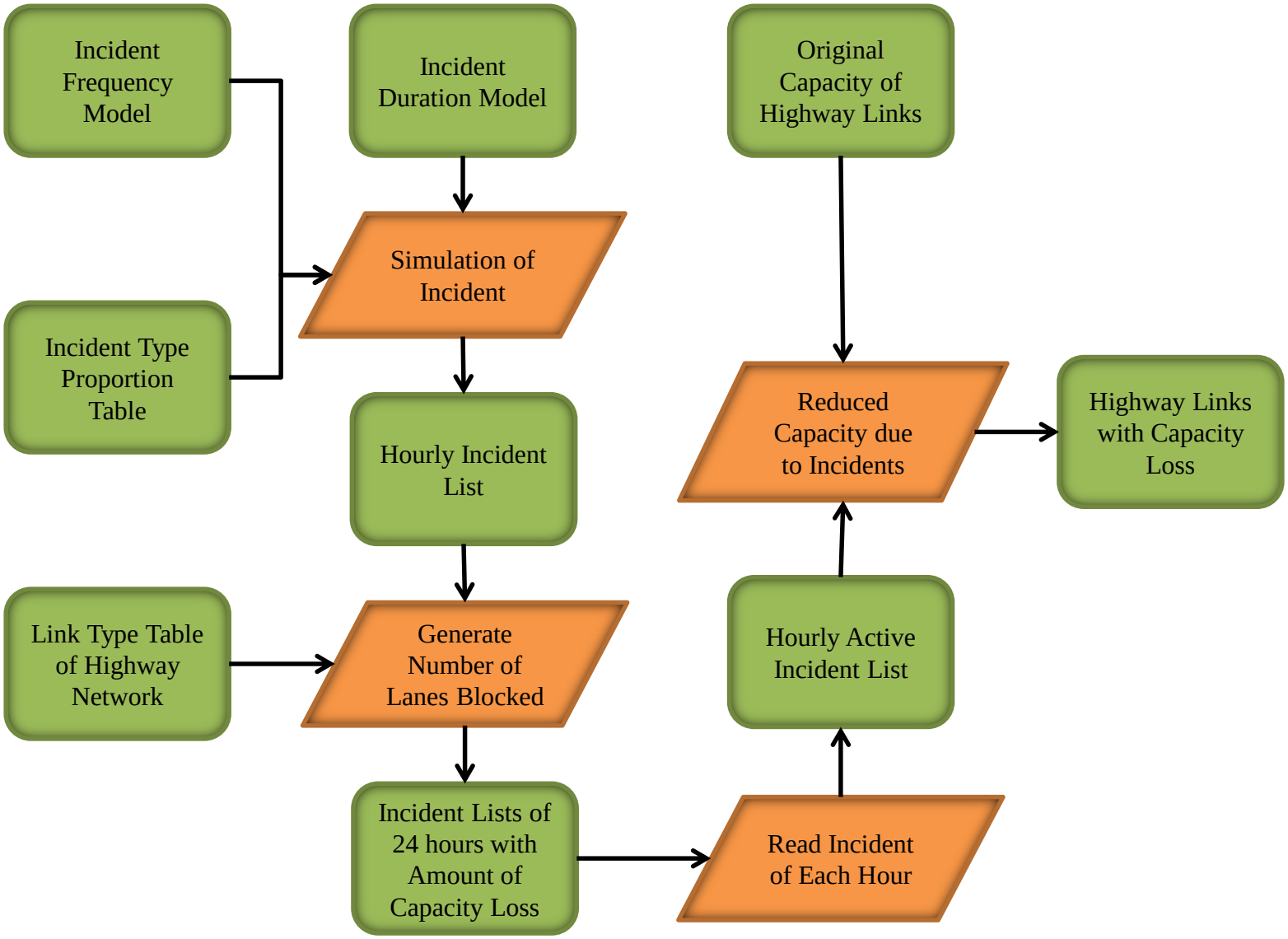
Incident-Induced Capacity Loss Scenarios & Simulation

- Methodology
  - Generate hourly incidents based on incident frequency and duration models developed in Task 4.1, and reduce capacity of corresponding links
- Incident Frequency Model
- Incident Duration Model
  - Multiple Linear Regression Model
  - For individual incident, durations are assumed to be lognormal distribution
- Simulation Results
  - Hourly Incident List
    - Location and Direction
    - Incident Type
    - Duration
    - Number of Lanes Affected
    - Capacity Reduced





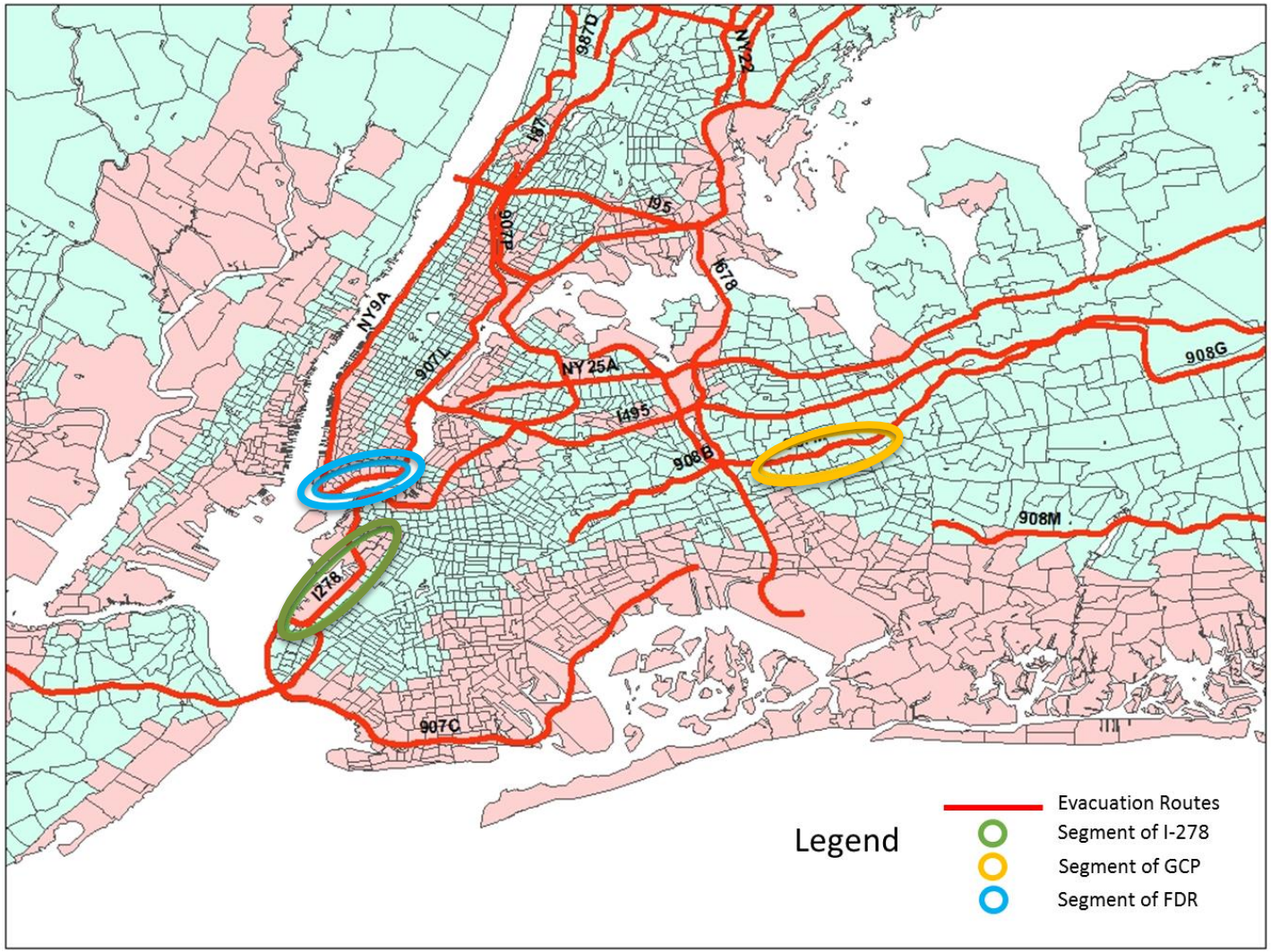
Simulation Procedure of Capacity Loss Scenario

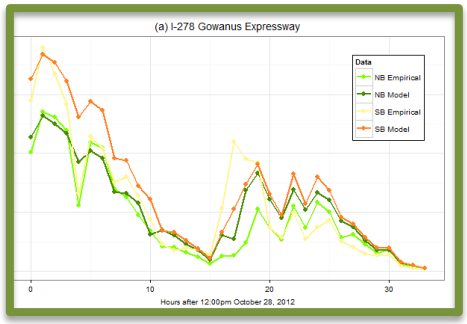


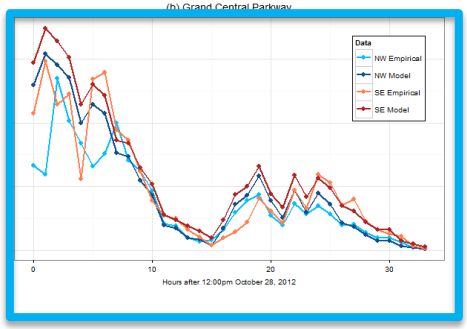
Hourly Simulation Scenarios

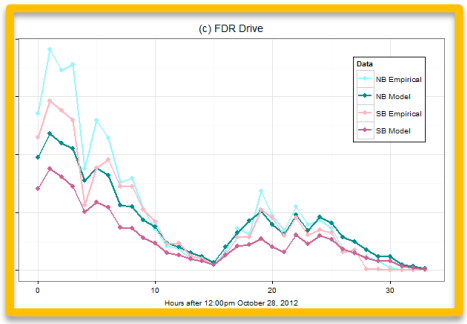
Scenarios	Evacuation Zones	Background Traffic Demand	Evacuation Demand	Link Capacity Loss
Base Scenario	No Evacuation Zones	Original NYMTC Trip Table	No Evacuation Demand	No Capacity Loss
Moderate Evacuation Scenario w/o Capacity Loss	Mandatory: Zone 1 Suggested: Zone 2 to 6	Exclude Trip Demands to Evacuation Areas	From Socioeconomic Data and Evacuation Plan of Hurricane Sandy	No Capacity Loss
Worst Case Evacuation Scenario w/o Capacity Loss	Mandatory: Zone 1 Suggested: Zone 2 to 6	Exclude Trip Demands to Evacuation Areas	From Socioeconomic Data and Evacuation Plan of Hurricane Sandy	No Capacity Loss
Moderate Evacuation Scenario with Capacity Loss	Mandatory: Zone 1 to 3 Suggested: Zone 4 to 6	Exclude Trip Demands to Evacuation Areas	From Socioeconomic Data and Evacuation Plan of Category 3 Hurricane	Incident Induced Capacity Loss

Volume Comparison Results

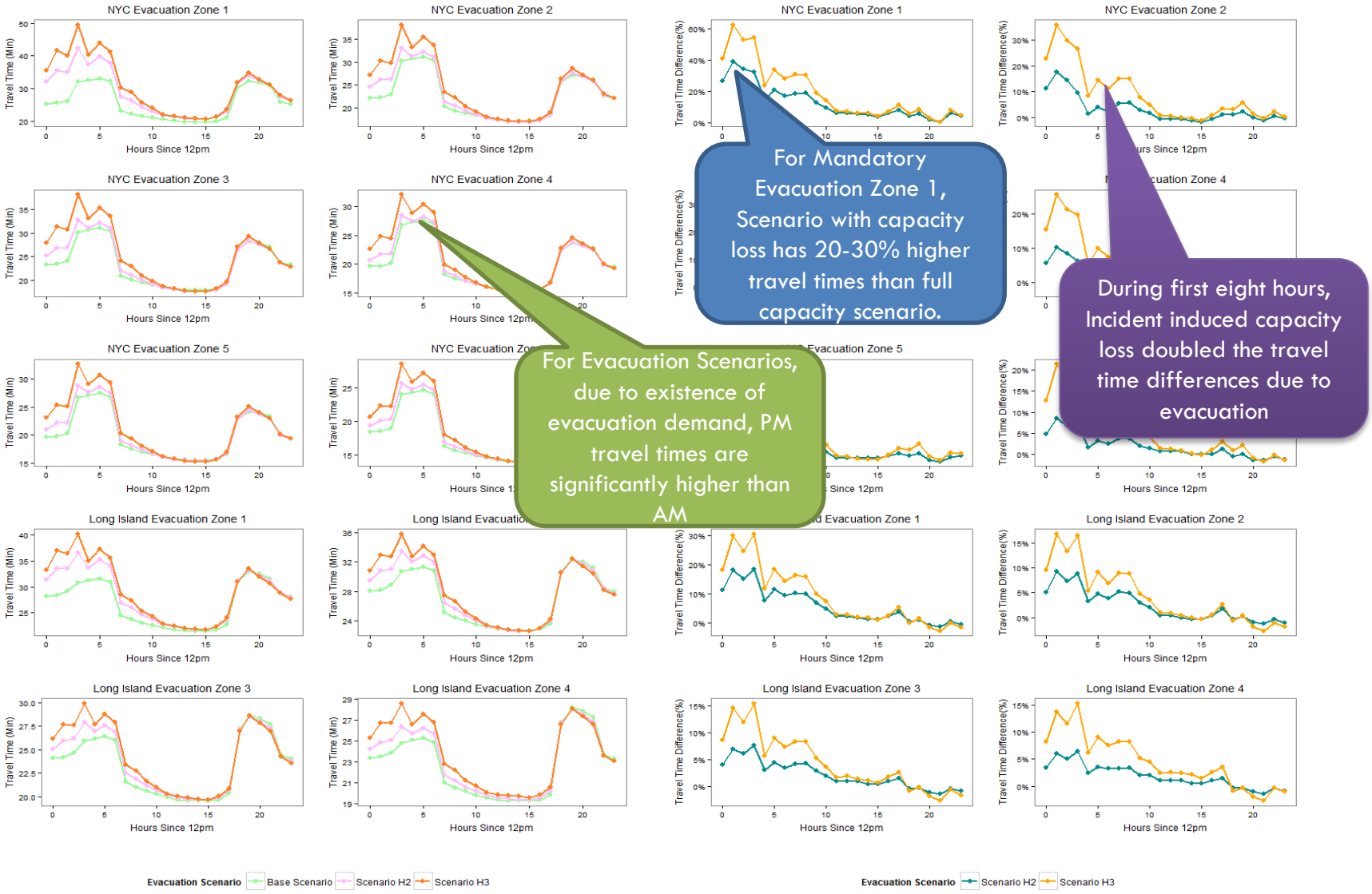








Comparison of Average Zonal Travel Time



For Mandatory Evacuation Zone 1, Scenario with capacity loss has 20-30% higher travel times than full capacity scenario.

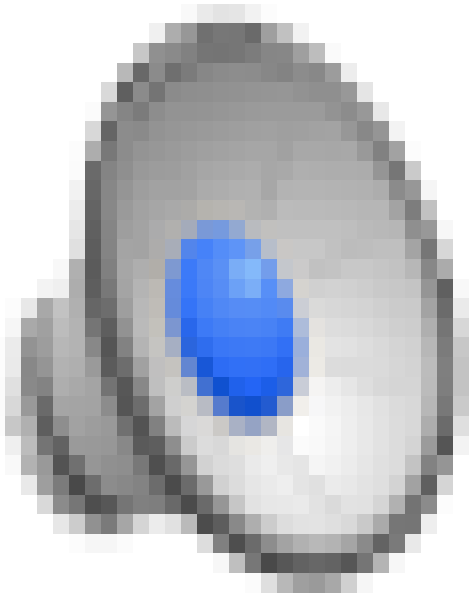
For Evacuation Scenarios, due to existence of evacuation demand, PM travel times are significantly higher than AM

During first eight hours, Incident induced capacity loss doubled the travel time differences due to evacuation

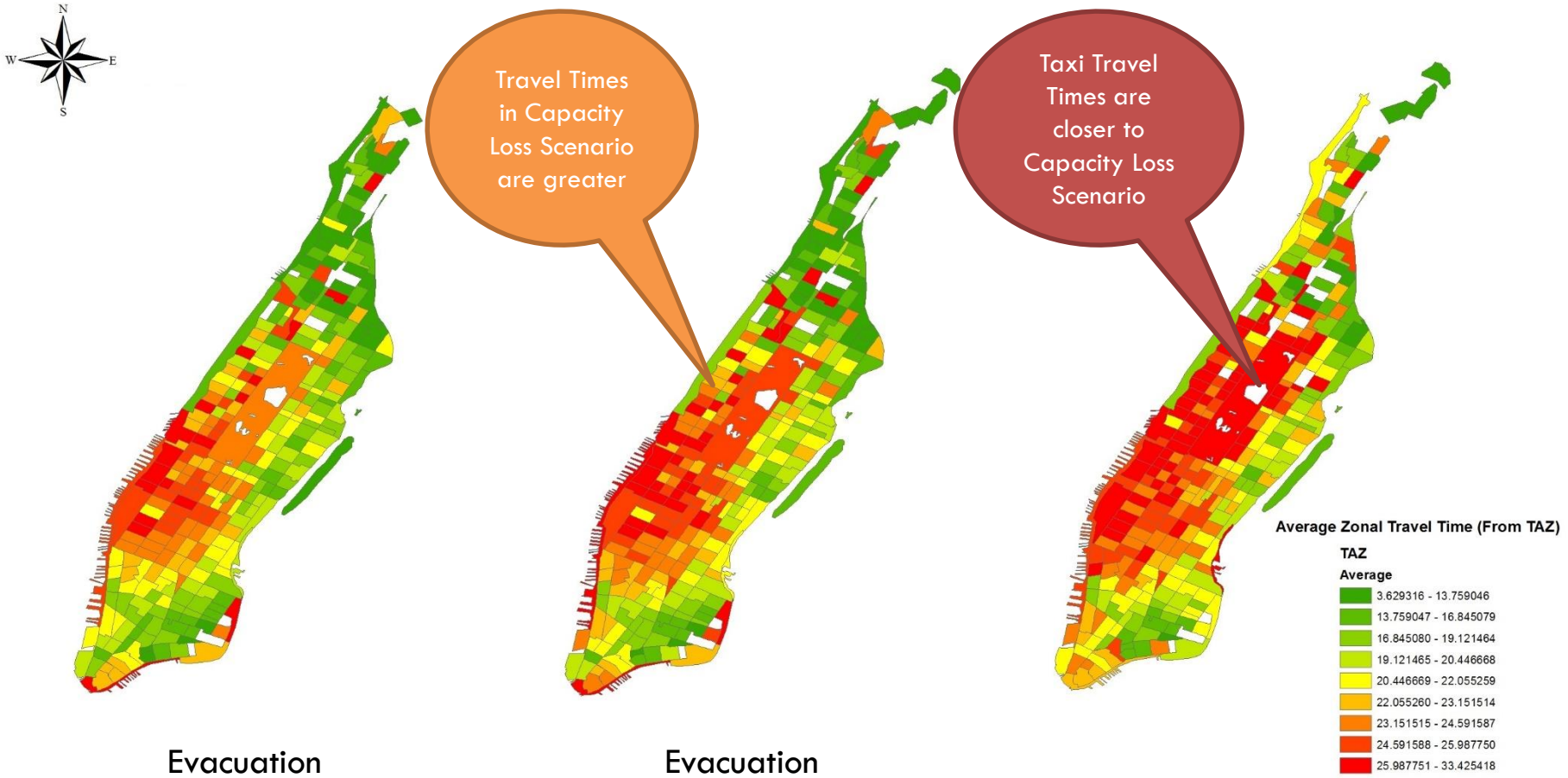
Left: Travel Time for Base Scenario, Evacuation Scenarios w/o and with Capacity Loss

Right: Comparison of Differences between Base Scenario and Evacuation Scenarios w/o & with Capacity Loss

Visualization of Sandy Evacuation Scenario (Travel Time Index)



Comparison of Average Taxi Travel Times before Sandy (12pm-12pm Oct 28-29, 2012)



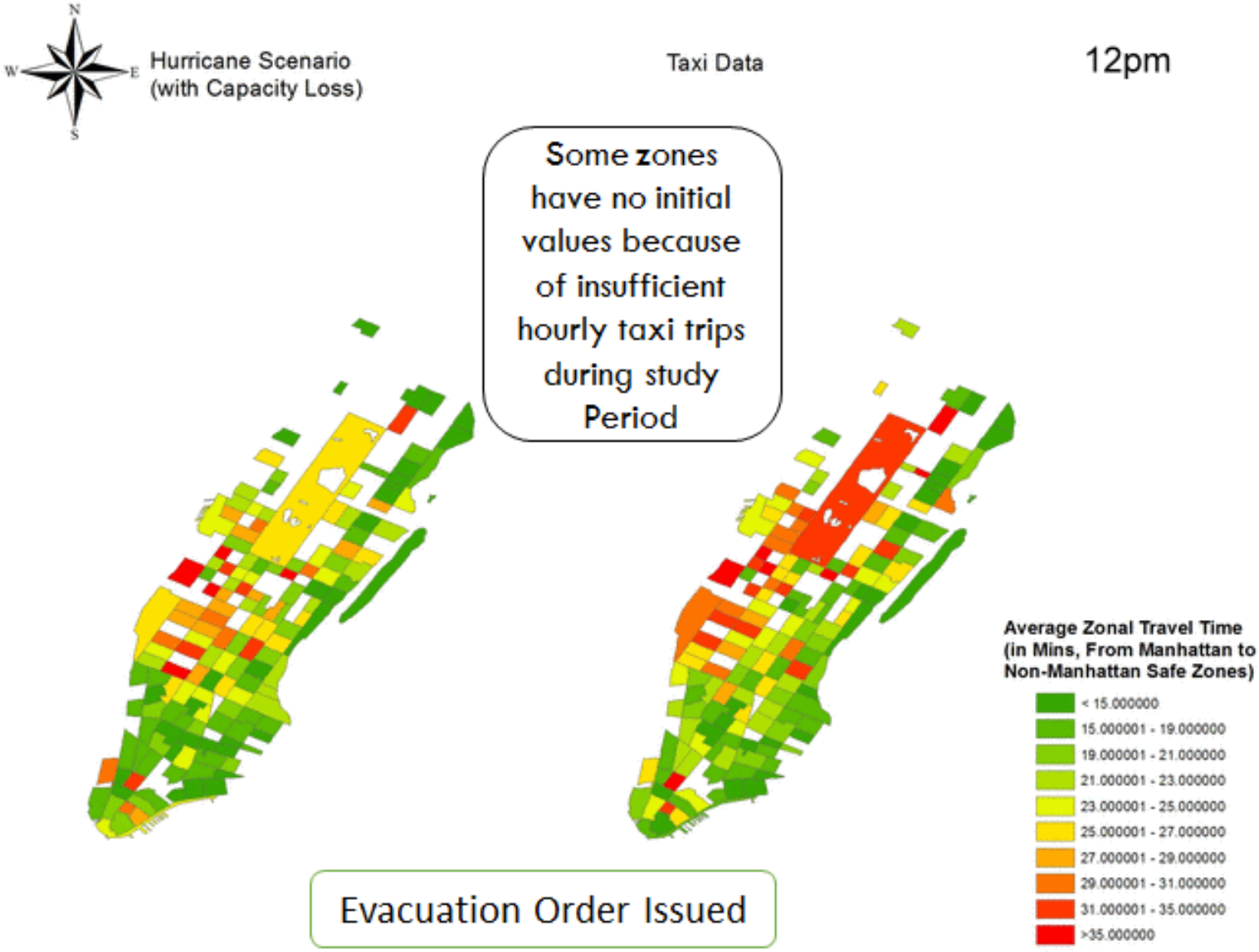
Evacuation Scenario w/o Capacity Loss

Evacuation Scenario with Capacity Loss

Taxi Data

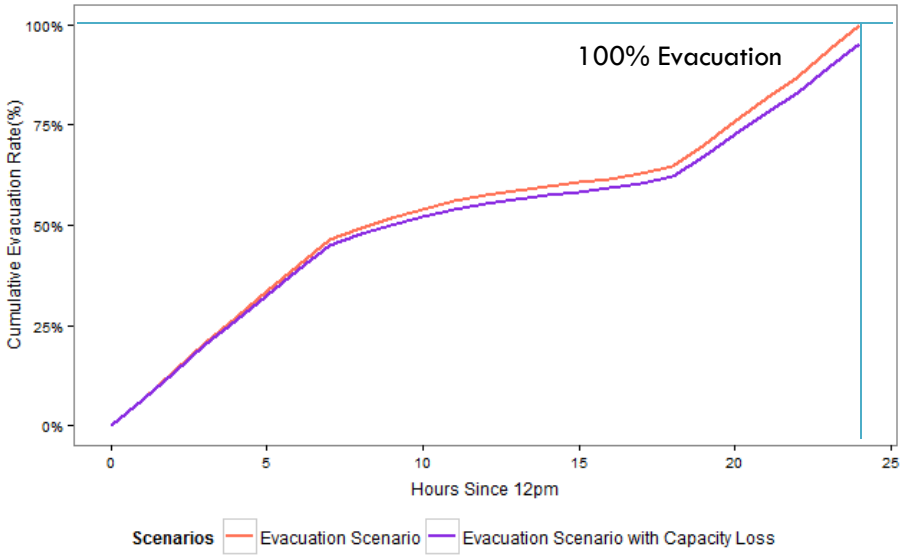
Average Zonal Travel Time for 24 Hours

Visualization of Hourly Travel Time Comparisons



Conclusions

- Network Behavior
  - Network wide demand increases in the beginning hours of evacuation, and then reduces due to loss of background trips and incoming trip restrictions
  - Incidents cause full or partial capacity losses for 400 links in the system and cause significant increase in travel time
- Computation Time
  - Simulation Time for Base and Evacuation Scenarios with Full Capacity are roughly equivalent
  - For the Capacity Loss Scenario, time is twice of the Base and Evacuation Scenarios with Full Capacity
- Evacuation Curve
  - Based on VMT of all critical links
  - After 24 hours, 90% of the total population can be evacuated for the capacity loss scenario, compared with 100% in full capacity scenario



CONCLUSIONS(CONT'D)

- Application of Simulation Model
  - Prediction of Evacuation Demand of Future Storms
    - Flexibility in modifying evacuation rates, evacuation zone settings and evacuation plans
    - Background traffic demand can be projected for future years
    - Implemented using incident models based on empirical data
- Future Work
  - More evacuation scenarios
    - Worst Case Scenario with moderate capacity loss
    - Worst Case Scenario with worst capacity loss
  - Connection to Task 4.1: Evacuation Zones
    - By using modified zones and projected socio-economic data of year 2050, the model can be used to verify rationality of proposed zones
  - Application of Dynamic Traffic Assignment (DTA)