FUTURE DIRECTIONS FOR SEISMIC RISK MANAGEMENT FOR TRANSPORTATION NETWORKS

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System Performance Evaluation Framework

- Spatially Distributed Systems
- Uncertainties
SYSTEM RISK EVALUATION FRAMEWORK

User Defined Options

- Type of Evaluation
- Risk-Reduction Options
- Performance Requirements
- Stakeholder Impacts
SYSTEM RISK EVALUATION FRAMEWORK

- System Attributes
- Component Attributes
- Service Demands

User Defined Options

Input Data
SYSTEM RISK EVALUATION FRAMEWORK

User Defined Options

Input Data

Scenario EQ
SYSTEM RISK EVALUATION FRAMEWORK

User Defined Options

Input Data

Scenario EQ

Evaluate Hazards

Hazard Analysis Procedure
- Ground Motions
- Liquefaction
- Landslide
- Fault Rupture
SYSTEM RISK EVALUATION FRAMEWORK

- User Defined Options
  - Input Data
    - Scenario EQ
      - Evaluate Hazards
        - Evaluate Component Performance and Post-EQ System States
          - Damage State
          - Repair Cost
          - Downtime
          - Functionality
          - Fragility Models
          - Repair Models
SYSTEM RISK EVALUATION FRAMEWORK

1. **User Defined Options**
2. **Input Data**
3. **Scenario EQ**
4. **Evaluate Hazards**
5. **Evaluate Component Performance and Post-EQ System States**
6. **Evaluate System Performance over Time after EQ**
7. **Estimate Losses**

**Network Analysis Procedure**
- System Connectivity
- Service Flow Rates
- System Resilience
HIGHWAY SYSTEM SRA LOSS METRICS

- Traffic Flow Decreases
- Travel Time Delays
- Trip Demands
- Resiliency

- Direct Economic Losses
  - Repair Costs
  - Due to Travel Time Delays and Trips Foregone

- Indirect Economic Losses
  - Regional / National

- System Wide
- To/From Selected Locations
- Along Selected Routes
SCOPE

• System Performance Evaluation Framework

Spatially Distributed Systems

• Uncertainties
<table>
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<th>Spatially Distributed Highway System</th>
<th>Single Site Systems</th>
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<tr>
<td><strong>Seismic Hazards</strong></td>
<td>For Given Scenario EQ • Compute Consistent Spatially Dispersed Hazards throughout System • Many Different Site Conditions</td>
<td>Starting Point: • Seismic Hazard Analysis • Compute One Set of Site-Specific Seismic Hazards • One Set of Site Conditions</td>
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<td><strong>Component Response</strong></td>
<td>• Large Number/ Many Types of Components • Compute Consistent Spatially Dispersed Component Damage States • Possible Multiple Spatially Dispersed Post-EQ Repair Activities</td>
<td>• Smaller Number of Facilities • Compute One Set of Localized Damage States for a Few Facilities • Localized Repair Activities</td>
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<td><strong>System Response</strong></td>
<td>• Spatially Dispersed: - Roadway Redundancies - Roadway Traffic Carrying Capacities - Damage Locations - Trip Demands - User Entry/Exit Locations</td>
<td>• Limited and Localized - Link Redundancies - Link Service Capacities - Damage Locations - Service Demands - User Entry/Exit Locations</td>
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SPATIALLY DISTRIBUTED HIGHWAY SYSTEM
Input Data

• Because of Size and Spatial Extent of System
  – Significant Input Data Needed

• Highways and Bridges (FHWA Electronic Databases)
  – Highway Performance Monitoring System (HPMS)
  – National Highway Planning Network (NHPN)
  – National Bridge Inventory (NBI)

• Soil Conditions
  – NEHRP Classifications
  – Other Soils Data: From State DOT

• Trip Demands:
  – Trip Tables from Metropolitan Planning Organizations (MPOs)
SCOPE

- System Performance Evaluation Framework
- Spatially Distributed Systems
- Uncertainties
UNCERTAINTIES IN SRA OF HIGHWAY SYSTEMS

• Well Recognized Sources of Uncertainty
  – Earthquake Occurrences over Time
  – Seismic Hazard Estimation
  – Bridge Damage Estimation

• Other Important Uncertainties
  – Damage Repair Requirements
  – Traffic/Travel Impacts
  – Input Data Constraints
UNCERTAINTIES IN SRA OF HIGHWAY SYSTEMS: Damage Repair Requirements

• Repair Requirements
  – Costs
  – Mobilization Time
  – Rate of Repair
  – Functionality of Component during Repairs

• Depends on
  – Prior Post-EQ Experience
  – Availability of Repair Resources
  – Extent of Damage within Highway System
  – Accessibility of Damage
  – Extent of Damage to Other Elements of Built Infrastructure
UNCERTAINTIES IN SRA OF HIGHWAY SYSTEMS: Traffic/Travel Impacts

- Effects of Increased Traffic Congestion due to EQ Damage to System
  - Increase Travel Times
  - Reduce Trip Demands

- Assumptions in Analysis of Post-EQ Travel within Disrupted System
  - Traveler Route Choice
  - Relationship between Trip Demand and Travel Time

- Other Potential Impacts on Post-EQ Travel Not Considered
  - Damage to Other Elements of Built Infrastructure
SPATIALLY DISTRIBUTED HIGHWAY SYSTEM: Some Input Data Constraints

• Possible Errors/Gaps in Highway Data from HPMS and NHPN

• Bridges
  – NBI Database Insufficient for Seismic Performance Evaluation
  – Some State DOTs have Supplementary Data

• Soil Conditions for Assessment of Liquefaction, Landslide Hazards
  – Data may be Time Consuming to Obtain
UNCERTAINTIES IN SRA OF HIGHWAY SYSTEM: Component Damage Estimation

• Bridge Fragility Modeling
  – Large Numbers of Bridges
  – Insufficient Input Data on Bridge Attributes
  – Combined Effects of Ground Shaking and Permanent Ground Displacement

• Fragility Modeling for Other Components
  – Tunnels, Roadways, Approach Fills, Retaining Walls, Culverts

• Damage State Definitions
  – Need for Improved Basis for Estimating Repairs
  – HAZUS Damage States are Insufficient for this Purpose