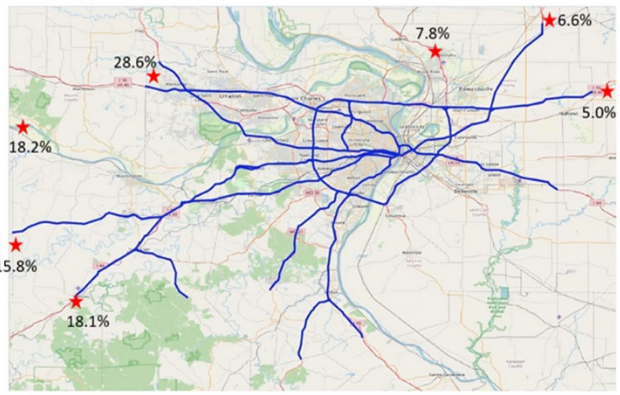
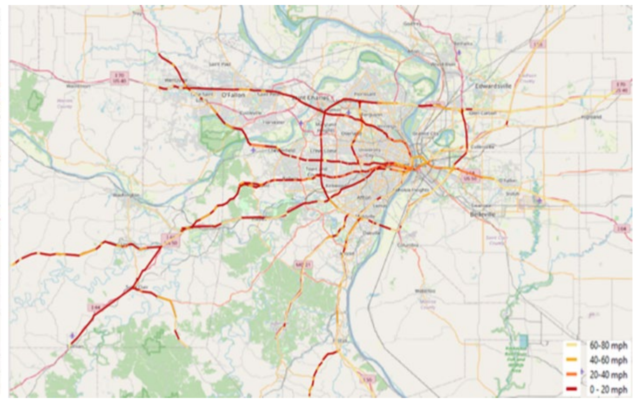
Identification of a Response and Rescue Network for the St. Louis Region





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16. Abstract

Emergency preparedness and response are crucial for mitigating the impact of natural disasters such as earthquakes. The St. Louis metropolitan region is vulnerable to earthquakes in the New Madrid and Wabash Valley Seismic Zones. This study focuses on understanding and addressing transportation impacts of an earthquake in the St. Louis region. An online survey conducted across eight counties in the St. Louis region gathered data on citizen preferences, travel patterns, and vehicle usage during an evacuation. The research team employed transportation simulation tools, including macroscopic and mesoscopic approaches, to assess regional traffic impacts. The research evaluated the effects of a magnitude 6.7 earthquake, considering infrastructure damage estimates from the USGS ShakeCast model. Performance measures like average vehicle speed and operating speed-to-speed limit ratio were gathered from the simulation to determine congestion across the road network. Twelve evacuation scenarios were assessed using simulation. The scenarios varied based on the level of damage to the road network, evacuation demand, and timing of the earthquake. Results showed that morning earthquakes resulted in the worst traffic impacts. Mesoscopic models confirmed severe congestion on MO 100 and identified bottlenecks on I-170 and US 67. A tabletop exercise was conducted with key emergency response stakeholders in the St. Louis region to better understand coordination and communication needs during an earthquake response. This study aims to equip stakeholders with tools for effective response, aiding emergency responders, urban planners, and policymakers in minimizing the impact of earthquakes.

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Final Report

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Disclaimer

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List of Abbreviations and Acronyms

EWG	East-West Gateway Council of Governments
FEMA	Federal Emergency Management Agency
HOV	High Occupancy Vehicle
IRB	Institutional Review Board
LOV	Low Occupancy Vehicle
MoDOT	Missouri Department of Transportation
NBI	National Bridge Inventory
NMSZ	New Madrid Seismic Zone
SEMA	State Emergency Management Agency
TMC	Traffic Management Center
USGS	United States Geological Survey
WVSZ	Wabash Valley Seismic Zone

Executive Summary

Emergency preparedness and response are critical to saving lives and minimizing human suffering during and after natural disasters. The St. Louis metropolitan area is vulnerable to large earthquakes in the New Madrid Seismic Zone (NMSZ) and Wabash Valley Seismic Zone (WVSZ) and sporadic seismic activity to the east and south of the region. Earthquakes' high frequency and magnitude make the St. Louis area particularly vulnerable. The large population, significant population density, numerous river crossings, and unreinforced building construction practices increase the potential for substantial damage and the difficulty of recovery efforts in the St. Louis region. Damage to road infrastructure, especially bridges, also constrains emergency response, evacuation, and recovery. This study addresses the transportation impacts of earthquakes in the St. Louis area.

An online survey was deployed to understand citizens' behavior and decision making in an evacuation. Survey responses were collected across the eight counties in the study region to obtain information on decision to evacuate, departure time, route and destination choice, vehicle usage, and others. The survey responses were used to adjust the regional travel demand model to study various evacuation scenarios. The regional travel demand model for the St. Louis region developed by East-West Gateway Council of Governments was obtained and served as the base model for the study. It consists of approximately 7.9 million daily trips. The CUBE simulation tool was used to study the effects of earthquakes in the region. Infrastructure damage estimates were obtained through the USGS ShakeCast model for a magnitude 6.7 earthquake.

Performance measures were collected at regional and local levels. Average vehicle speed, operating speed-to-speed limit ratios, and a list of bottlenecks were generated. The earthquake scenarios were assumed to occur at two different times of day, 7 A.M. and 4 P.M. The existing travel demand model represented a baseline scenario, and twelve evacuation scenarios were created by varying travel demand, road network, and earthquake occurrence time. Twelve evacuation scenarios were assessed using simulation. The scenarios varied based on the level of damage to the road network, evacuation demand, and timing of the earthquake. Results showed that morning earthquakes resulted in the worst traffic impacts. Mesoscopic models confirmed severe congestion on MO 100 and identified bottlenecks on I-170 and US 67.

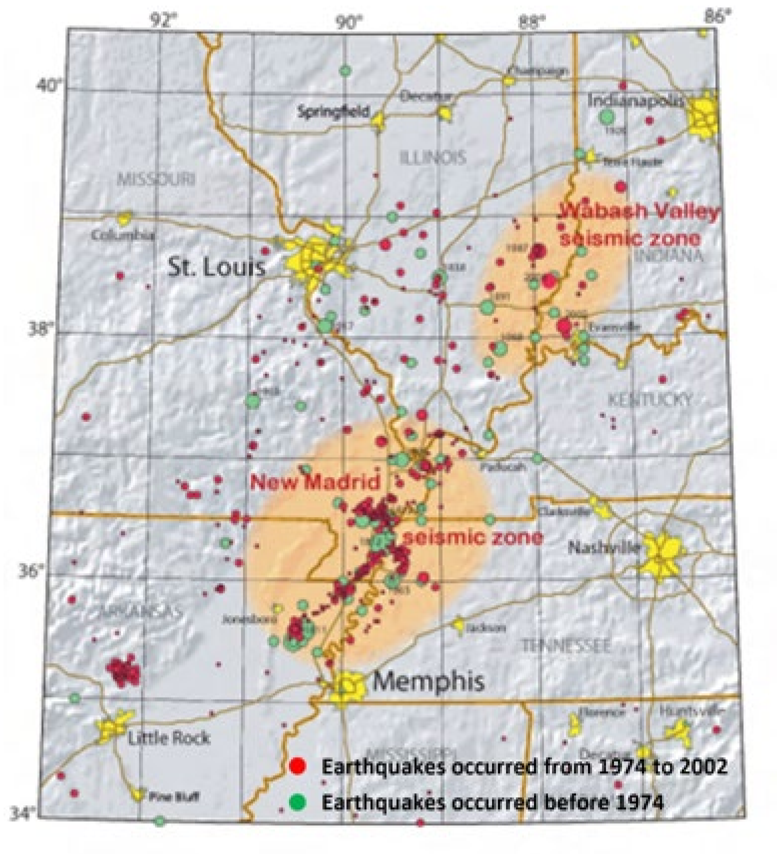
A tabletop exercise was conducted with key emergency response stakeholders in the St. Louis region to better understand coordination and communication needs during an earthquake response. The stakeholders included Missouri Department of Transportation (MoDOT), local law enforcement, local emergency management, health care, and other pertinent agencies. The exercise covered effective communication, coordination needs, anticipated infrastructure damage, and essential support resources. Participants emphasized the importance of comprehensive support covering food, water, and medical services, combined with challenges related to supply chain management and infrastructure issues (e.g., communication systems) to address emergency response effectively.

This study aims to equip stakeholders with tools for effective response, aiding emergency responders, urban planners, and policymakers in minimizing the impact of an earthquake in the St. Louis region.

Chapter 1. Introduction

Background and Motivation

Emergency preparedness and response are critical to saving lives and minimizing human suffering during and after natural disasters. The St. Louis metropolitan region is vulnerable to large earthquakes in the New Madrid Seismic Zones (NMSZ) and Wabash Valley Seismic Zones (WVSZ) in addition to scattered seismicity east and south of the region. Figure 1 shows the locations of magnitude 2.5 and above earthquakes that have occurred in the New Madrid and Wabash Valley seismic zones. The red circles show the earthquakes that occurred between 1974 and 2002 while the green circles show the ones that occurred before 1974. The combination of high frequency and magnitude (circle size in the picture) of earthquakes make the St. Louis region particularly vulnerable. The large population, substantial population density, numerous river crossings, and unreinforced building construction practices increase the potential for significant damages and difficulty of recovery operations in the St. Louis region. Emergency response, evacuation, and restoration will also be constrained by the damage to roadway infrastructure, particularly to bridges.



(USGS)

Figure 1. Previous Earthquakes in the New Madrid and Wabash Valley Seismic Zones with magnitude larger than 2.5

Objective and Methodology

The primary goal of this project is to assist the Missouri Department of Transportation (MoDOT) in planning and responding to earthquakes affecting the St. Louis region. The project involves a structured approach encompassing several key steps.

First, citizen surveys were created and distributed to understand evacuation decisions during severe earthquakes. Second, the impact of an earthquake on the road network was assessed. This information was used in a traffic evacuation model to study the traffic impacts of a compromised road network during an evacuation. The evacuation model was developed for two periods (A.M. and P.M.) using the base travel demand model provided by the East-West Gateway Council of Governments (EWG). The comparative analysis, incorporating various scenarios and simulation results, aimed to identify bottlenecks and congestion points across the St. Louis region.

Finally, a tabletop exercise was designed and implemented in St. Louis with participation from several emergency management and earthquake response stakeholders. The exercise focused on communication and coordination needs across agencies and the public to effectively respond to an earthquake.

Chapter 2. Literature Review

This chapter provides an overview of existing literature regarding emergency preparedness and responses to earthquakes including research about the New Madrid Seismic Zone (NMSZ), research studies, and emerging research.

The NMSZ affects eight states including Missouri, Illinois, Indiana, Kentucky, Tennessee, Alabama, Mississippi, and Arkansas. Among these states, three states (Tennessee, Arkansas, and Missouri) are expected to have major impacts from an earthquake. There could be extensive damage and substantial travel delays in both Memphis, Tennessee, and St. Louis, Missouri, thus hampering search and rescue as well as evacuation.

Recently, the Federal Emergency Management Agency (FEMA) and Missouri State Emergency Management Agency (SEMA) developed the NMSZ Earthquakes Interagency Operations Plan. The purpose of the plan is to provide an overall framework for key decision-makers and partners to successfully respond to an earthquake in the region (FEMA and SEMA, 2018).

Extensive research has been conducted on understanding the behavior of evacuees during advance-notice events such as hurricanes. The literature includes studies that examine various aspects of evacuation, such as destination choice during evacuations (Charnkol et al., 2007; Liu et al., 2008), the timing of evacuations (Fu et al., 2004; Dixit et al., 2012; Hasan et al., 2013), and the selection of evacuation routes (Robinson and Khattak, 2010; Wu et al., 2012; Chang et al., 2021). These studies have shown that socio-demographic factors such as age, gender, income level, number of children in the household, and evacuation-related factors such as evacuation orders, previous evacuation experience, and perception of risk influence evacuation behavior. Some of the factors are found to be critical to determining destination choice (e.g., relative's home or public shelters), time to evacuate (e.g., time of day, day of the week), vehicle usage, and preference of routes (e.g., freeways or local roads).

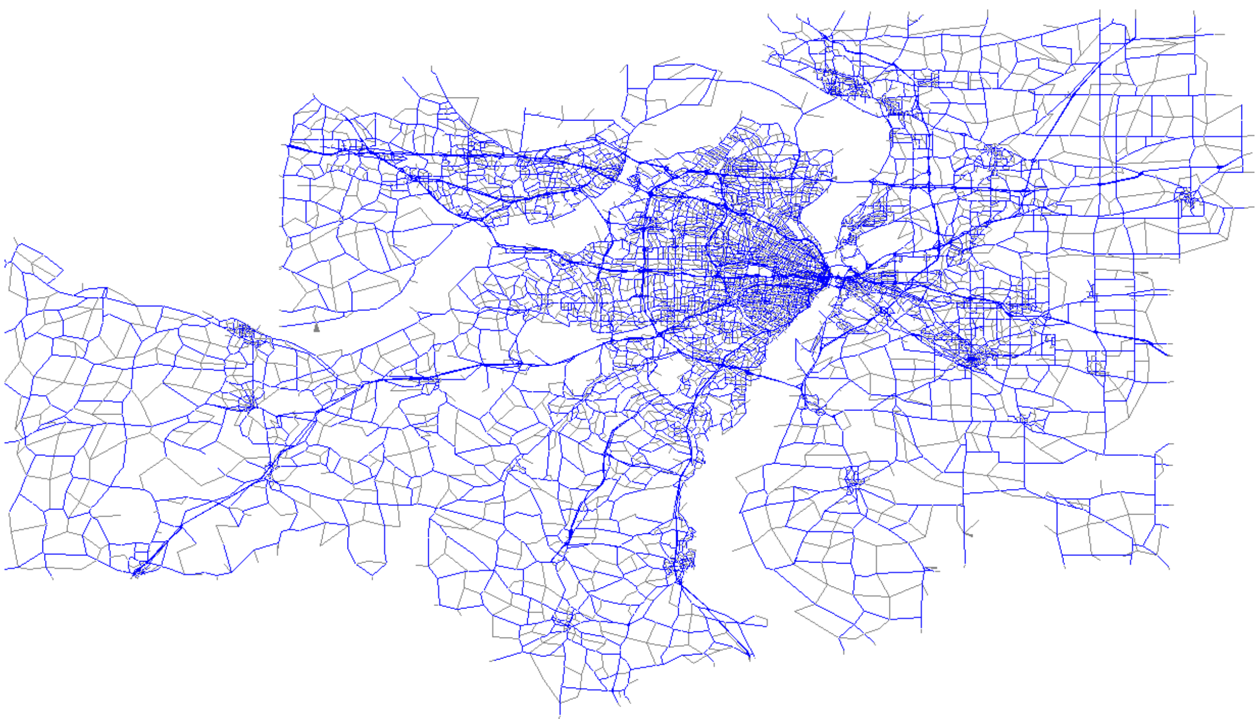
Although there have been many studies about evacuation decisions for advance-notice events, few studies have studied evacuation behavior for no-notice events such as earthquakes. Chiu et al. (2007) investigated no-notice evacuation with joint decision-making. They showed that optimal decisions can be made in a unified optimization model by simultaneously solving decisions about evacuation destination, traffic assignment, and departure schedule. Hsu and Peeta (2013) utilized a joint model for choosing evacuation decision and route choice. They found that the proposed model to capture evacuation behavior during terrorist attacks, incorporating fuzzy logic into a mixed logit model, performed better. Liu et al. (2012) proposed a logit model to identify households' child pick-up behavior during no-notice events. They found that traffic would be underestimated if daytime trips to pick up the children were ignored. Liu et al. (2014) indicated that considering family gatherings and mode selection in unexpected evacuation modeling for hypothetical disasters results in completely different evacuation times. Golshani et al. (2019) investigated evacuation decision behavior during no-notice events. Using clustering analysis, they identified several factors influencing evacuees' behavioral decisions. However, since their survey did not mention the types of disasters.

Chapter 3. Evacuation Model

Overview

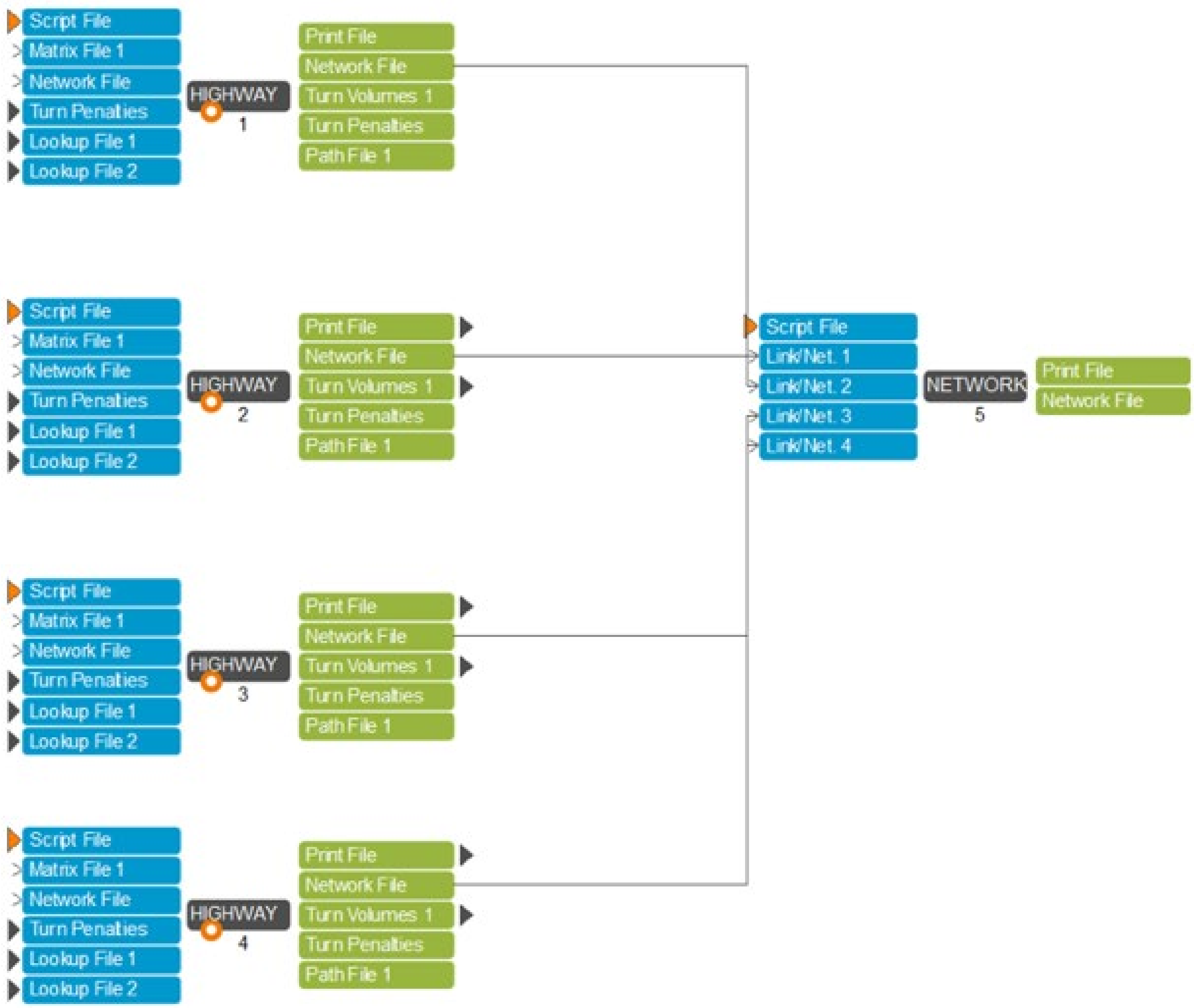
Evacuation models are crucial for managing and planning the safe and efficient movement of people away from vulnerable regions during emergencies. A travel demand model is used for various transportation planning applications including special events. In this study, the East-West Gateway Council of Government's travel demand model for the St. Louis region was used as the base model to study various evacuation scenarios. The base model contains various types of data, including transportation network data as well as travel demand data with several origin-destination (O-D) matrices for normal conditions (i.e., not for earthquake conditions).

Road network data including road hierarchy, number of lanes, capacity, speed limit, and segment length were provided as part of the model. The entire network has 48,151 links and 3,003 traffic analysis zones. A screenshot of the road network is shown in Figure 2. The overall model structural representation of the model in the CUBE software is shown in Figure 3.



(Figure obtained by CUBE Voyager software)

Figure 2. Road network near the St. Louis region



(Figure obtained by CUBE Voyager software)

Figure 3. Simulation environment in CUBE software

The daily trip matrix consists of four different time periods - A.M., Off-Peak (OP), P.M., and Night-Time (NT). Thus, the traffic performance can be obtained for four different time periods. Also, the demand was classified into three different types of vehicles: low occupancy vehicle (LOV), high occupancy vehicle (HOV), and Truck. A screenshot of the partial O-D matrix is shown in Figure 4.

*1 LOVAM | 2 HOVAM | 3 TRKAM | 4 LOVOP | 5 HOVOP | 6 TRKOP | 7 LOVPM | 8 HOVPM | 9 TRKPM | 10 LOVNT | 11 HOVNT | 12 TRKNT

	1	2	3	4	5	6	7	8	9	10
1	2.92	2.67	0.12	0.85	0.63	2.54	1.00	0.89	1.19	0.94
2	3.55	46.98	0.18	1.80	0.92	3.27	1.70	1.53	1.49	0.98
3	0.23	0.27	1.31	0.12	0.56	1.08	0.13	0.13	0.23	0.16
4	1.65	2.49	0.12	5.73	0.78	2.92	0.56	0.53	0.88	0.58
5	0.48	0.51	0.24	0.35	2.22	4.39	0.38	0.36	0.79	0.40
6	2.73	2.60	0.56	1.65	5.67	16.78	2.13	2.09	4.83	2.49
7	1.58	1.88	0.11	0.42	0.67	2.76	1.95	2.57	1.67	1.15
8	1.04	1.32	0.08	0.31	0.51	2.13	1.91	1.55	1.41	0.91
9	2.25	1.95	0.20	0.79	1.39	6.69	2.49	2.63	9.30	3.91
10	0.85	0.70	0.08	0.29	0.47	2.18	0.68	0.71	2.02	1.02
11	0.01	0.02	0.07	0.01	0.03	0.06	0.01	0.01	0.01	0.01
12	9.21	7.75	0.53	4.30	2.26	9.99	4.14	3.36	5.08	3.31
13	0.46	0.52	2.22	0.31	1.10	2.13	0.26	0.27	0.51	0.32
14	0.32	0.20	0.01	0.06	0.09	0.38	0.10	0.10	0.12	0.10
15	0.02	0.17	0.01	0.02	0.01	0.03	0.02	0.02	0.02	0.01
16	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.34	0.86	0.01	0.14	0.06	0.23	0.17	0.14	0.14	0.08
18	0.24	0.74	0.01	0.11	0.04	0.17	0.16	0.13	0.13	0.08
19	1.58	4.49	0.14	2.75	0.62	2.37	0.54	0.53	0.79	0.62
20	0.04	0.14	0.00	0.10	0.02	0.06	0.02	0.02	0.03	0.02

(Figure obtained by CUBE Voyager)

Figure 4. O-D matrix in CUBE software

Evacuation Demand

While the baseline model consists of demand data for normal conditions, new demand matrices were generated to reflect travel demand during earthquake conditions. A survey was designed and deployed in the study region to help determine evacuation demand information.

Survey

An online survey was conducted to obtain information on evacuee behavior. The survey sought responses from individuals living in any of the eight counties (five in Missouri, three in Illinois) in the St. Louis metropolitan region. The survey was approved by the University of Missouri's Institutional Review Board (IRB) and deployed via Qualtrics software. The survey consisted of 42 questions including the following questions about evacuation decision-making by individuals:

- How likely is that you and your family will be impacted by an earthquake in the next five years?
- Have you ever experienced an earthquake?
- If an earthquake was going to impact your neighborhood, what would you be most likely to do? Evacuate, shelter in home, etc.
- If you evacuated, where would you go, what road would you take?
- How many personal vehicles does your household have available for use in an evacuation?

The survey was advertised primarily using MoDOT and FEMA social media and local news media. Figure 5 shows a screenshot of the social media post by MoDOT.

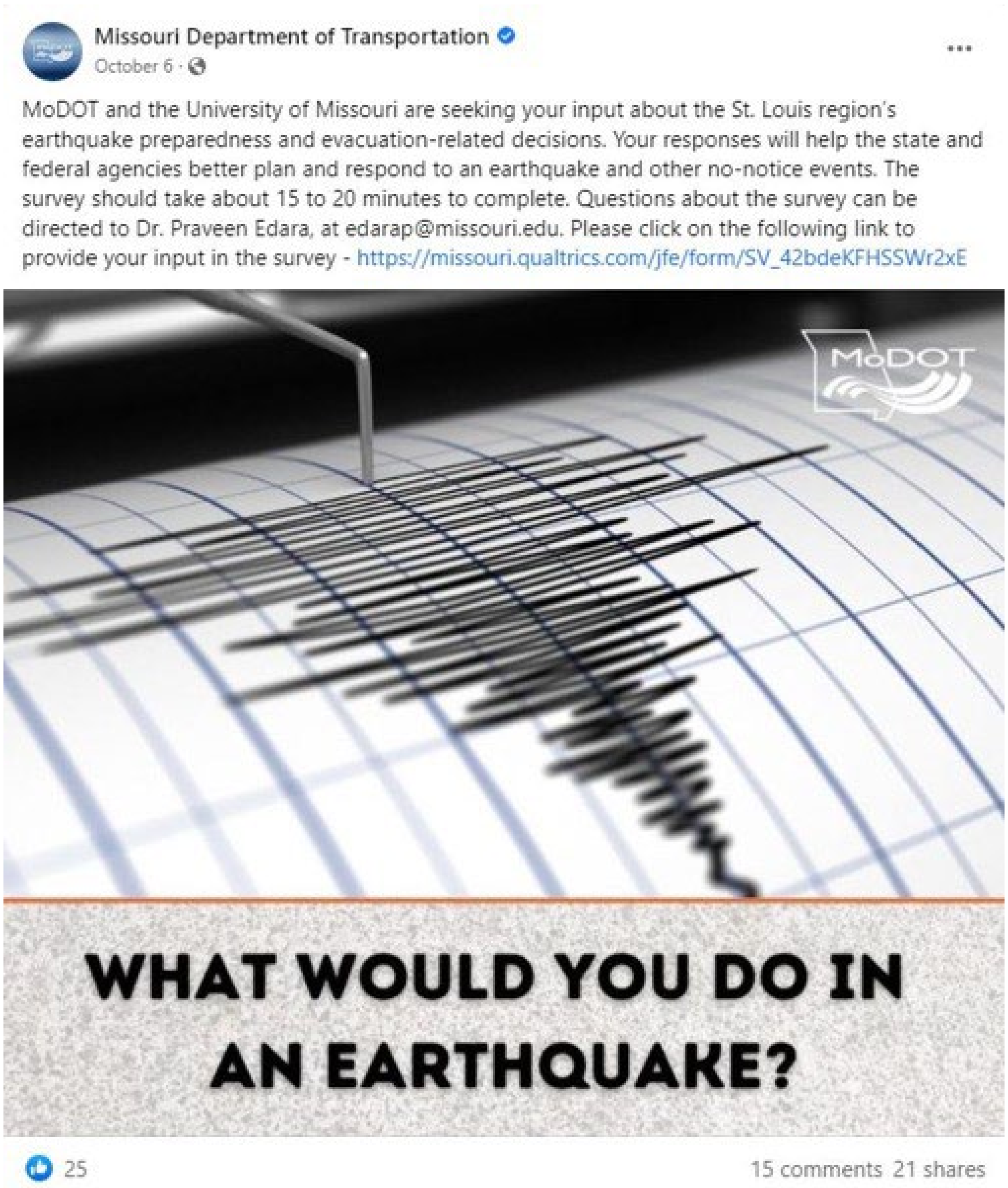


Figure 5. Survey distribution via social media

The survey was available for a month during which 149 responses were received. Table 1 shows the Census 2020 population for each county, the percentage of county population in the region, and the number (percentage) of survey responses received from each county. The higher number of responses from Missouri counties was expected as the survey was primarily marketed using MoDOT social media.

Table 1. Survey Responses by County

County Name	Population (Census 2020)	Percentage of Population in Region	Sample Size	Percentage of Total Responses
Jefferson (MO)	226,739	8.7%	22	14.8%
Franklin (MO)	104,682	4.0%	11	7.4%
St. Charles (MO)	405,262	15.6%	27	18.1%
St. Louis City (MO)	301,570	11.6%	14	9.4%
St. Louis (MO)	1,004,125	38.7%	65	43.6%
Madison (IL)	264,776	10.2%	3	2.0%
Monroe (IL)	35,033	1.4%	0	0.0%
St. Clair (IL)	252,671	9.7%	7	4.7%

A summary of responses to the survey questions is presented next. When asked about the likelihood of being impacted by an earthquake in the next five years, 29 percent of respondents said likely or very likely, 39 percent were unsure, and 32 percent said unlikely or very unlikely (see in Figure 6).

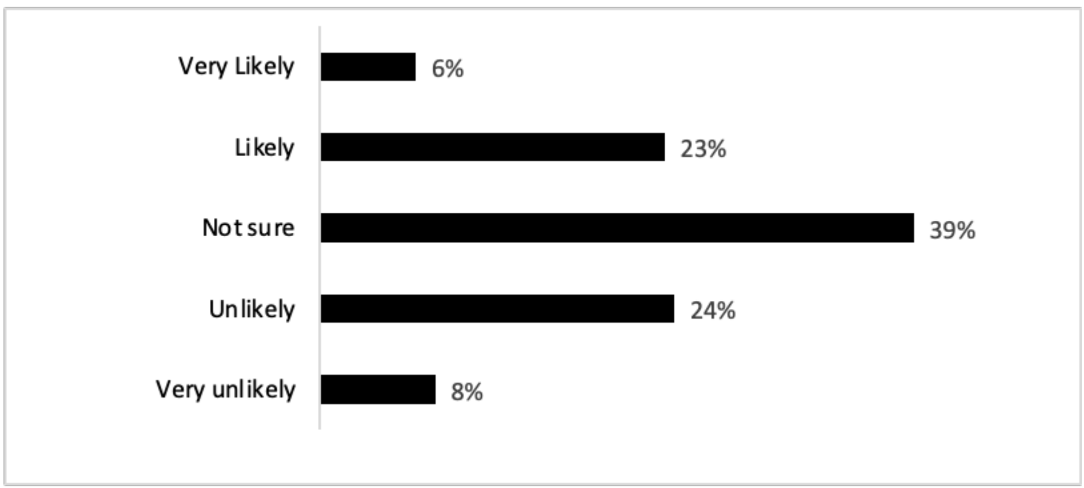


Figure 6. Likelihood of being impacted by an earthquake in the next five years (N= 149)

Figure 7 shows the earthquake impacts experienced in the past by these respondents with twelve percent indicating experiencing disruption to daily life, eight percent experiencing property damage, and two percent experiencing injury.

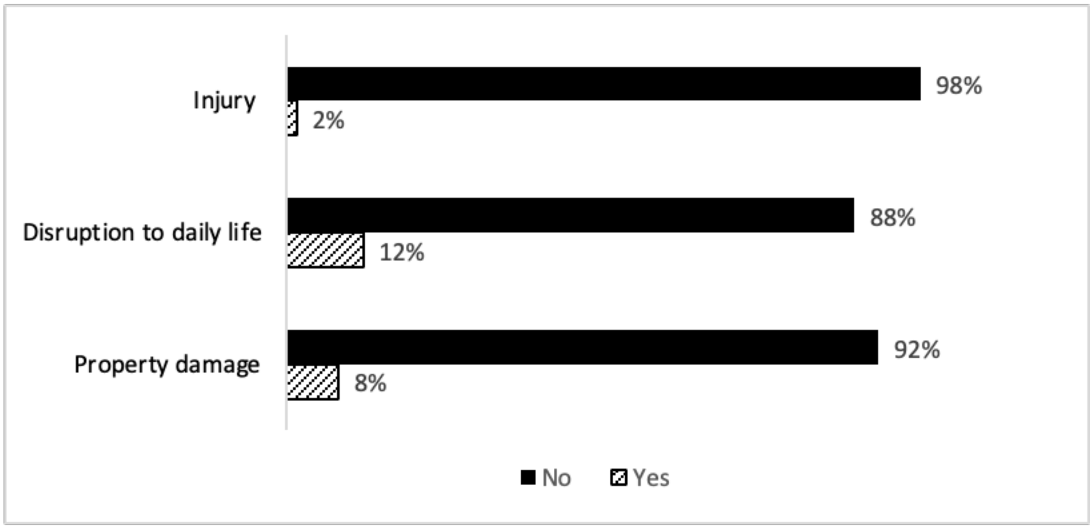


Figure 7. Impacts during any prior earthquake experience (N= 149)

When asked about their preferred destinations, 54 percent said they would go to a relative's or friend's home, 13 percent to a hotel/motel/inn, 11 percent to a shelter, and 7 percent to a second home. Fifteen percent of the respondents said "other" (Figure 8).

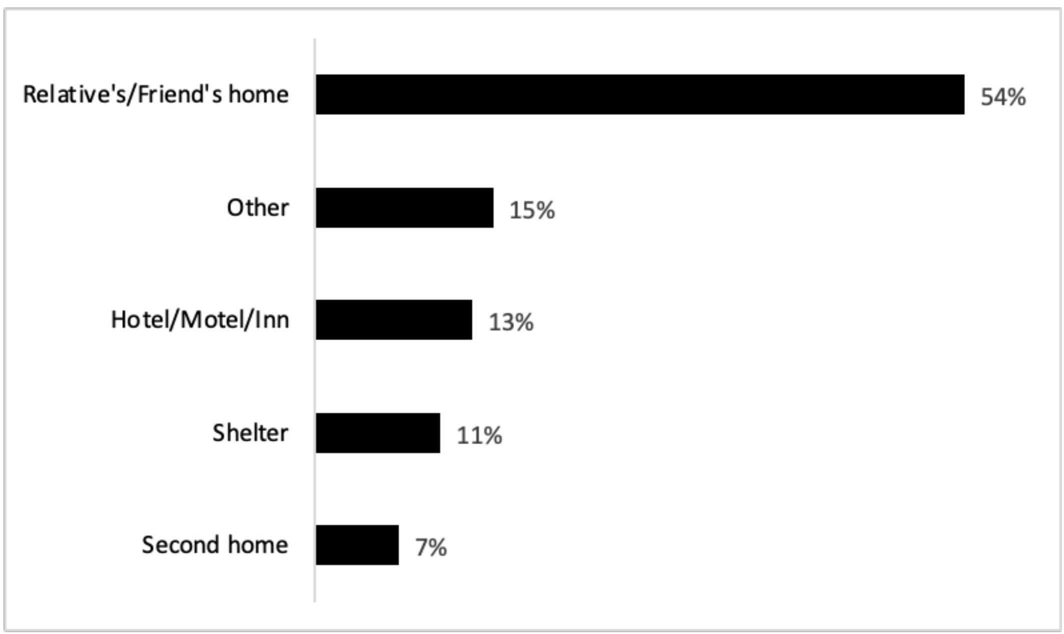


Figure 8. Preferred destination type for evacuation (N= 114)

Figure 9 illustrates the distribution of evacuation time preferences among evacuees regarding their intended departure to preferred destinations following an earthquake. The data reveals that a majority of respondents, 56 percent, plan to evacuate within the first 3 hours. Twenty-six percent indicated a preference for evacuating between 3 to 6 hours. A further 10 percent would evacuate to between 6 and

12 hours, while only 4 percent would wait between 12 and 24 hours. Another 4 percent stated they would evacuate more than 24 hours after the earthquake.

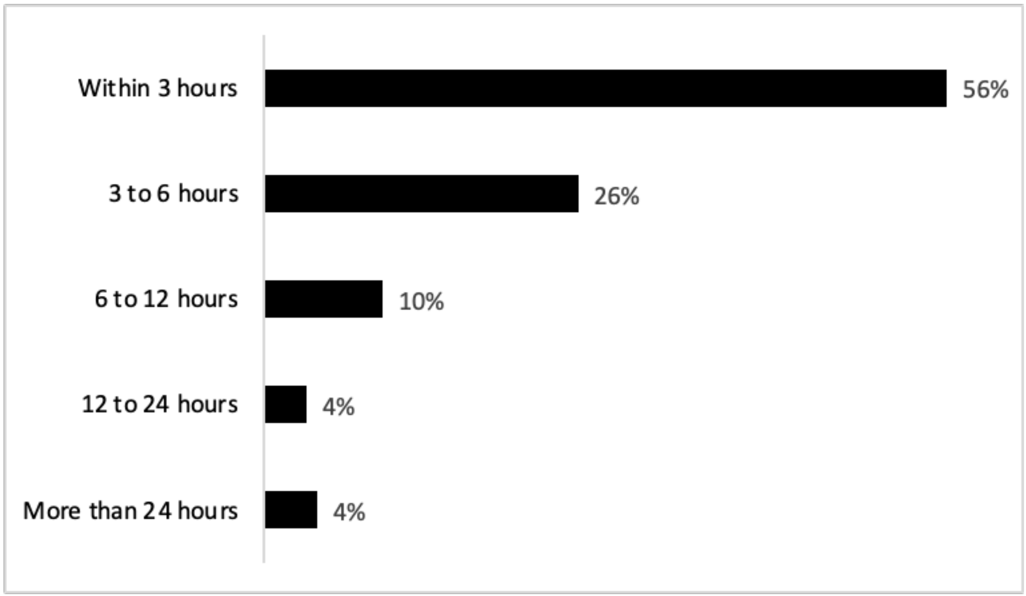


Figure 9. Preferred departure time of evacuation (N= 112)

When asked what type of roadway they preferred to travel on, 54 percent preferred freeway, 17 percent chose major roads with traffic signals, 18 percent selected local roads, and 12 percent were unsure (see Figure 10).

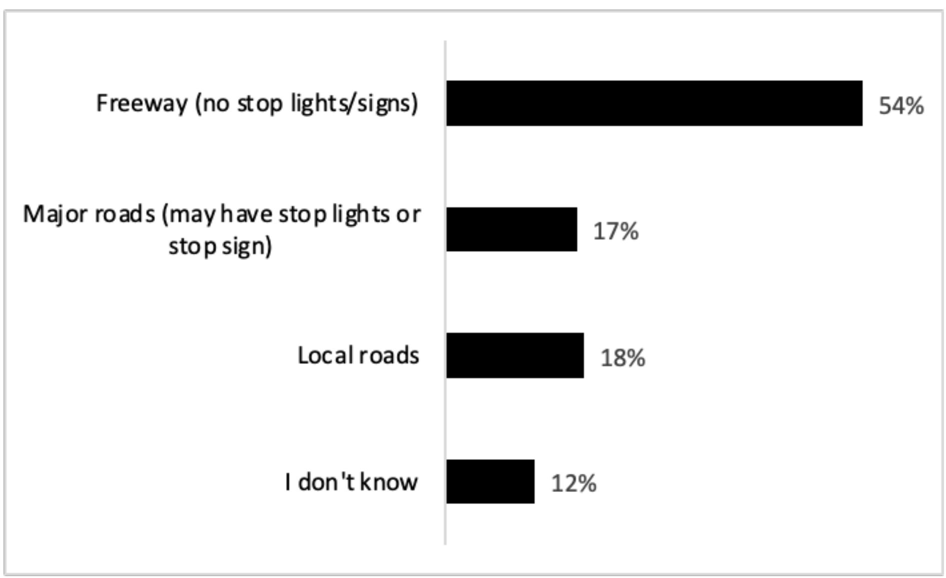


Figure 10. Preferred roadway type for evacuation (N= 112)

Figure 11 shows the response to compliance with official evacuation routes recommended by government agencies. Eighty-six percent of the respondents stated that they would or probably use the recommended route while 11 percent said they would probably not or would not use the recommended route.

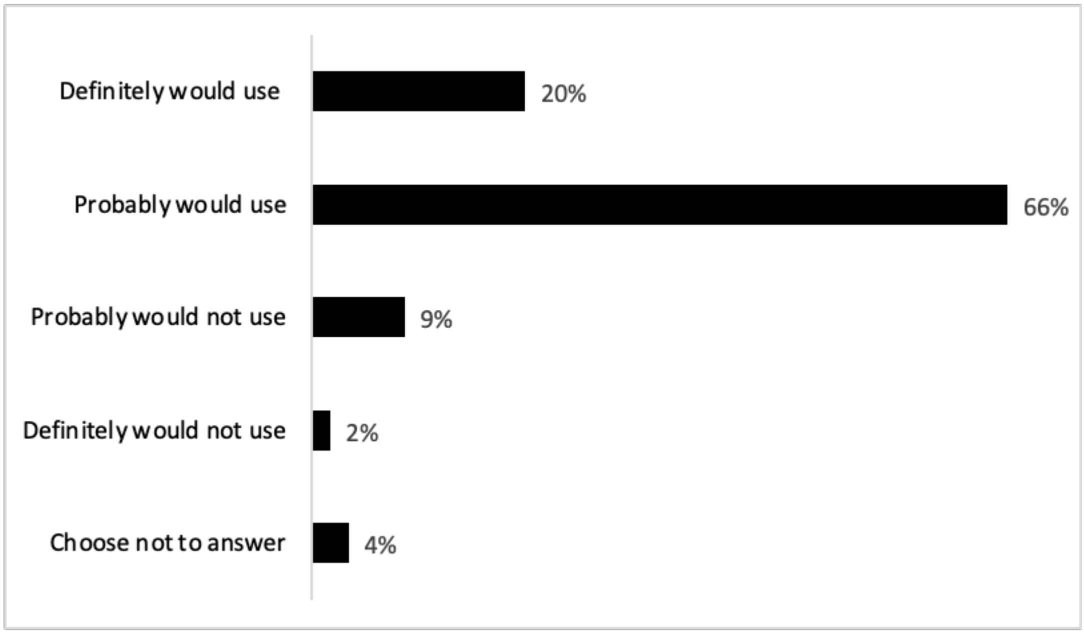


Figure 11. Compliance with official recommended routes for evacuation (N= 114)

When asked about vehicle availability in determining the number of evacuation trips taken by a household. Figure 12 shows that most of the respondents (65 percent) have one vehicle available for evacuation. Twenty-six percent said they had two vehicles while 5 percent said they had three or more vehicles available for evacuation. The remaining 4 percent said they were unsure.

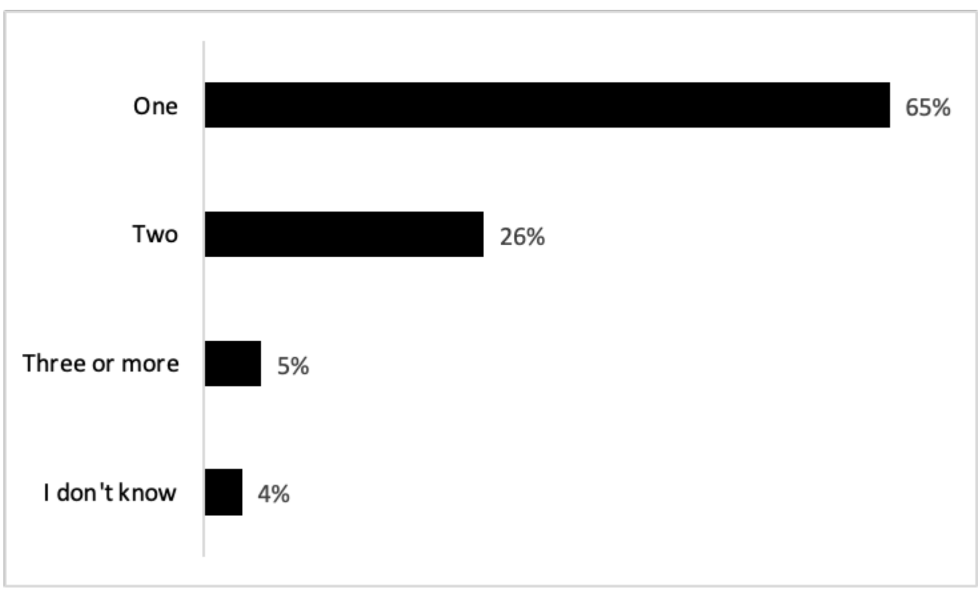
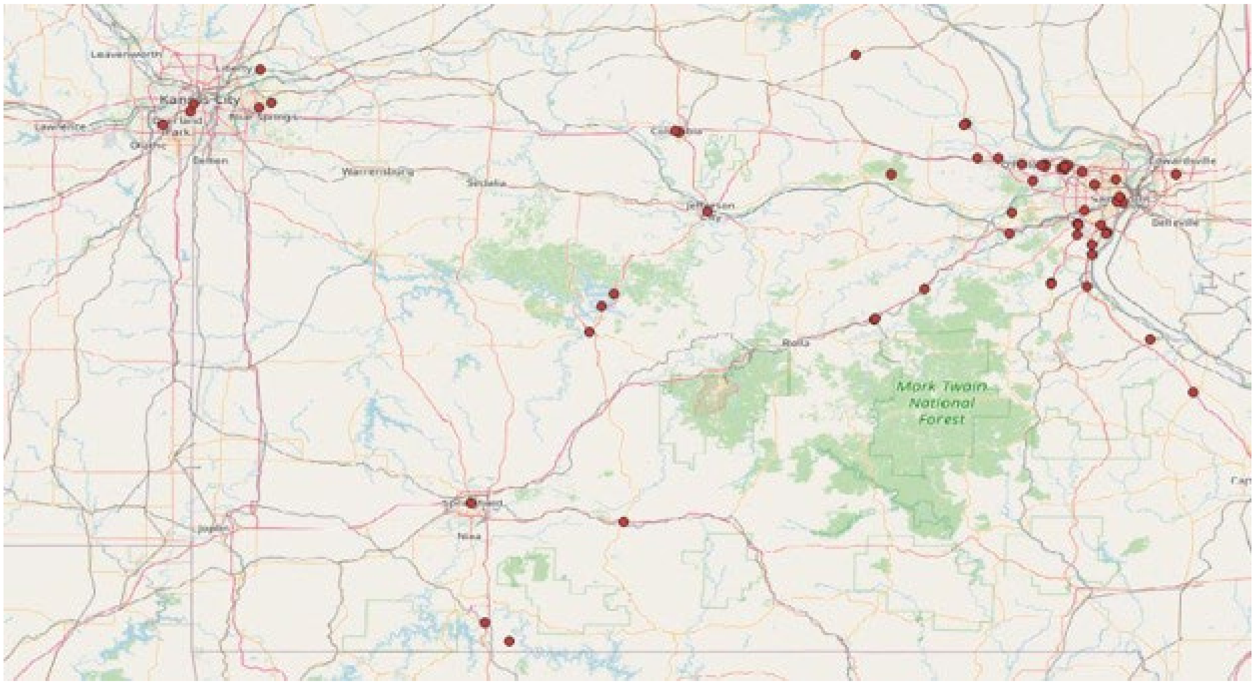


Figure 12. Personal vehicle availability for evacuation (N= 110)

The survey asked the respondents to provide the preferred destinations in a mandatory evacuation. The map of the destinations is displayed as a red dot in Figure 13. Most of the respondents plan to stay within the St. Louis region with some evacuating west out of the region.



(Map created by Quantum Geographic Information System with obtained survey data)
Figure 13. Map showing destination choices for evacuation trips in a mandatory evacuation (N= 82)

In addition to the preferred destination, respondents were also asked to provide their preferred route they would take to reach their destination. A word cloud of the routes is shown in Figure 14. The size of the word indicates the relative number of responses with larger font size words indicating higher number of responses. For example, I-70 was selected by more individuals than US 30.

(Figure created by R programming word cloud package)
Figure 14. Word Cloud of route choices for evacuation trips in a mandatory evacuation (N= 105)

Demand Curve

The hourly distribution of demand for baseline and earthquake conditions are shown in Figure 15. Survey data was used to generate the curves for two earthquake event times - 7 A.M. and 4 P.M. Based on the survey, 56 percent of respondents would evacuate within 3 hours of an earthquake, 26 percent would evacuate between 3 to 6 hours, and the rest would evacuate afterwards. This surge in demand can be seen in the earthquake demand curves in Figure 15.

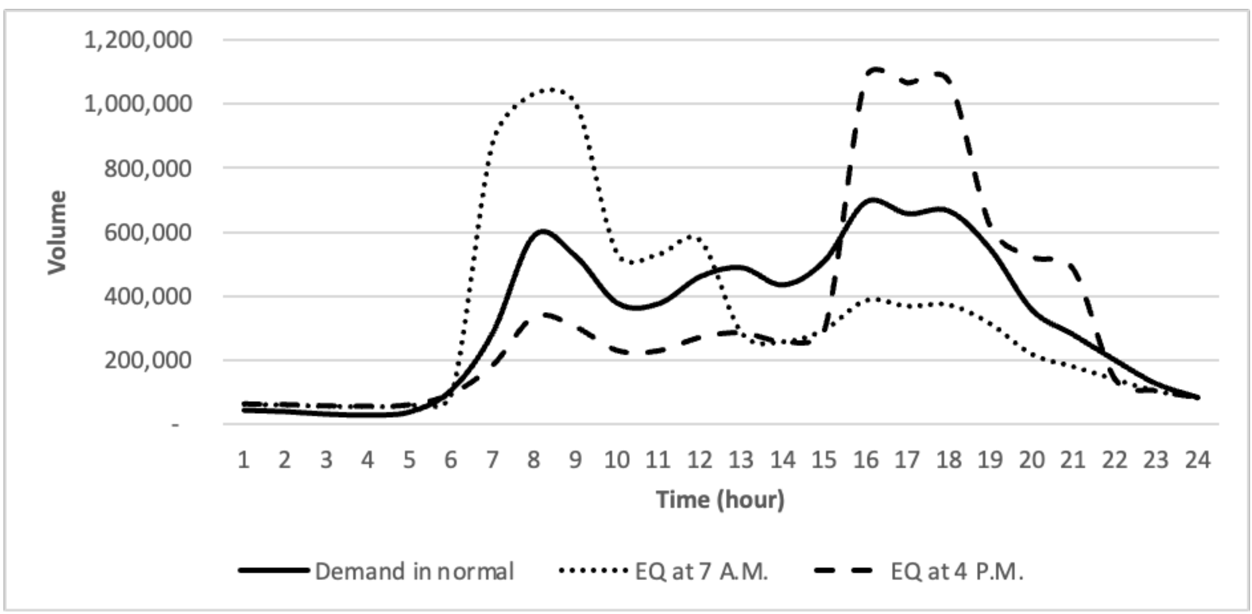
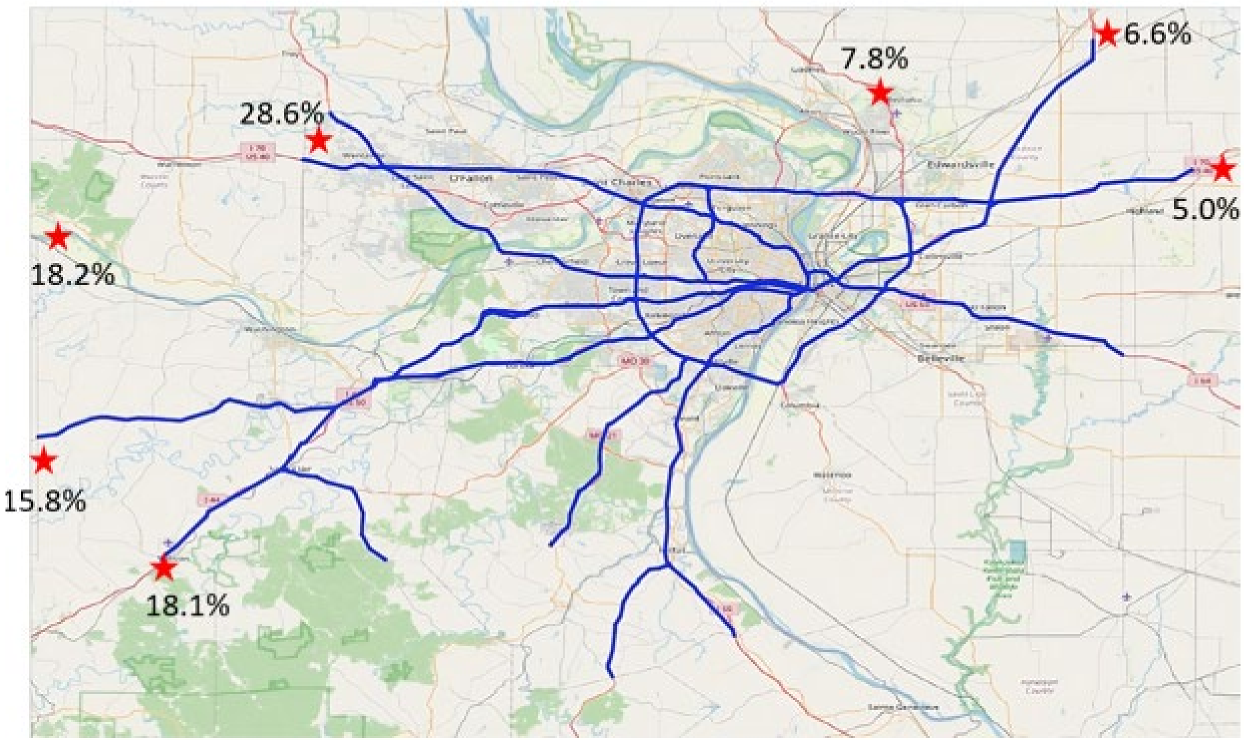


Figure 15. Travel demand curve for evacuation scenarios

Evacuation Destinations

Based on the survey responses and feedback from MoDOT's emergency management leadership, all evacuees were expected to leave the study region. Thus, seven super zones at the edge of the study region were created (shown as red stars in Figure 16). The demand to each destination was proportional to the distance from the origin zone. Figure 16 also shows (in blue) designated priority routes that evacuees are expected to use during an evacuation.



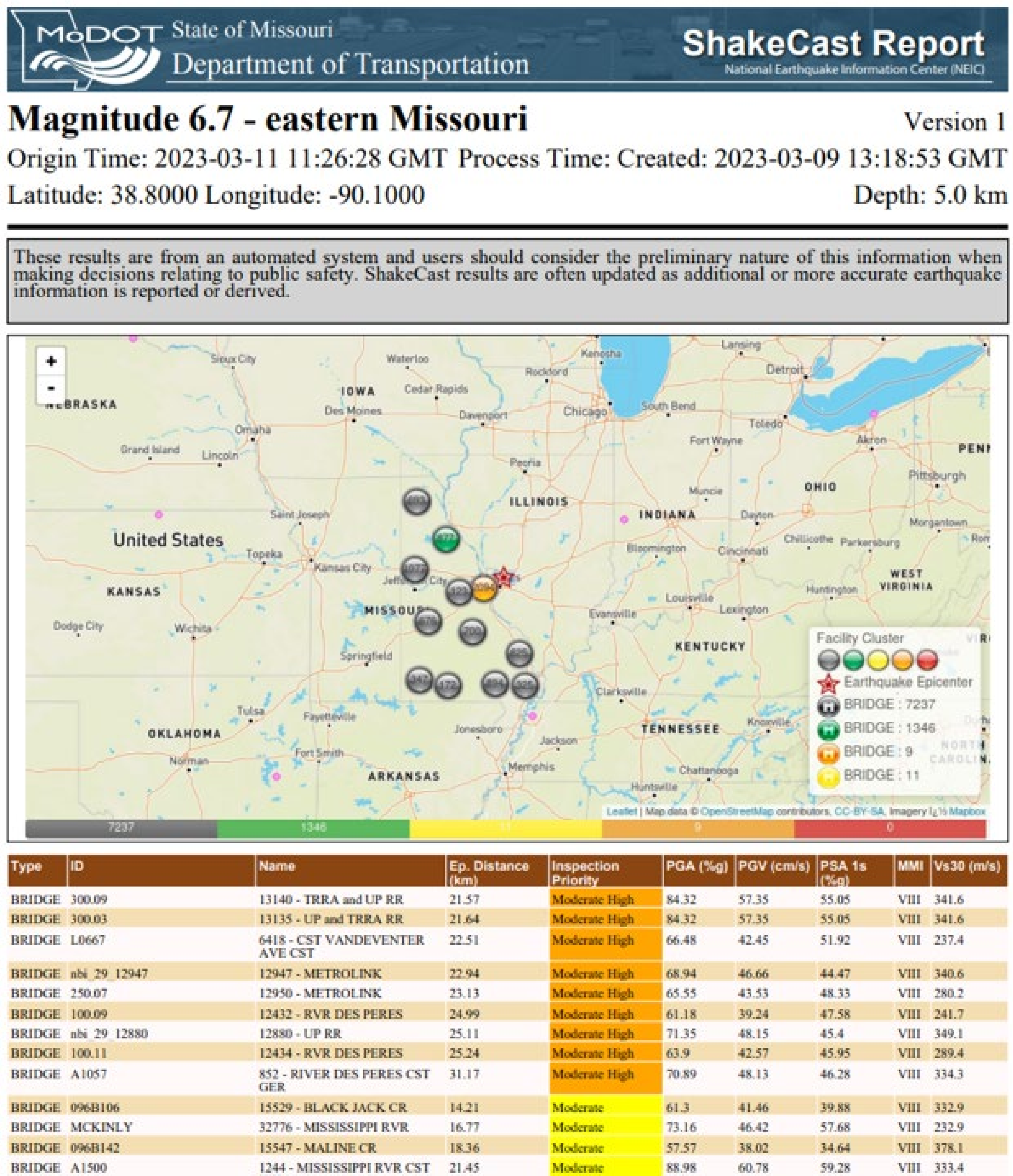
(Map created by Quantum Geographic Information System with manipulating zone data)

Figure 16. Super zone destination with priority routes in the study region

Network Vulnerability

The United States Geological Survey (USGS) has developed the ShakeCast tool in partnership with several state DOTs to assess the damage to bridges after an earthquake. ShakeCast uses National Bridge Inventory (NBI) data to assess bridge vulnerability and produce ShakeMap data containing information of bridges that might need immediate attention after an earthquake.

In this study, the research team requested USGS staff to run ShakeCast for an earthquake of magnitude 6.7 with epicenter inside the St. Louis region. Figure 17 shows a screenshot of the ShakeCast output showing bridges with different inspection priorities (based on expected damage). Seventy-eight bridges experienced moderate-high level of damage, displayed in orange color in Figure 17, whereas 27 bridges are expected to experience moderate level of damage, shown in yellow. The exact locations of the impacted bridges are shown in Figure 18. This bridge information was used in the travel demand model to study the impact of a damaged network on evacuation operations.



MoDOT State of Missouri Department of Transportation

ShakeCast Report

National Earthquake Information Center (NEIC)

Magnitude 6.7 - eastern Missouri Version 1

Origin Time: 2023-03-11 11:26:28 GMT Process Time: Created: 2023-03-09 13:18:53 GMT

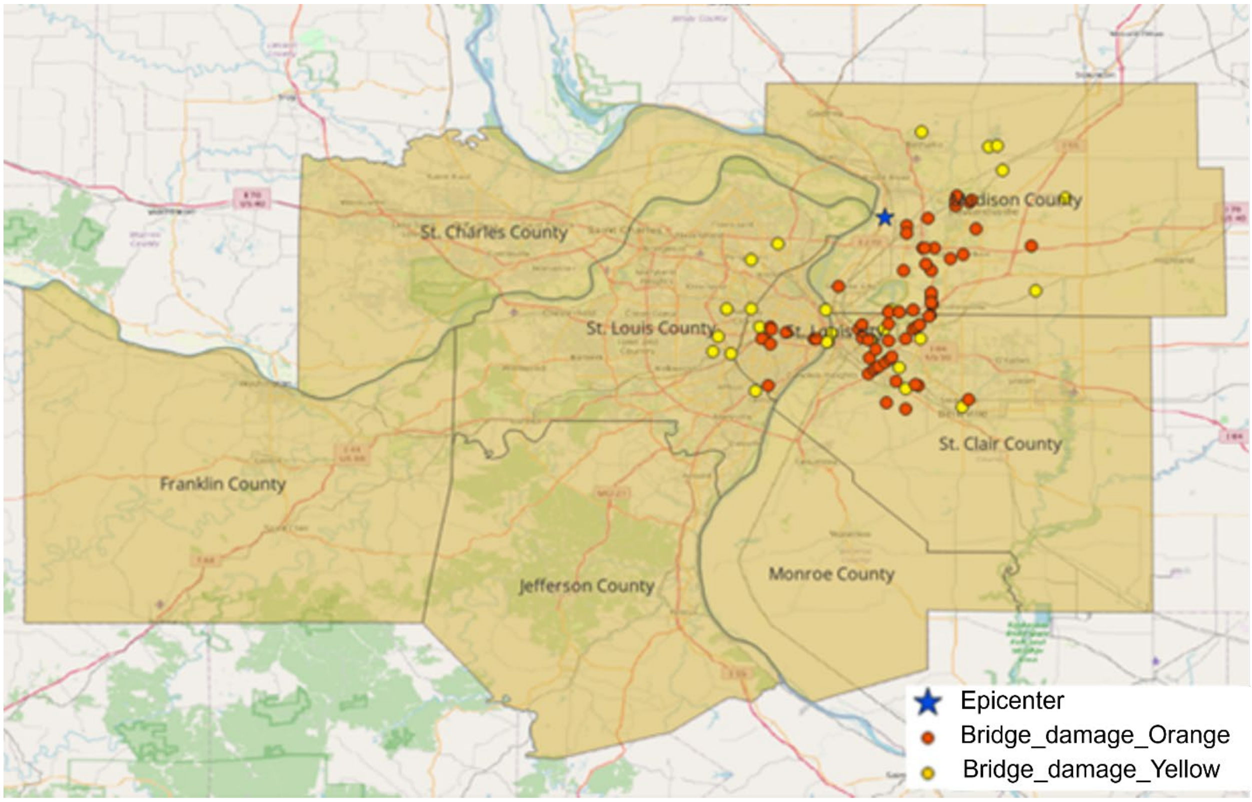
Latitude: 38.8000 Longitude: -90.1000 Depth: 5.0 km

These results are from an automated system and users should consider the preliminary nature of this information when making decisions relating to public safety. ShakeCast results are often updated as additional or more accurate earthquake information is reported or derived.

Type	ID	Name	Ep. Distance (km)	Inspection Priority	PGA (%g)	PGV (cm/s)	PSA 1s (%g)	MMI	Vs30 (m/s)
BRIDGE	300.09	13140 - TRRA and UP RR	21.57	Moderate High	84.32	57.35	55.05	VIII	341.6
BRIDGE	300.03	13135 - UP and TRRA RR	21.64	Moderate High	84.32	57.35	55.05	VIII	341.6
BRIDGE	L0667	6418 - CST VANDEVENTER AVE CST	22.51	Moderate High	66.48	42.45	51.92	VIII	237.4
BRIDGE	nbi_29_12947	12947 - METROLINK	22.94	Moderate High	68.94	46.66	44.47	VIII	340.6
BRIDGE	250.07	12950 - METROLINK	23.13	Moderate High	65.55	43.53	48.33	VIII	280.2
BRIDGE	100.09	12432 - RVR DES PERES	24.99	Moderate High	61.18	39.24	47.58	VIII	241.7
BRIDGE	nbi_29_12880	12880 - UP RR	25.11	Moderate High	71.35	48.15	45.4	VIII	349.1
BRIDGE	100.11	12434 - RVR DES PERES	25.24	Moderate High	63.9	42.57	45.95	VIII	289.4
BRIDGE	A1057	852 - RIVER DES PERES CST GER	31.17	Moderate High	70.89	48.13	46.28	VIII	334.3
BRIDGE	096B106	15529 - BLACK JACK CR	14.21	Moderate	61.3	41.46	39.88	VIII	332.9
BRIDGE	MCKINLY	32776 - MISSISSIPPI RVR	16.77	Moderate	73.16	46.42	57.68	VIII	232.9
BRIDGE	096B142	15547 - MALINE CR	18.36	Moderate	57.57	38.02	34.64	VIII	378.1
BRIDGE	A1500	1244 - MISSISSIPPI RVR CST	21.45	Moderate	88.98	60.78	59.28	VIII	333.4

(Figure provided by ShakeCast tools with support of USGS)

Figure 17. ShakeCast Report for magnitude 6.7 earthquake in eastern Missouri



(Map created by Quantum Geographic Information System with ShakeCast data and census data)

Figure 18. Damaged bridges and epicenter in the study region with map

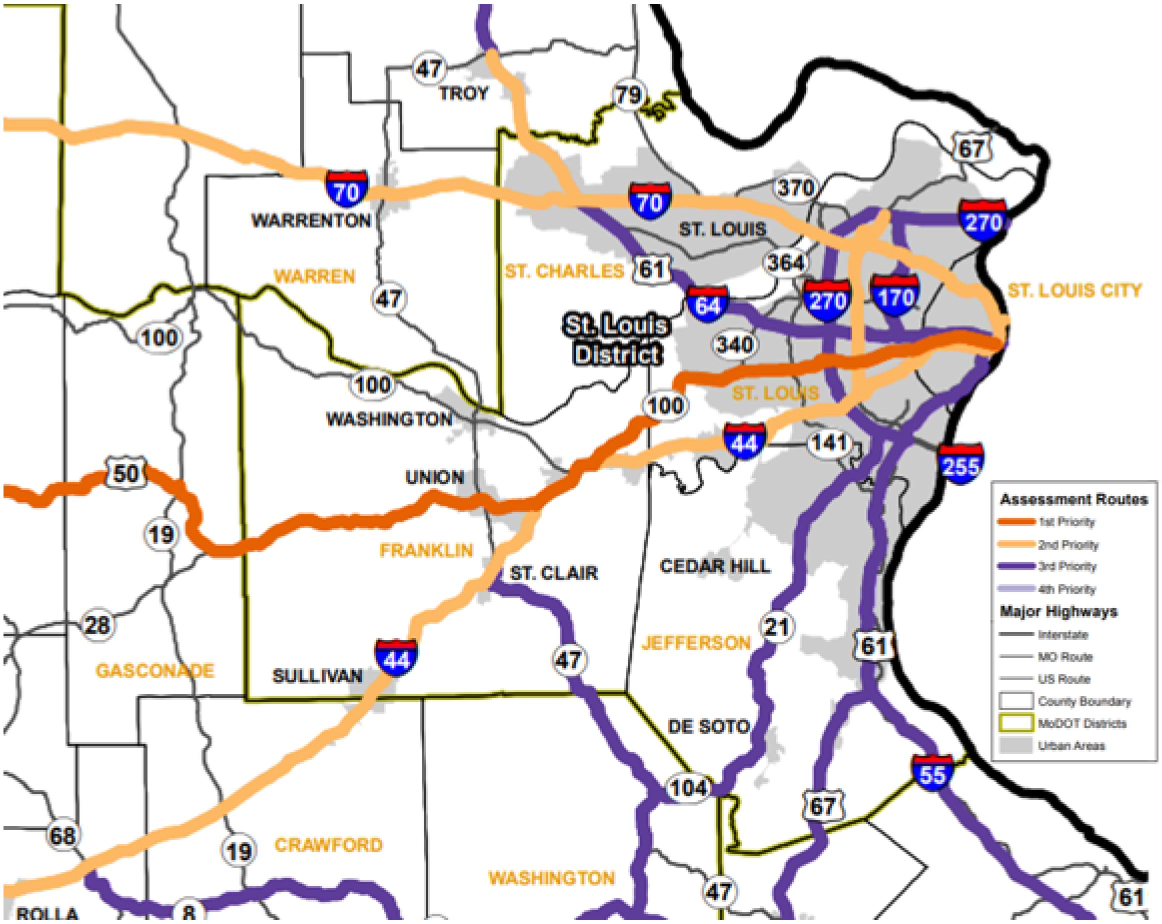
Chapter 4. Performance Evaluation of Scenarios

The impacts of a magnitude 6.7 earthquake occurring in the St. Louis region were studied using twelve evacuation scenarios. A baseline scenario assumes that the road network is intact and no roadways are damaged. Table 2 lists the baseline and 12 earthquake scenarios. Scenarios 1-4 simulate 100 percent of the normal day travel demand whereas scenarios 5-8 simulate 50 percent and scenarios 9-12 simulate 30 percent of the entire demand. The network treatment is shown in the second column of Table 2. The fourth column shows two earthquake occurrence times – 7 A.M. and 4 P.M.

Table 2. Evacuation scenarios studied in this project

Scenario	Network	Demand	Time for earthquakes
0	Baseline	Original O-D	No earthquakes
1	Baseline	100% demand	7 A.M.
2	Network Damage	100% demand	7 A.M.
3	Baseline	100% demand	4 P.M.
4	Network Damage	100% demand	4 P.M.
5	Baseline	50% demand	7 A.M.
6	Network Damage	50% demand	7 A.M.
7	Baseline	50% demand	4 P.M.
8	Network Damage	50% demand	4 P.M.
9	Baseline	30% demand	7 A.M.
10	Network Damage	30% demand	7 A.M
11	Baseline	30% demand	4 P.M.
12	Network Damage	30% demand	4 P.M.

In the travel demand model, the evacuation demand was loaded onto the road network for the 24-hour period. The evacuation was assumed to start either at 7:00 A.M. or 4:00 P.M. depending on the scenario. The performance measures (i.e., average traffic speeds) were evaluated for all designated priority routes (see Figure 19).



(Figure obtained by MoDOT EPG)

Figure 19. Missouri earthquake emergency highway routes

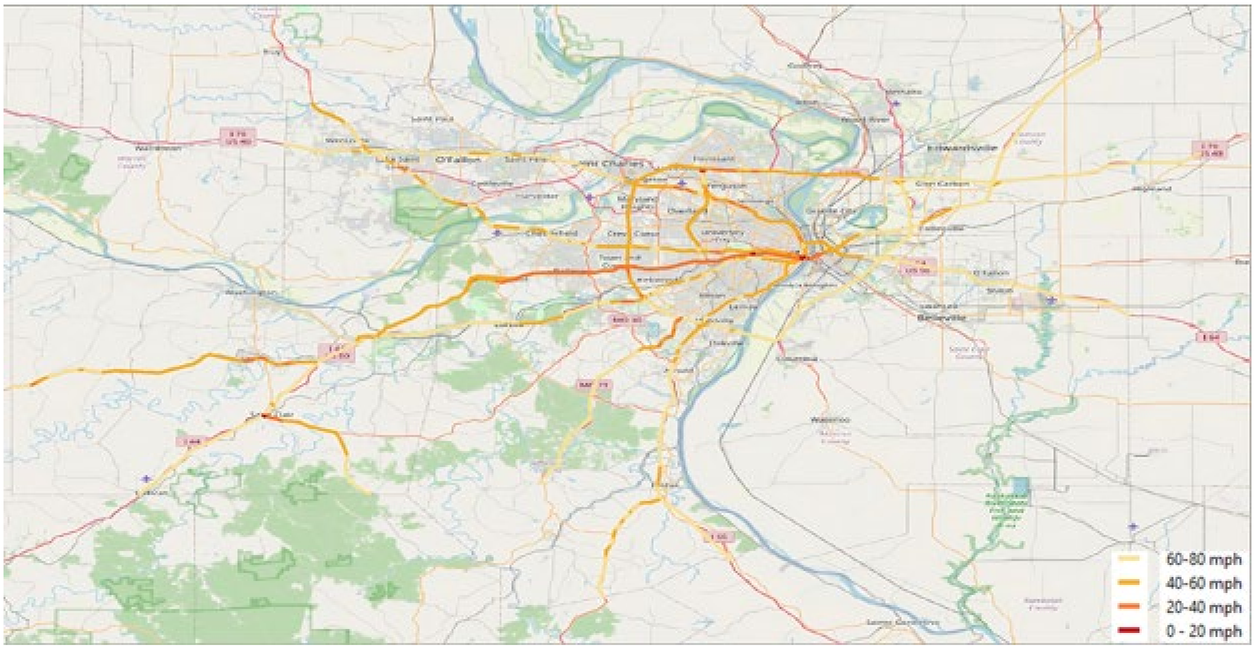
Macroscopic Evaluation

Figures 20-24 show color-coded maps for priority routes based on average operating speeds. The legend on the bottom right of each figure shows the speed interval for each color. These maps represent the average conditions throughout the 24-hour period. Figure 20 shows the average speed for the entire day for scenario 0 (baseline with normal demand). Figures 21 to 24 illustrate the outcomes of simulations conducted under 100 percent demand conditions. Figure 21 depicts the average speed results for scenario 1, representing the baseline network with a 100 percent evacuation demand. Most priority routes display severe congestion, with average speeds falling below 20 miles per hour (mph.

Figure 22 shows the average speed results for scenario 2, incorporating a damaged network and 100 percent demand during the earthquake at 7 AM. As is expected, compared to the baseline network, traffic movement in a compromised network is generally worse. Average speeds decreased noticeably on I-55 and I-170.

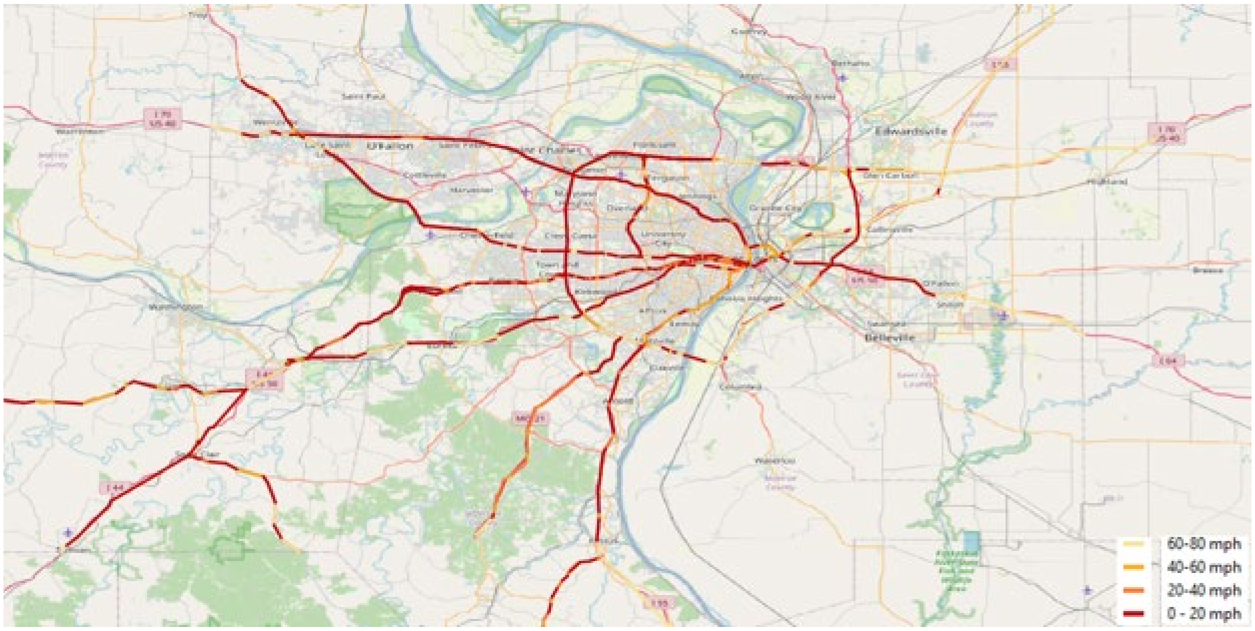
Figure 23 presents the average speed results for scenario 3, featuring the baseline network and a 100 percent demand during an earthquake at 4 P.M. When comparing scenario 3 with scenario 1 (same network condition but earthquakes occurring at different times), scenario 3 appeared to have less congestion than in scenario 1. However, there was still significantly more congestion than with the network intact.

Finally, Figure 24 details the average speed outcomes for scenario 4, involving a damaged network and 100 percent travel demand during an earthquake at 4 P.M. The results are worse than those in scenario 3, particularly lower speeds on I-64, I-70, I-55, MO 21, and I-170.



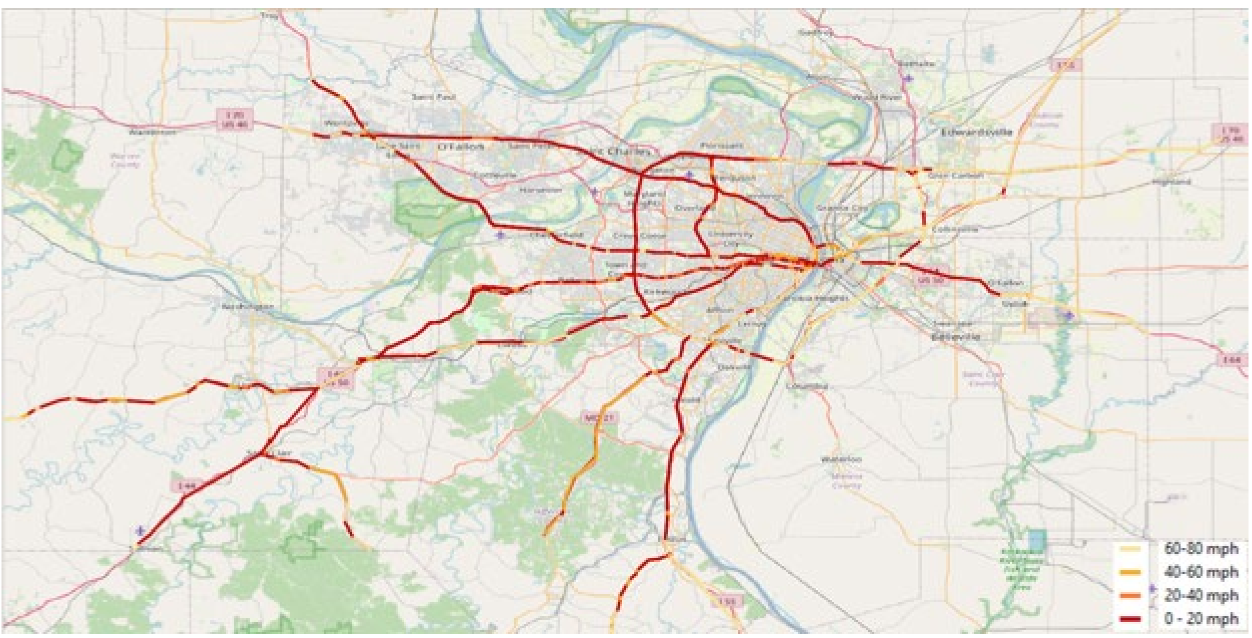
(Map created based on results of CUBE Voyager and displayed in Quantum Geographic Information System)

Figure 20. Average speed of scenario 0 (baseline network with normal demand)



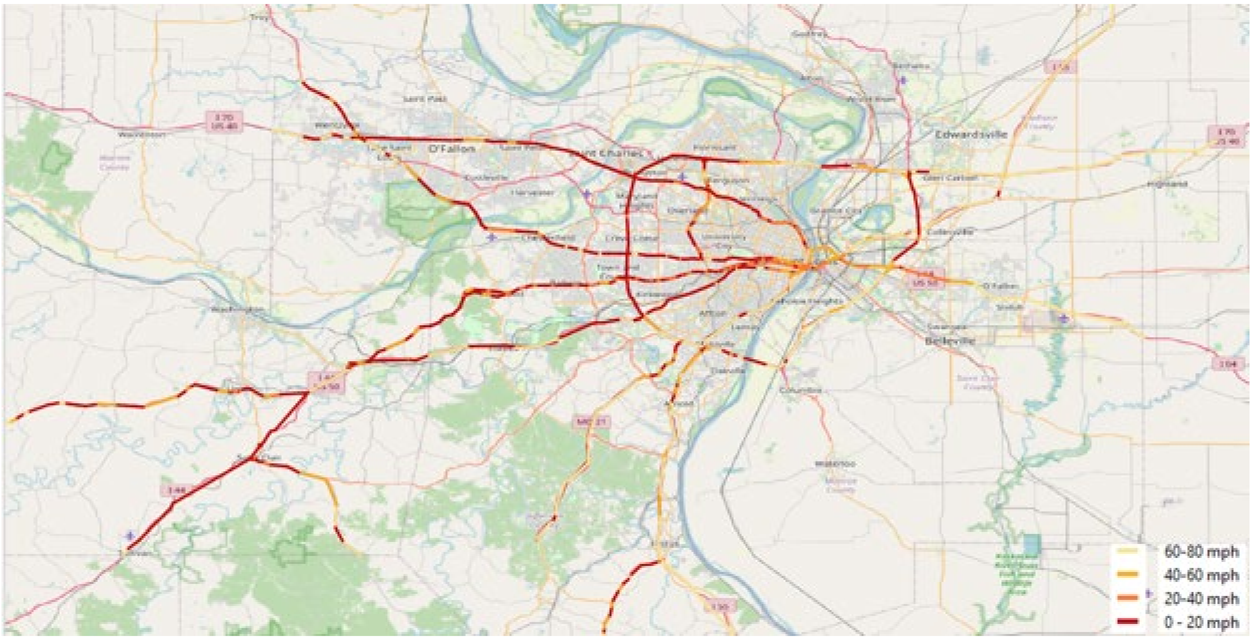
(Map created based on results of CUBE Voyager and displayed in Quantum Geographic Information System)

Figure 21. Average speed of scenario 1 (baseline network and 100 percent demand when earthquake occurs at 7 A.M.)



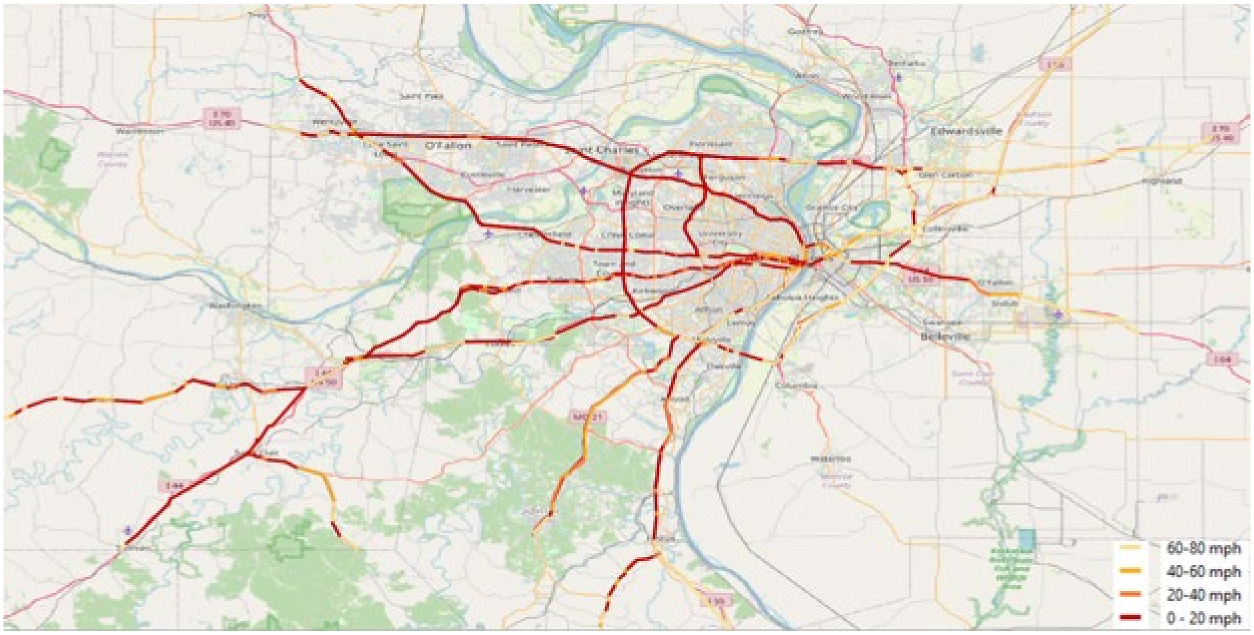
(Map created based on results of CUBE Voyager and displayed in Quantum Geographic Information System)

Figure 22. Average speed of scenario 2 (damaged network and 100 percent demand when earthquake occurs at 7 A.M.)



(Map created based on results of CUBE Voyager and displayed in Quantum Geographic Information System)

Figure 23. Average speed of scenario 3 (baseline network and 100 percent demand when earthquake occurs at 4 P.M.)



(Map created based on results of CUBE Voyager and displayed in Quantum Geographic Information System)

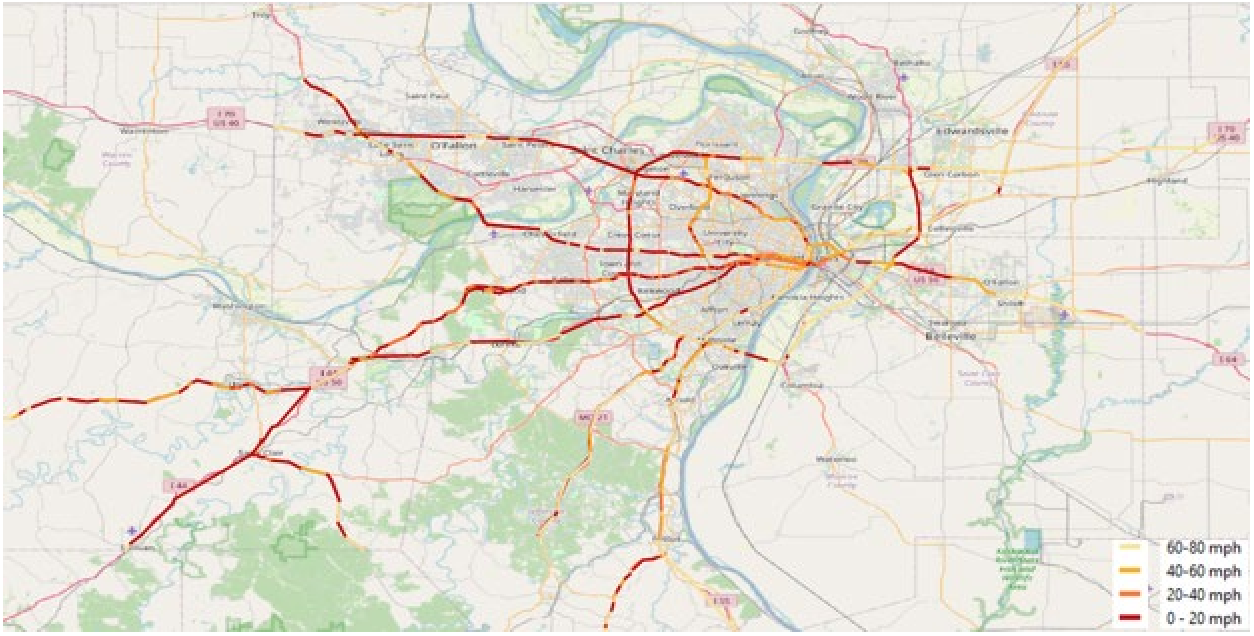
Figure 24. Average speed of scenario 4 (damaged network and 100 percent demand when earthquake occurs at 4 P.M.)

Figures 25 to 28 illustrate the outcomes of simulations conducted under 50 percent normal demand conditions. Figure 25 represents the average speed results for scenario 5, indicating the baseline network and 50 percent demand during the earthquake at 7 AM. Many priority routes are shown to experience poor traffic conditions.

Figure 26 presents the average speed results for scenario 6, featuring a damaged network and 50 percent demand during the earthquake at 7 AM. Compared to scenario 5, congestion is greater, especially on I-70, I-170 and I-64.

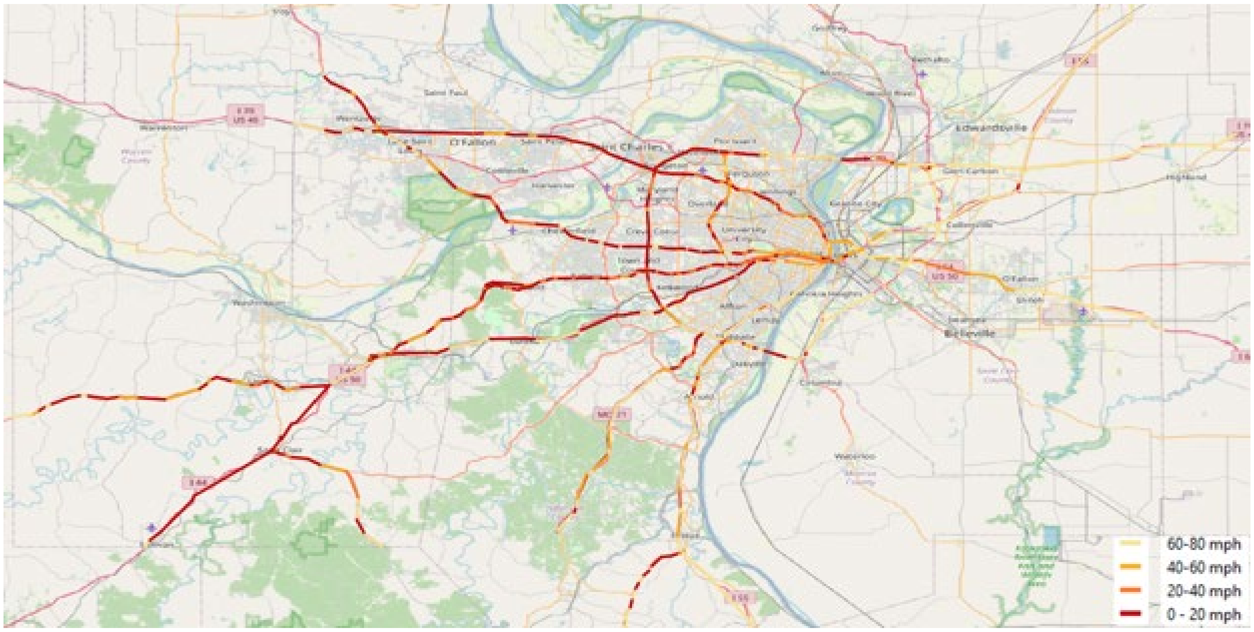
Figure 27 shows the average speed results for scenario 7, containing the baseline network and a 50 percent demand during an earthquake at 4 P.M. Again, when comparing the results with scenario 5 (same condition but earthquakes occurring at different time), less congestion occurred during scenario 7 than during scenario 5.

Figure 28 details the average speed outcomes for scenario 8, involving a damaged network and a 50 percent demand during an earthquake at 4 P.M. The results are worse than those in scenario 7, particularly along I-270, I-170, I-64 and I-70 priority routes.



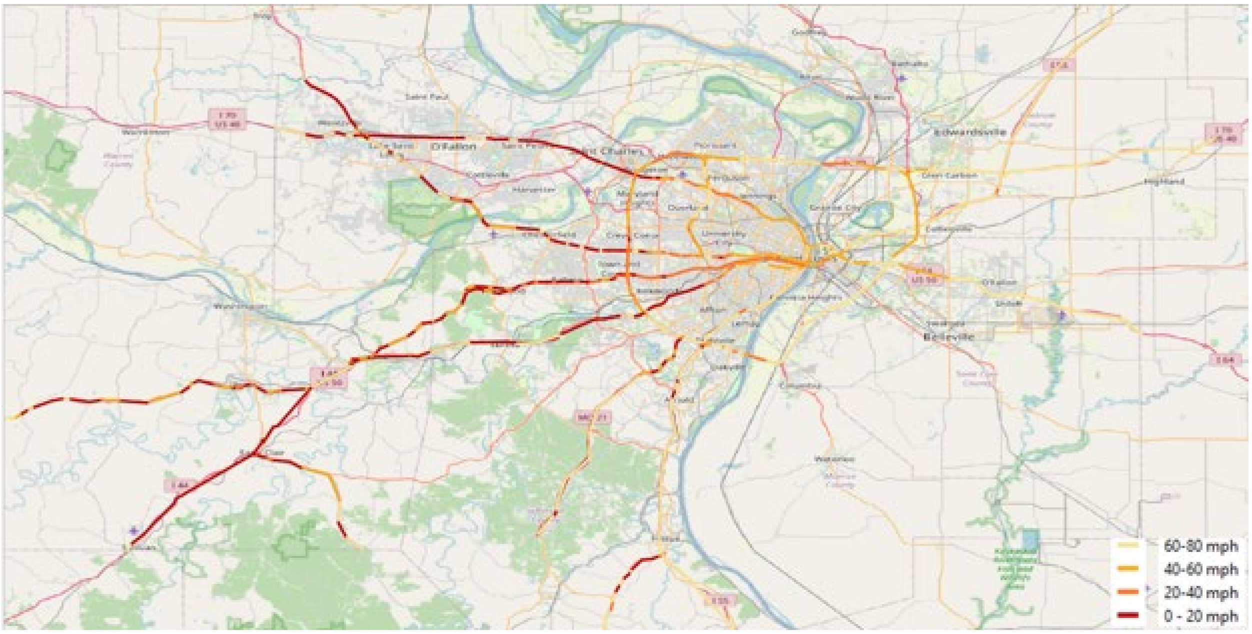
(Map created based on results of CUBE Voyager and displayed in Quantum Geographic Information System)

Figure 25. Average speed of scenario 5 (baseline network and 50 percent demand when earthquake occurs at 7 A.M.)



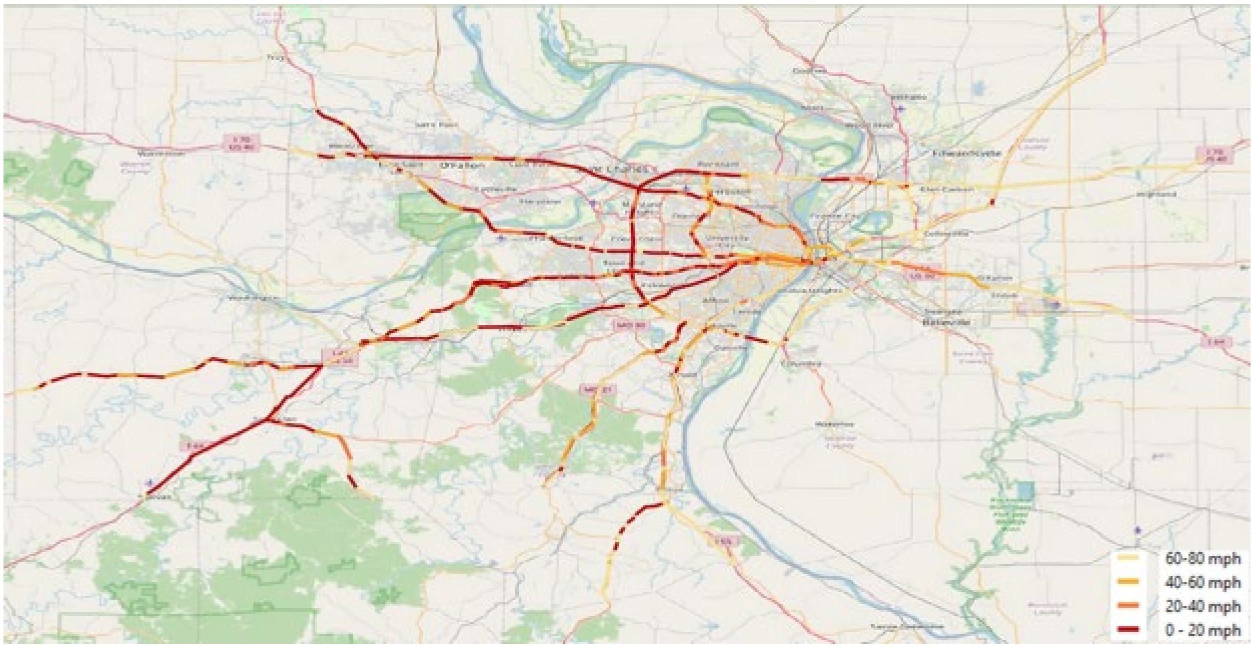
(Map created based on results of CUBE Voyager and displayed in Quantum Geographic Information System)

Figure 26. Average speed of scenario 6 (damaged network and 50 percent demand when earthquake occurs at 7 A.M.)



(Map created based on results of CUBE Voyager and displayed in Quantum Geographic Information System)

Figure 27. Average speed of scenario 7 (baseline network and 50 percent demand when earthquake occurs at 4 P.M.)



(Map created based on results of CUBE Voyager and displayed in Quantum Geographic Information System)

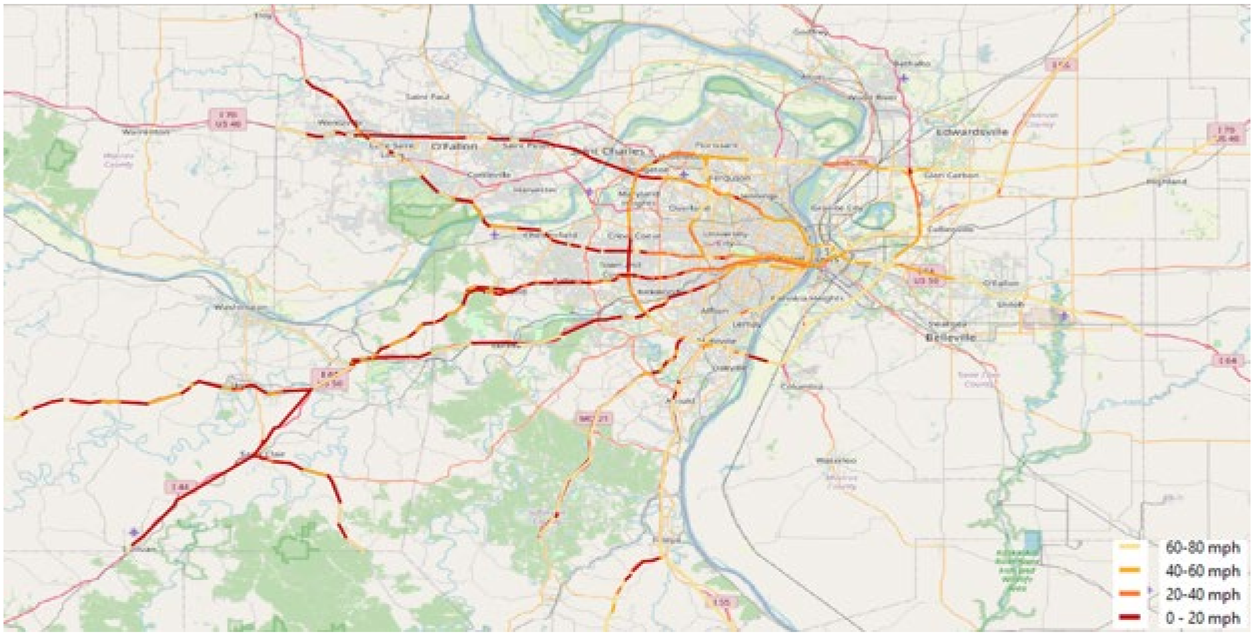
Figure 28. Average speed of scenario 8 (damaged network and 50 percent demand when earthquake occurs at 4 P.M.)

Figures 29 to 32 show the results for average speed conducted under 30 percent demand conditions. Figure 29 reveals speed outcomes for scenario 9, depicting the baseline network and a 30 percent demand during an earthquake at 7 A.M. The network's traffic conditions exhibit some improvement over the 100 percent and 50 percent demand scenarios, particularly in the St. Louis region. However, severe congestion persists on the west side of the study area.

Figure 30 illustrates the average speed results for scenario 10, featuring a damaged network and 30 percent demand during the earthquake at 7 A.M. Compared to scenario 9, congestion increases partially on routes I-70, I-170, and I-64.

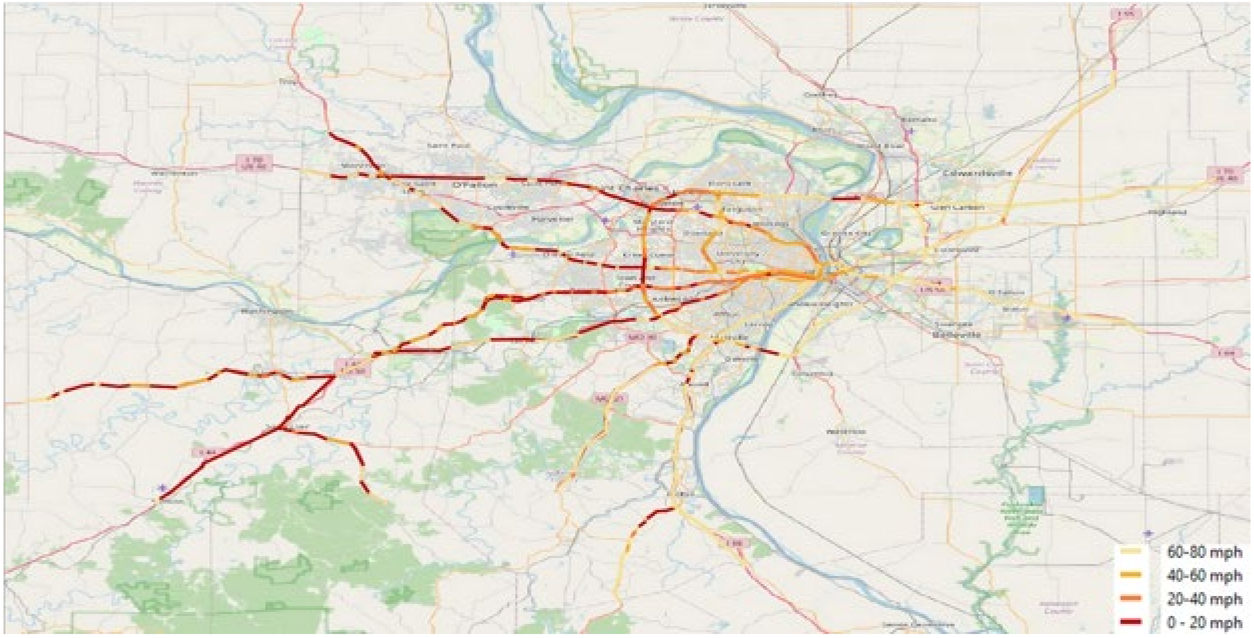
Figure 31 presents the average speed outcomes for scenario 11, involving the baseline network and a 30 percent demand during an earthquake at 4 P.M. Compared to scenario 9 (same conditions but different earthquake times), there is less congestion, especially on I-170 and I-44. However, several roads still experience congestion and reduced speeds.

Figure 32 details the average speed results for scenario 12, which includes a damaged network and a 30 percent demand during an earthquake at 4 P.M. The results are slightly worse than those in scenario 11, particularly on I-270, MO 100, and I-170.



(Map created based on results of CUBE Voyager and displayed in Quantum Geographic Information System)

Figure 29. Average speed of scenario 9 (baseline network and 30 percent demand when earthquake occurs at 7 A.M.)

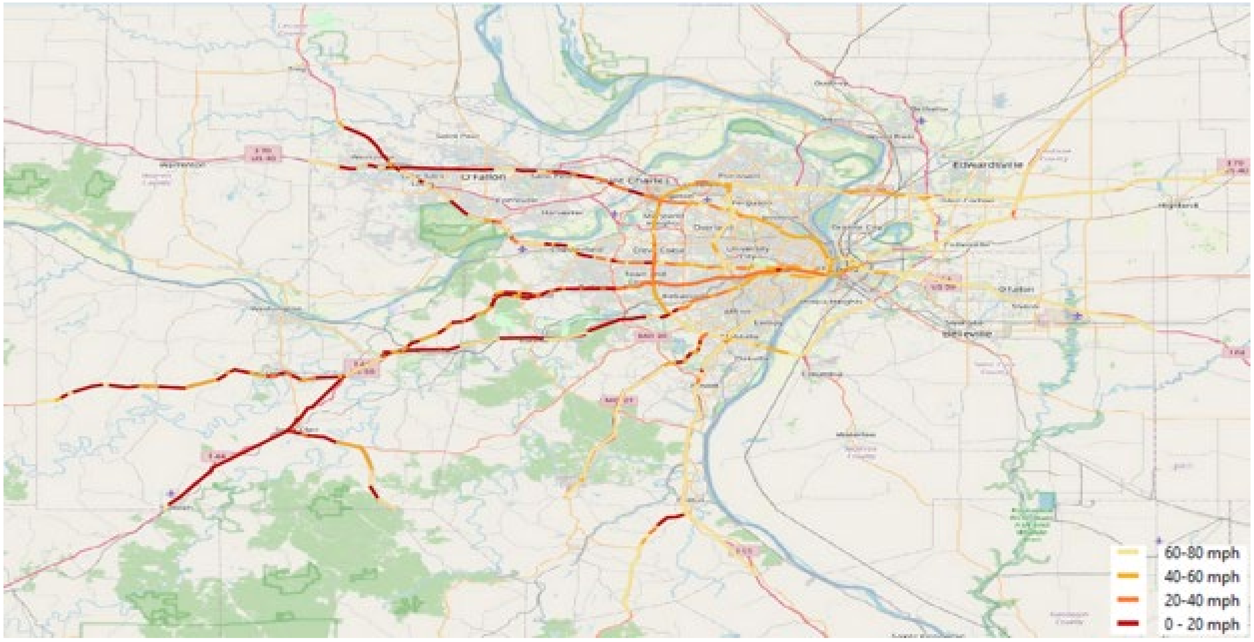


(Map created based on results of CUBE Voyager and displayed in Quantum Geographic Information System)

Figure 30. Average speed of scenario 10 (damaged network and 30 percent demand when earthquake occurs at 7 A.M.)

(Map created based on results of CUBE Voyager and displayed in Quantum Geographic Information System)

Figure 31. Average speed of scenario 11 (baseline network and 30 percent demand when earthquake occurs at 4 P.M.)



(Map created based on results of CUBE Voyager and displayed in Quantum Geographic Information System)

Figure 32. Average speed of scenario 12 (damaged network and 30 percent demand when earthquake occurs at 4 P.M.)

Overall, for earthquakes occurring in the morning (at 7 A.M.), the traffic conditions were much worse than for earthquakes occurring in the evening (at 4 P.M.). As expected, damaged road network adversely affected the speeds and congestion across the road network. Figure 33 plots the overall average speed across the road network for all scenarios.

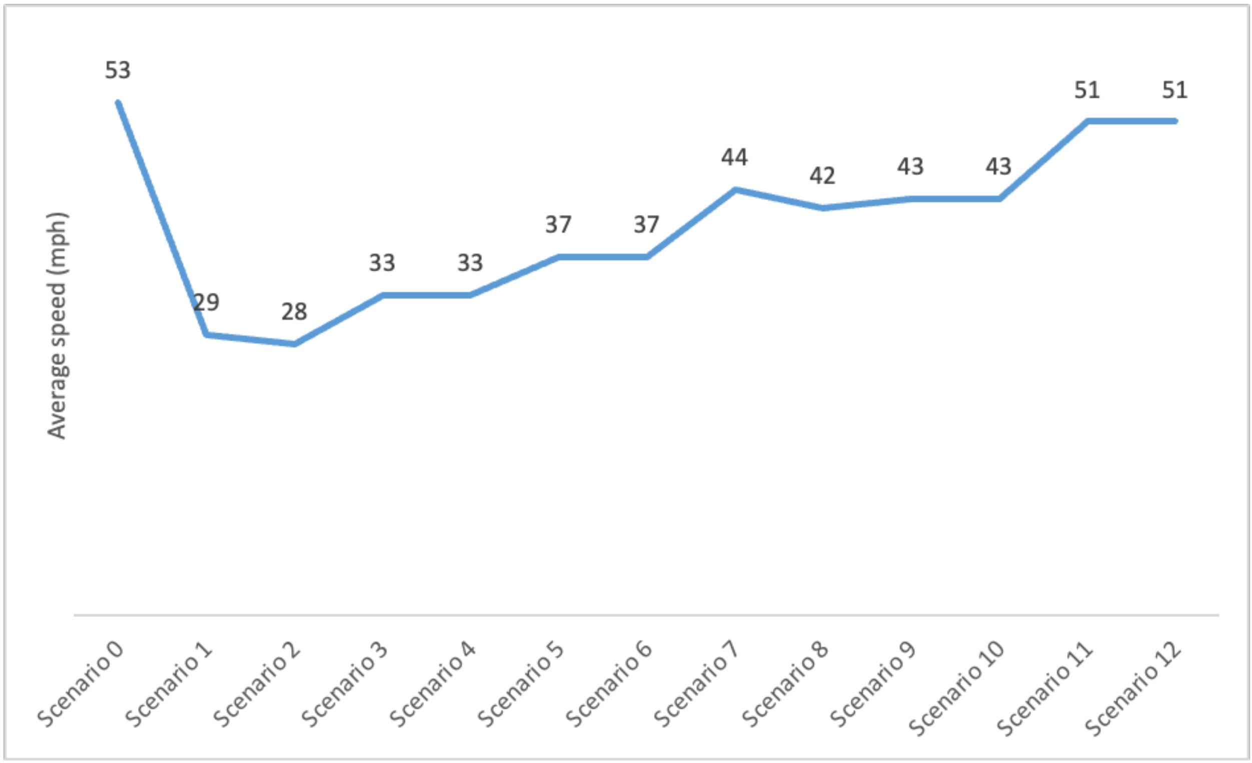


Figure 33. Average speed across the scenarios

Mesoscopic Evaluation

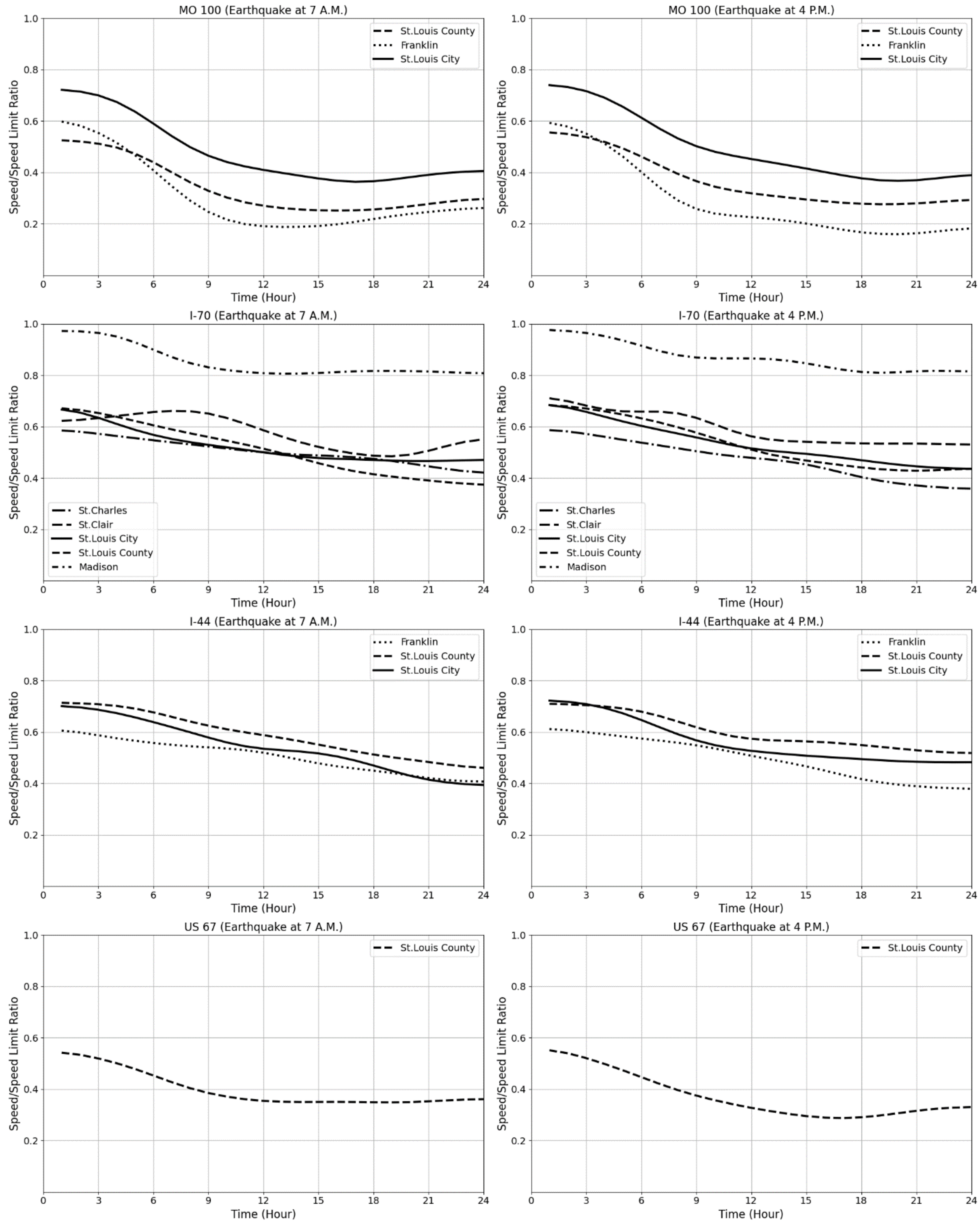
While the previous results showed average speeds for the entire 24-hour period, a mesoscopic simulation allows examining the evacuation performance during shorter time periods such as A.M. peak, P.M. peak, etc. Due to computational constraints, implementation was limited to four scenarios (scenarios 1 to 4), explicitly focusing on 100 percent demand situations. The comparison of results centered on priority routes throughout each county. A new congestion metric, speed-to-speed limit ratio, was used to evaluate conditions on various priority routers. Low values of the ratio indicate congested conditions.

Figures 34 and 35 show the results of speed to speed-limit ratio of the baseline network with 100 percent demand (i.e., scenarios 1 and 3). Figure 45 displays the first and second priority routes, whereas the third priority routes are shown in Figure 35. The left-hand side of each figure shows results for earthquake occurrence time of 7 A.M. while the right-hand side plots show the results for 4 P.M earthquake occurrence time.

From Figure 34 it can be inferred that MO 100, a designated priority route, experiences significant congestion in all earthquake scenarios. In 7 A.M. earthquake scenarios, the ratio was lower than 0.2 in Franklin County around noon, while for 4 P.M. scenario the ratio was lower than 0.2 in Franklin County from 6 P.M to Midnight. Another reason for higher congestion levels observed in Franklin County is due to its location on the west end of the study region where evacuees are heading toward their destinations.

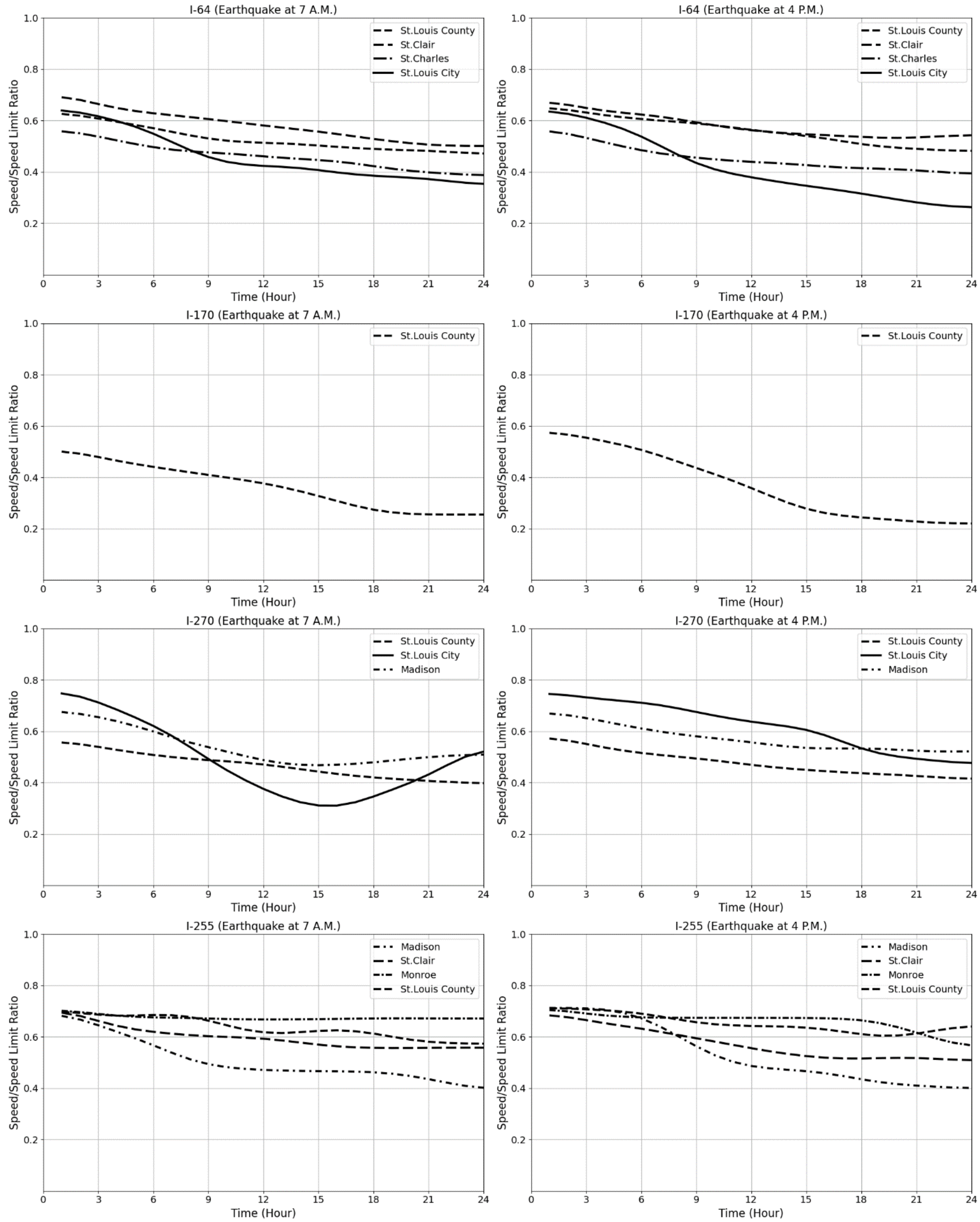
For I-70, both A.M. and P.M. earthquake scenarios, most of the segments experienced ratios between 0.4 to 0.6. The worst congestion on I-70 was observed in St. Louis County for 7 A.M. earthquake and in St. Charles for the 4 P.M. earthquake. Traffic conditions on I-44 seem to be better than those on other priority routes except for the segment in Franklin County that experienced congestion. US 67 experienced worse congestion during the 4 P.M. earthquake than during the 7 A.M. earthquake.

For the third priority routes represented in Figure 35, I-64, I-170, and I-270 all experienced deteriorating conditions as the evacuation unfolded. I-64 segment in St. Louis City experienced higher congestion during the 4 P.M. earthquake than a 7 A.M. event. The I-270 segment in St. Louis City experienced a drastic reduction in the speed-to-speed limit ratio followed by recovery in the late evening for the 7 A.M. event. Conditions on I-255 remained steady across the evacuation period except for the segment in Madison County, IL, which experienced deteriorating conditions towards the latter half of evacuation.



(Figures obtained from simulation results)

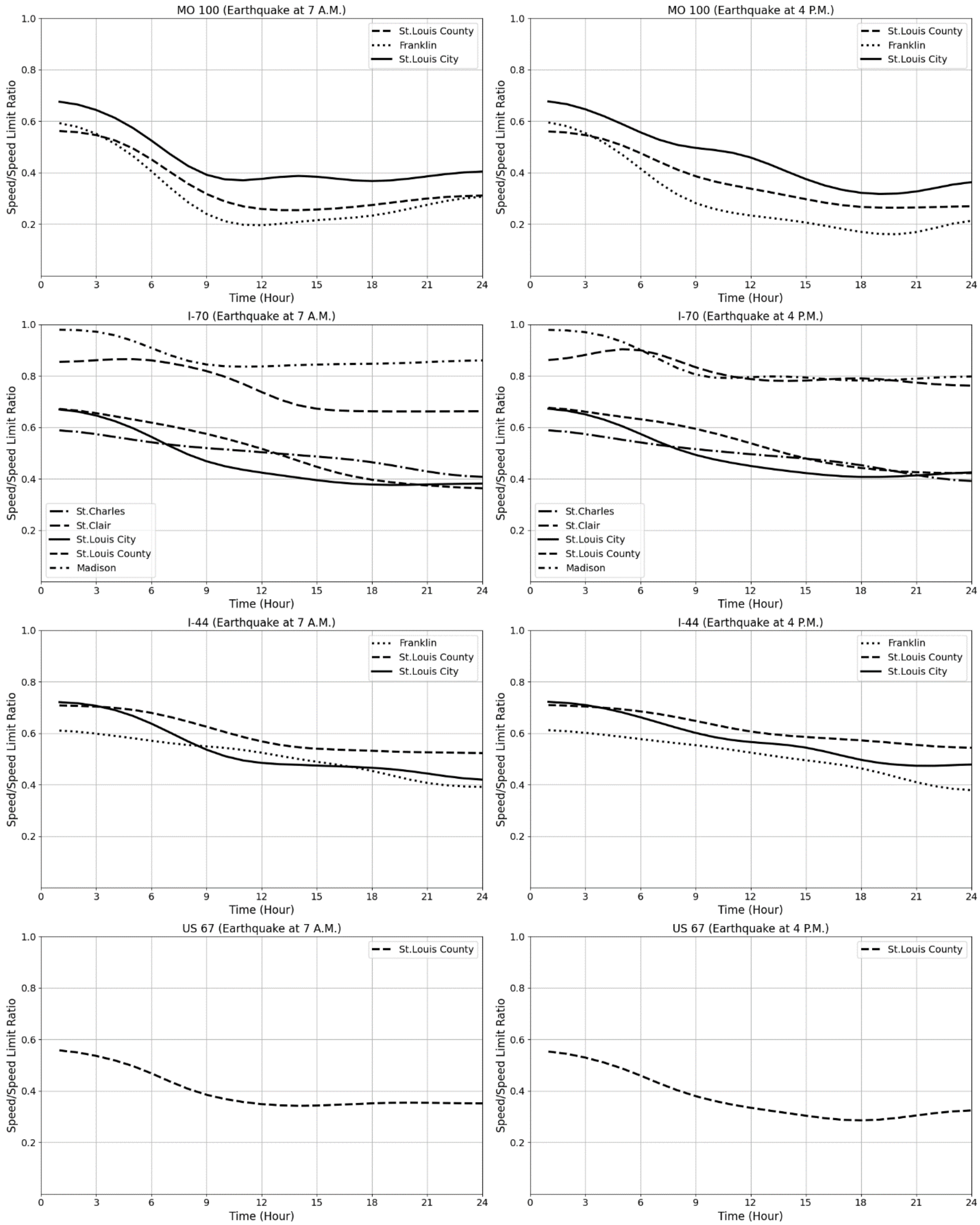
Figure 34. Hourly plot of speed-to-speed limit ratio for first and second priority routes for scenarios 1 and 3.



(Figure obtained from simulation results)

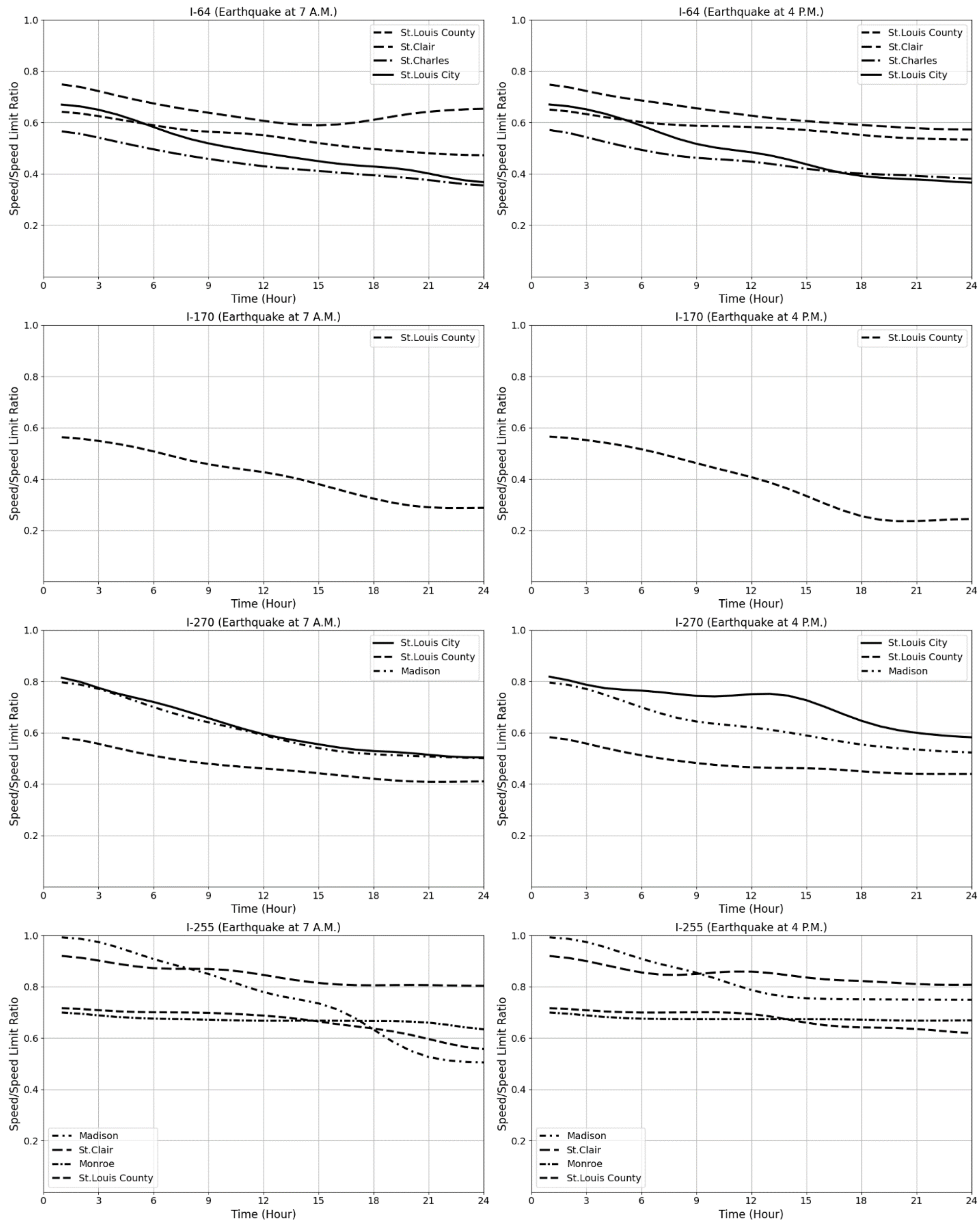
Figure 35. Hourly plot of speed-to-speed limit ratio for third priority routes for scenarios 1 and 3.

Figures 36 and 37 show the hourly plots for scenarios 2 and 4 that examine the impact of a damaged road network for both earthquake events - 7 A.M. and 4 P.M. As expected, the traffic conditions on most routes deteriorated due to the loss of key bridges and traffic reorganizing throughout the network.



(Figure obtained from simulation results)

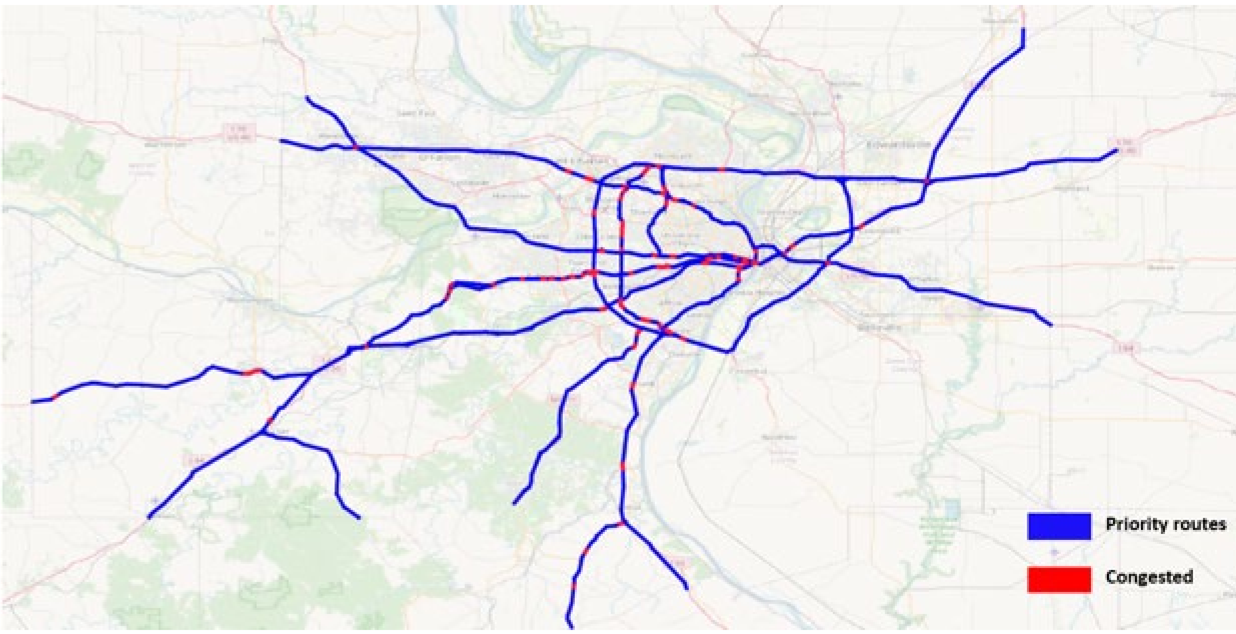
Figure 36. Hourly plot of speed-to-speed limit ratio for first and second priority routes for scenarios 2 and 4.



(Figure obtained from simulation results)

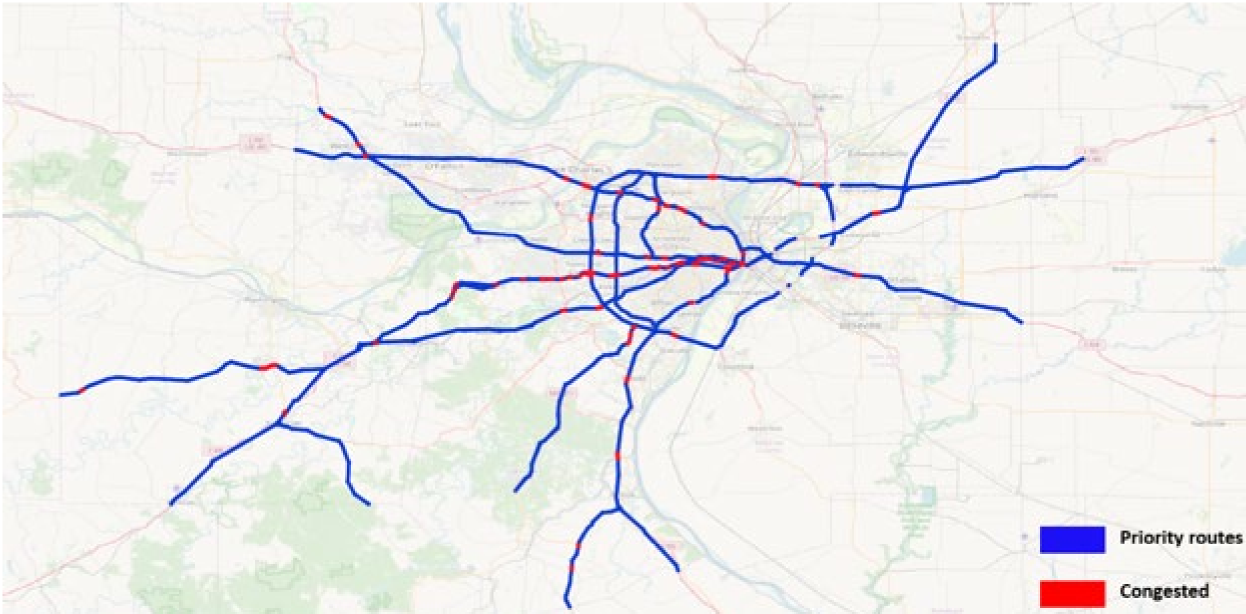
Figure 37. Hourly plot of speed-to-speed limit ratio for third priority routes for scenarios 2 and 4.

In addition to the speed-to-speed limit profiles shown in Figures 34 to 37, simulation was used to identify bottleneck locations. Figures 38 and 39 depict the top 5 percent most congested segments due to a 7 A.M. earthquake for the baseline and damaged networks, respectively. Since many evacuees depart within 3 hours, the congestion measurement started after 3 hours. MO 100 and US 67 stand out as experiencing significantly higher congestion compared to other priority routes. Table 3 shows the list of the top 5 percent bottleneck locations in the study region for a 7 A.M. earthquake. This list can be used by MoDOT and other emergency response agencies to better coordinate evacuation, response, and recovery operations.



(Map created by Quantum Geographic Information System with results obtained by simulation)

Figure 38. Top 5 percent congested segments for scenario 1 (status at 10 A.M.)

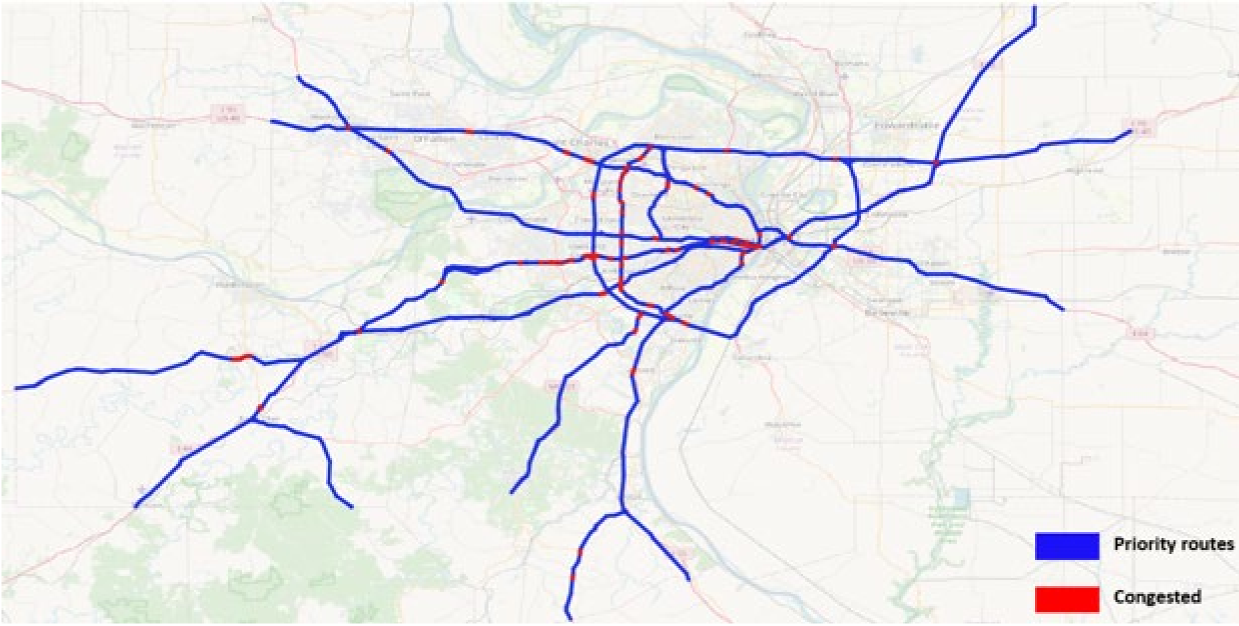


(Map created by Quantum Geographic Information System with results obtained by simulation)
Figure 39. Top 5 percent congested segments for scenario 2 (status at 10 A.M.)

Table 3. Bottlenecks on priority routes for scenarios 1 and 2 (earthquake occurs at 7 A.M.)

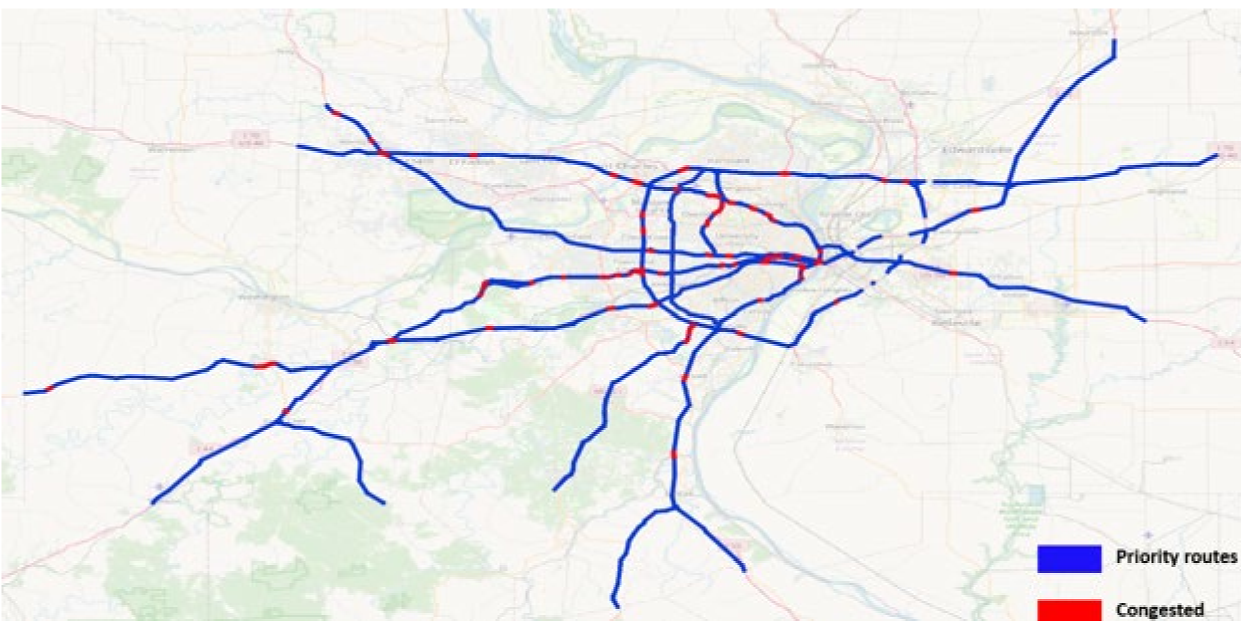
Scenario	Bottleneck Locations
Scenario 1	MO 100 WB (0.4 miles, from South Newstead Avenue to South Kingshighway Boulevard)
	MO 100 WB (0.3 miles, from Louis Avenue to Sulphur Spring Road)
	MO 100 WB (0.3 miles, from Lock Drive to Timka Drive)
	MO 100 WB (0.2 miles, from Wild Horse Creek Road to South Old Wild Horse Road)
	MO 100 EB (0.2 miles, from Dietrich Road to Manchester Meadows)
	I-70 WB (0.3 miles, between on ramp and off ramp for North Hanley Road)
	I-70 WB (0.2 miles, between on ramp and off ramp for I-170)
	I-70 WB (0.2 miles, between on ramp and off ramp for I-170)
	I-70 WB (0.3 miles, between on ramp and off ramp for MO 141)
	I-70 EB (0.3 miles, between off ramp and on ramp for MO 141)
	I-70 EB (0.2 miles, from South fifth Street to South Main Street)
	I-44 WB (0.3 miles, from South Kings highway Boulevard to Marconi Avenue)
	I-44 WB (0.4 miles, from Stoneywood Drive to Soccer Park Road)
	US 67 SB (0.3 miles, from Chapel Ridge Drive to James S McDonnell Boulevard)
	US 67 SB (0.6 miles, from off ramp for MO 180 to Blake Drive)
	US 67 SB (0.2 miles, from Morrow Drive to Margatehall Drive)
	US 67 SB (0.4 miles, from Schuetz Road to Forest Brook Lane)
Scenario 2	MO 100 WB (0.3 miles, from South Tucker Boulevard to Dillon Drive)
	MO 100 WB (0.4 miles, from Central Industrial Avenue to South Sarah Street)
	MO 100 WB (0.4 miles, from South Newstead Avenue to South Kingshighway Boulevard)
	MO 100 WB (0.3 miles, from Louis Avenue to Sulphur Spring Road)
	MO 100 EB (0.2 miles, from I-270 to West County Center Drive)
	I-70 WB (0.2 miles, from Lucas & Hunt Road to San Diego Avenue)
	I-70 WB (0.3 miles, between on ramp and off ramp for North Hanley Road)
	I-70 WB (0.2 miles, between on ramp and off ramp for I-170)
	I-70 WB (0.2 miles, between on ramp and off ramp for I-170)
	I-70 WB (0.3 miles, between on ramp and off ramp for MO 141)
	I-70 EB (0.3 miles, between off ramp and on ramp for MO 141)
	I-70 EB (0.2 miles, from South fifth Street to South Main Street)
	I-44 WB (0.3 miles, between on ramp and off ramp for I-55)
	I-44 WB (0.3 miles, from South Kings highway Boulevard to Marconi Avenue)
	I-44 WB (0.4 miles, from Stoneywood Drive to Soccer Park Road)
	US 67 SB (0.6 miles, from off ramp for MO 180 to Blake Drive)
	US 67 SB (0.2 miles, from Morrow Drive to Margatehall Drive)
	US 67 SB (0.4 miles, from Schuetz Road to Forest Brook Lane)
	US 67 SB (0.3 miles, from Bayer Drive to North Tealbrook Drive)
	US 67 SB (0.3 miles, from East Watson Road to West Watson Road)
	US 67 SB (0.2 miles, from Crescent Drive to South Country Center Way)
	US 67 NB (0.2 miles, from Telegraph Road to Ringer Road)

Figures 40 and 41 show the top 5 percent congested segments for a 4 P.M. earthquake i.e., scenarios 3 and 4. Table 4 shows the same results in a tabular format. While there is some overlap between Tables 3 and 4, there are other segments that experience greater congestion during the 4 P.M. than they did in the 7 A.M. scenarios.



(Map created by Quantum Geographic Information System with results obtained by simulation)

Figure 40. Top 5 percent congested segments for scenario 3. (status at 7 P.M.)



(Map created by Quantum Geographic Information System with results obtained by simulation)

Figure 41. Top 5 percent congested segments for scenario 4. (status at 7 P.M.)

Table 4. Bottlenecks on priority routes for scenario 3 and 4 (earthquake occurs at 4 P.M.)

Scenario	Bottleneck Locations
Scenario 3	MO 100 WB (0.2 miles, from South 6th street to South 9th street)
	MO 100 WB (0.4 miles, from South Spring Avenue to South Vandeventer Avenue)
	MO 100 WB (0.2 miles, from South Newstead Avenue to Cadet Avenue)
	MO 100 WB (0.3 miles, from North Ballas Road to I-270)
	MO 100 WB (0.2 miles, from Topping Road to pointe Drive)
	MO 100 WB (0.2 miles, from Manchester Meadows to Dietrich Road)
	MO 100 WB (0.3 miles, from Dean Reiter Lane to Sulphur Spring Road)
	MO 100 WB (0.2 miles, from Lock Drive to Timka Drive)
	I-70 WB (0.5 miles, from off ramp to on ramp for MO 141)
	I-70 WB (0.2 miles, from South Main Steet to South fifth Street)
	I-44 WB (0.4 miles, from Stoneywood drive to Soccer Park Road)
	US 67 NB (0.2 miles, form Pershall Road to I-270)
	US 67 SB (0.4 miles, from Hazelwood Logistic Center Drive to Missouri Bottom Road)
	US 67 SB (0.2 miles, from Litzsinger Road to Huntleigh Woods)
	US 67 NB (0.4 miles, from Lemay Ferry Road to I-55)
Scenario 4	MO 100 WB (0.2 miles, from South 6th street to South 9th street)
	MO 100 WB (0.3 miles, from South Tucker Boulevard to Dillon Drive)
	MO 100 WB (0.4 miles, from South Spring Avenue to South Vandeventer Avenue)
	MO 100 WB (0.2 miles, from South Newstead Avenue to Cadet Avenue)
	MO 100 WB (0.2 miles, from Wood Avenue to Lynchester Lane)
	MO 100 WB (0.3 miles, from North Ballas Road to I-270)
	MO 100 WB (0.2 miles, from Topping Road to pointe Drive)
	MO 100 WB (0.2 miles, from Manchester Meadows to Dietrich Road)
	MO 100 WB (0.3 miles, from Dean Reiter Lane to Sulphur Spring Road)
	MO 100 WB (0.2 miles, from Lock Drive Timka Drive)
	I-70 WB (0.3 miles, from US 67 to Fee Fee Road)
	I-70 WB (0.5 miles, from off ramp to on ramp for MO 141)
	I-70 WB (0.2 miles, from South Main Steet to South fifth Street)
	I-44 WB (0.4 miles, from Stoneywood drive to Soccer Park Road)
	US 67 NB (0.2 miles, form Pershall Road to I-270)
	US 67 SB (0.4 miles, from Hazelwood Logistic Center Drive to Missouri Bottom Road)
	US 67 SB (0.2 miles, from Morrow Drive to Margatehall Drive)
	US 67 SB (0.2 miles, from Litzsinger Road to Huntleigh Woods)
	US 67 SB (0.2 miles, from Sunset Hills Plaza to East Watson Road)
	US 67 NB (0.4 miles, from Lemay Ferry Road to I-55)

Chapter 5. Tabletop Exercise

Overview

The exercise was a discussion-based tabletop exercise conducted at MoDOT's St. Louis Traffic Management Center on September 21, 2023. Participants included MoDOT staff from St. Louis and Central Office, Illinois DOT, Florissant Valley Fire Department, St. Louis County, St. Louis County Fire Department, State Emergency Management Agency, Missouri Department of Natural Resources, St. Louis City Fire Department, and Mercy Hospital. The first part of the exercise was spent giving an overview of the research project and presenting new tools for earthquake planning related to estimating traffic impacts in the St. Louis Metropolitan area following a major earthquake.

The following scenario was then presented to workshop participants. At 3 P.M. on a weekday, a significant earthquake of 7.5 occurred. By 5 P.M., reports of damage across the entire eastern part of Missouri have surfaced, particularly affecting bridges and roadways. Traffic-related challenges in St. Louis are being documented, with reports indicating substantial congestion on multiple routes. Additionally, the St. Louis area is grappling with telecommunication and power outages. The tabletop exercise involved facilitated discussion from all participants. The following provides a summary of major themes and issues that developed from this discussion.

Discussion

All the participating agencies were asked to summarize their latest earthquake plans. The following are some key points and commonalities to these plans.

- There is a need for ingress of support resources, at least as important as evacuation.
- Evacuation destinations are also critical, as well as support to get people to those destinations (i.e., food, water, medical).
- Communications systems are critical to all elements of the response. Agencies are highly dependent on telecommunications. Systems are needed for internal agency communications at various levels, interoperability, communications to and from field devices, and public information.
- Accurate information to the public is critical to convey the evolving traffic situation, recommended actions, and public expectations.
- Supply chain and just-in-time deliveries is a big concern, particularly in the medical community.
- Significant infrastructure damage and utility issues (including pipelines) are still a concern.
- Resource management is critical for all agencies.

Protection

- Facilitate the development of a comprehensive understanding among MoDOT staff and key stakeholders regarding the post-earthquake traffic challenges and their potential impact on response efforts.

- Delve into the intricate ways in which traffic congestion may influence critical aspects of agency plans, including situational awareness and damage assessment, shelter activation location and resources, and the deployment of local emergency responders.
- Evaluate the effectiveness of MoDOT's response plan concerning traffic issues and craft targeted interventions to address challenges on priority routes, considering factors such as Traffic Management Center (TMC) limitations, freeway detector and camera outages, as well as the accessibility of MoDOT crews for damage assessment and debris removal. Assess the potential ingress of external support resources.

Response

- Develop insights into the initial movement of critical internal resources, encompassing fire, medical, police departments, and infrastructure owners like MoDOT, Ameren (power), Spire (natural gas), pipelines, and access to vital facilities such as hospitals, shelters, and stores.
- Gain a nuanced understanding of the impact on the ingress of external critical resources, beginning with emergency medical services, search and rescue teams, food, and fuel providers.
- Examine the practical challenges of earthquake evacuation in the context of real-time traffic issues.
- Evaluate the effectiveness of existing public information tools related to post-earthquake traffic and identify challenges in situational awareness and damage assessment tied to traffic issues.
- Grasp the potential traffic challenges following an earthquake, particularly in a worst-case scenario where the event coincides with peak periods on weekdays.

Three breakout groups were developed and were facilitated by the research team to discuss two modules. Module one was focused on initial situational awareness and module two was focused on initial movement of critical response resources. There were many common themes and key issues which are summarized as follows.

- Communications systems are a common need across all agencies. Some systems may work well such as 2-way radio systems, texting, and FirstNet, while others are vulnerable, particularly systems that are reliant on utility electric power.
- Infrastructure damage and utility issues (including pipelines) are still a concern.
- Significant utility and infrastructure damage and outages are still expected, such as electric power, pipelines, telecommunications.
- Response times for response agencies will be delayed. Both response agencies and the public need to understand this issue. Understanding the realities and related expectations for everyone is a critical issue. Some emergency responses may be difficult or impossible (e.g., fire response in some areas).
- Mutual aid across regions and disciplines remains an important need.
- Vulnerable people are a major issue as they may need special resources and transportation. It may be better to support this population in place given the traffic issues.

- Everybody (responders and citizens) needs basic support resources, food, water, medical, and shelter. This is at least as important as evacuation and will need further planning considering the potential traffic issues.
- Traffic signals on the urban arterial routes are key to traffic flow and planning for establishing evacuation-specific traffic control is needed.

The discussions were also grouped by the response agency and are summarized below. The purpose of this grouping was to show the key issues that were important for an agency during an earthquake.

Agency Discussion

MoDOT St. Louis District Traffic

- Prioritizing both entry and exit: While earthquake response typically focuses on getting in (ingress), MoDOT recognizes the need for smooth egress routing too, ensuring both emergency response and evacuation can flow efficiently.
- Boots on the ground, eyes in the sky: Limited resources demand creative solutions. Inspecting primary routes, managing field staff, and utilizing resources like the Civil Air Patrol for aerial assessments are key to maintaining situational awareness.
- Beyond bad weather plans: Clear communication is crucial. With traditional methods vulnerable to outages, MoDOT needs a robust plan to inform the public, exceeding basic "be prepared" warnings and actively guiding them through the crisis.

Hospitals/EMS/Healthcare

- Shaky ground, shaky deliveries: Flood-focused supply chain plans need earthquake-proofing. Identifying resupply routes, factoring in road damage, and real-time information sharing are crucial to keeping pharmacies and trauma centers stocked.
- Words get through, walls crumble: Communication redundancy reigns supreme. With 3 trauma centers boasting backup options like satellite and amateur radio, broader healthcare networks need similar resilience to ensure information flows even when infrastructure falters.
- Business lifeline, not bystander: Beyond evacuation plans, hospitals and human-impact businesses need a clear connection. Creating a central hub for sharing transportation plans and fostering collaboration will ensure everyone gets the support they need, even when the earth cracks beneath them.

St. Louis County

- Earthquakes may differ from other responses. The plan includes supporting MoDOT Emergency Operations Center (EOC) from the county.

St. Louis County Fire

- Local knowledge, swift action: Effective earthquake response relies on understanding local needs and capabilities. Talking to residents about their usual evacuation routes and key community resources is crucial to crafting an efficient response plan.

- Collaborative network, seamless data: Close coordination with MoDOT as the lead agency for transportation infrastructure is essential. Sharing real-time information about open and closed roads, along with assessments of arterial routes, ensures everyone has the latest picture.
- Closing the communication loop: Addressing the information gap between MoDOT and local responders is critical. Streamlining processes for sharing data about ingress and egress routes, both upwards and downwards, empowers both sides to make informed decisions quickly.

SEMA

- Shelter beyond borders: Long-term displacement may force evacuees across state lines. Identifying optimal locations for "one-stop shop" shelters, offering first aid, food, and transportation assistance, is crucial, with ongoing evaluation for the best solutions.
- Infrastructure under siege: Gas pipelines could be down for years, requiring residents to be prepared for extended displacement. Clear communication is vital, explaining potentially year-long absences while infrastructure rebuilds.
- Beyond immediate needs: Schools may be unavailable for over a year, highlighting the need for long-term support systems. Utilizing advanced mapping tools, like real-time GIS layers, can effectively disseminate critical information throughout the affected area.

SEMA MoDOT St. Louis TMC

- Beyond disaster drills: Public education needs an earthquake makeover. Clear communications outlining evacuation guidelines, potential displacement timelines, and self-reliance strategies are essential, even beyond school drills and family plans.
- Resource resilience: We must consider scenarios where vital resources like natural assets, power, and manpower are compromised. Planning for such disruptions and developing alternative operating procedures is crucial for sustained functionality.
- Technology's tectonic fault: MoDOT's heavy reliance on communication devices, cameras, and apps faces vulnerability during an earthquake. Power outages, fiber optic damage, and signal disruptions can cripple operations. Prioritizing infrastructure resilience and backup contingencies is vital.

Chapter 6. Conclusion

This study evaluated the earthquake planning and response from multiple perspectives. First, an online survey was conducted for citizens in the St. Louis region. The survey documented decision making by citizens in the event of an earthquake. Specifically, survey questions focused on decision to evacuate, departure times, preferred destinations, route preferences, and personal vehicle use. The survey responses informed the next step of modeling traffic during an evacuation. The East-West Gateway Council of Government's travel demand model for normal conditions was used as a baseline. Evacuation demand was generated using survey responses and MoDOT technical committee's input. USGS ShakeCast tool was used to assess bridge conditions and the information was incorporated into the travel demand model. Two forms of simulation were used to assess the overall network impact and more localized impacts (i.e., route specific measures). A detailed list of bottlenecks was also generated to inform MoDOT of expected congestion locations during an evacuation. Finally, various emergency response stakeholders were brought together through a tabletop exercise of an earthquake scenario consisting of an evacuation. Agencies expressed the importance of effective coordination and communication across agencies to effectively respond to an earthquake in the St. Louis region.

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Appendix A: Household Survey for Earthquakes

This survey is being conducted by the University of Missouri as part of a research study on identification of a response and rescue network for the St. Louis region sponsored by the Missouri Department of Transportation (MoDOT). The survey will take approximately 20 minutes to complete. If you have any questions regarding the survey, please contact Dr. Praveen Edara (edarap@missouri.edu). Participants must be 18 years of age or older. Your participation is voluntary, and there is no compensation offered for completing the survey.

You may contact the University of Missouri Institutional Review Board (IRB) if you have any questions about your rights as a study participant, want to report any problems or complaints, or feel under any pressure to take part or stay in this study. The IRB is a group of people who review research studies to make sure the rights of participants are protected. You can reach them at 573- 882-3181 or muresearchirb@missouri.edu. The IRB number for this study is. If you want to talk privately about your rights or any issues related to your participation in this study, you can contact University of Missouri Research Participant Advocacy by calling 888-280-5002 (a free call), or emailing MUResearchRPA@missouri.edu.

1. Select the county you live in. Options should be – St. Charles, St. Louis, Jefferson, St. Louis City and Franklin in MO; Madison, St. Clair and Monroe in IL.

2. Are you at least 18 years old?
   ☐ Yes ☐ No

3. How likely do you think that you and your family will be impacted by an earthquake in the next five years?
   ☐ Very likely ☐ Likely ☐ Not sure ☐ Unlikely ☐ Very unlikely

4. Have you ever experienced an earthquake?
   ☐ Yes, in what year was your most recent earthquake experience and where (it is ok to estimate): ________________
   ☐ No

5. If you have experienced an earthquake before, did you have any of the following happen to you?

Damage type	Yes	No
A. Property damage	☐	☐
B. Disruption to daily life	☐	☐
C. Injury to self and/or injury or death of a friend or relative	☐	☐

<u>Earthquake Scenario</u>

For the rest of the survey, we want you to imagine that a catastrophic earthquake of magnitude 8.0 has occurred in the New Madrid region. This region has experienced severe infrastructure damage with households losing access to basic utilities (power, internet, water, gas). A mandatory evacuation order has been given to your neighborhood. Please keep this scenario in mind as you answer the remaining questions.

6. Where would you likely begin your evacuation from? Please enter the city name and cross-street or intersection. ____

7. What kind of place would you go to?

   ☐ Relative's /Friend's home

☐ Hotel/motel/inn
☐ Second home/property
☐ Shelter
☐ Other (: _______)

8. Where would you go? Please enter the city name and cross-street or intersection.
   ____

9. What route would you take to get there?
   ____

10. On a normal day (when there is not an evacuation happening), approximately how long (in hours) would it take you to travel to your chosen evacuation destination?
    ____

11. Approximately how long (in hours) do you think it would take you to travel to your destination *during an evacuation* (it is ok to estimate)? ___________________________

12. If mandatory evacuation order was issued, when do you think you would be most likely to leave for your destination after the order was issued?

☐ Within 3 hours
☐ 3 to 6 hours
☐ 6 to 12 hours
☐ 12 to 24 hours
☐ More than 24 hours

13. From what devices do you expect to receive information related to evacuation (especially regarding question 12 and 13)?
☐ Cell phone
☐ Personal computer
☐ TV
☐ Radio
☐ Others (: _________)
☐

14. From what sources do you expect to receive information related to evacuation (especially regarding question 12 and 13)?

☐ Text message
☐ Social media

☐ Public warning
☐ Message board
☐ Others (: __________)

15. How frequently would you check for updated information on the earthquake and/or the evacuation?

☐ About every 30 minutes
☐ About every hour
☐ About every two hours
☐ About every six hours
☐ About every 12 hours
☐ About once a day
☐ I would not check for updated information

16. Which of the following options would you be most likely to use to evacuate?

☐ Personal vehicle
☐ Get a ride from family or friends
☐ Public Transit
☐ Emergency Mass Transit
☐ Walk
☐ Other

17. If you answered 'Personal vehicle' in Question 14, how many vehicles would you use to evacuate?

☐ One
☐ Two
☐ Three or more
☐ I would not evacuate by personal vehicle
☐ I don't know

18. How many licensed drivers are there in your household?

☐ One
☐ Two

- ☐ Three or more
- ☐ I would not evacuate by personal vehicle
- ☐ I don't know

19. Which type of road would you mostly travel on?

- ☐ Freeway (road with on/off ramps and no stop lights/signs)
- ☐ Major roads (may have stop lights or stop signs)
- ☐ Any other local or back roads
- ☐ I don't know

20. If government officials recommended using a particular evacuation route, would you use that route?

- ☐ I definitely would use the recommended route
- ☐ I probably would use the recommended route
- ☐ I probably would not use the recommended route
- ☐ I definitely would not use the recommended route
- ☐ Choose not to answer

21. Who do you think is responsible for the safety of individual people and ensuring people have the resources to evacuate?

- ☐ More of an individual/household responsibility
- ☐ Shared equally between households and the government
- ☐ More of a government responsibility
- ☐ Choose not to answer

22. If you had to evacuate today, how much money do you think the evacuation would cost (consider travel costs, a place to stay, lost income, food, and fuel)?

    ____

23. If you had to evacuate today, how much money (cash, savings, credit card, money you could borrow) do you have available to spend on evacuation?

    ____

24. About how much fuel is in your household's primary vehicle right now?

- ☐ Full tank
- ☐ ¾ tank
- ☐ ½ tank

- ☐ $^1/_4$ tank
- ☐ Near empty tank
- ☐ I have an electric car
- ☐ I don't know
- ☐ I don't have any vehicles

25. Do you think this is enough fuel for you to reach the place you think you would evacuate to?

- ☐ Yes
- ☐ No
- ☐ I don't know
- ☐ I don't have any vehicles

26. Do you have family or friends outside of your household that would be willing to let you evacuate with them?

- ☐ Yes
- ☐ Maybe
- ☐ No
- ☐ I don't know

27. If you have any pets, would you take them with you if you needed to evacuate?

- ☐ Yes
- ☐ No, I will leave them home or at a pet shelter or with friends/family
- ☐ I do not have any pets
- ☐ Choose not to answer

In this last section, we would like to ask a few questions about you and the members of your household. You may choose not to answer any question, but know that your choice does affect the quality of the study.

28. What is your age?____

29. How many people live in your household who are…
    A. under the age of 18? ____
    B. age 18-64? ____
    C. age 65 or older? ____

30. How many people live in your household who have…
    A. Seriously impaired hearing?____________________________________
    B. Seriously impaired vision even with glasses? ______________________
    C. Serious difficulty concentrating, remembering, or making decisions? ____
    D. Serious difficulty walking/climbing stairs? ________________________
    E. Difficulty dressing or bathing? __________________________________
    F. Difficulty doing errands alone such as visiting a doctor's office or shopping? ____

31. How many pets (if any) live in your household? ________________________

32. If you have pets, what kind of animals are they? ________________________

33. What is the highest level of education you have completed?

- ☐ Did not finish high school
- ☐ High school graduate or GED
- ☐ Vocational/ Technical School after High School
- ☐ Some College (without finishing a degree)
- ☐ 2-year college degree (Associate)
- ☐ 4-year college degree (Bachelor)
- ☐ Graduate degree (Master's or Ph.D.)
- ☐ Professional degree (D.D.M., J.D., M.D., etc.)

34. Which of the following best describes your gender?

- ☐ Male
- ☐ Female
- ☐ Other (:______)

35. Which of the following best describes your marital status?
- ☐ Married
- ☐ Single/Never married
- ☐ Widowed
- ☐ Separated
- ☐ Divorced

36. Which category best describes your race/ethnicity?

- ☐ Caucasian/White
- ☐ African American/Black

- ☐ Asian
- ☐ American Indian
- ☐ Pacific Islander
- ☐ Hispanic
- ☐ Multi-racial
- ☐ Other (:______)

37. Which of the following best describes your current employment status?

- ☐ Employed full-time
- ☐ Employed part-time
- ☐ Unemployed
- ☐ Homemaker
- ☐ Student
- ☐ Retired
- ☐ Unable to work

38. Which of the following best describes your home?

- ☐ Single family home
- ☐ Duplex, or townhome
- ☐ Manufactured home or trailer
- ☐ Apartment or condominium
- ☐ Some other kind of structure
- ☐ I don't know

39. Do you (or your family) own your residence or do you rent?

- ☐ Own
- ☐ Rent
- ☐ Other (:______)

40. How many years have you lived in the current region? _____________

41. Please mark the income range that best describes your annual household income from all sources. This is before taxes and other deductions.

- ☐ $0 - $14,999
- ☐ $15,000 - $34,999
- ☐ $35,000 - $49,999

- ☐ $50,000 - $74,999
- ☐ $75,000 - $99,999
- ☐ $100,000 - $149,999
- ☐ $150,000 - $199,999
- ☐ $200,000 –

42. Please enter any additional comments you may have regarding earthquake emergency evacuation.
____

Thank you for taking the time to complete this survey.

Appendix B: St. Louis Tabletop Exercise 9/21/2023

Executive Summary

This exercise is part of the "Identification of a Response and Rescue Network for the St. Louis Region". The exercise was a discussion-based tabletop exercise. The first part of the exercise was spent giving an overview of the research project and presenting new tools for earthquake planning related to estimating traffic issues in the St. Louis Metropolitan area following a major earthquake.

Participants included MoDOT staff from St. Louis and Central Office, Illinois DOT, various local agencies, and Mercy Hospital.

The research project is developing a process for modelling traffic demand and speeds on the road network as a tool for planning and response to an earthquake. There has been little work done in this area, the information resulting from this study has the potential to change our earthquake plans in Missouri. There is potential for traffic congestion issue across the road network in St. Louis that would create challenges for earthquake response. Traffic congestion from citizen evacuation and initial responses may be a larger issue than the earthquake damage to infrastructure in the St. Louis area.

In addition to this research project, MoDOT is also developing some other tools for earthquake response. Of primary interest is the application of the USGS ShakeCast model to develop more accurate predictions of highway system damage. Map based tools are also under development including some tools for field staff.

The exercise involved facilitated discussion from all participants. The following provides a summary of major themes and issue that developed from this discussion.

All the participating agencies were asked to summarize their latest earthquake plans. The following are some key points and commonalities.

- There is a need for ingress of support resources, at least as important as evacuation.
- Evacuation destinations are also critical, and support to get people to those destinations (i.e. food, water, medical).
- Communications systems are critical to all elements of the response. Agencies are highly dependent on telecommunications. Systems are needed for internal agency communications at various levels, interoperability, communications to and from field devices, and public information.
- Accurate information to the public is critical to convey the traffic situation, recommended actions, public expectations.
- Supply chain and just-in-time deliveries is a big concern, particularly in the medical community.
- Significant infrastructure damage and utility issues (including pipelines) are still a concern.
- Resource management is critical for all agencies.

Three breakout groups were developed and there were two discussion modules. Module one was focused on initial situational awareness and module two was focused on initial movement of critical response resources. There were many common themes and key issues summarized as follows.

- Communications systems are a common need across all agencies. Some systems may work well such as 2-way radio systems, texting, and FirstNet (AT&T first responder system), others are vulnerable, particularly systems that are reliant on utility electric power.
- Infrastructure damage and utility issues (including pipelines) are still a concern.
- Significant utility and infrastructure damage and outages are still expected, such as electric power, pipelines, telecommunications.
- Response times for response agencies will be delayed. Bot agencies and the public need to understand this issue. Understanding the realities and related expectations for everyone is a critical issue. Some emergency response may be difficult or impossible (e.g. fire response in some areas).
- Mutual aid across regions and disciplines remains an important need.
- Vulnerable people are a major issue, they may need special resources and transportation and may be better to support in place given the traffic issues.
- Everybody (responders and citizens) needs basic support resources, food, water, medical, place to sleep. This is at least as important as evacuation and will need further planning considering the potential traffic issues.
- Traffic signals on the urban arterial routes are key to traffic flow and planning for earthquake traffic flow is needed.

The next steps were discussed primarily focused on a follow up meeting recommendation for 2024.

Exercise Schedule

0730 – 0800	Registration
0800 – 0830	Welcome and Introductions
0830 – 0915	Traffic for Earthquake Project Overview (Praveen Edara)
0915 - 0945	Overview of ShakeCast, Traffic Planning Resources, Other New Tools (Mike White)
0945 - 1015	Brief overview of agency plans - 5 minutes each – what are you going to do (Agency Reps)
1015 - 1030	Presentation of exercise scenario (Rick Bennett)
1030 – 1045	Break
1045 – 1200	Module 1: Situation Awareness and Assessment – In general, how will the traffic situation affect initial situational awareness development. Traffic situational awareness (2-3 Breakout groups with facilitators)
1200 - 1215	Module 1 Group Brief outs
1215 – 1315	Lunch
1315 – 1430	Module 2: Critical Resources – In general how will the traffic situation affect the movement of initial critical resources – e.g. emergency medical, fire, PD, SAR, food/water, critical infrastructure clearance/repair (2-3 Breakout groups with facilitators)
1430 – 1445	Module 2 Group Brief outs
1445 – 1500	Break
1500 – 1530	Key points, common issues, interagency coordination items. Common Operating Picture Issues – Put the pieces together, identify dependencies, overlaps, needed coordination pieces, resource gaps. (Rick Bennett)
1530 – 1600	Hot Wash, Closing Comments. (Mike White)

Welcome and Introductions

All attendees were given ample time to introduce themselves. The attendee list is found in Table 5. A participant handout was also provided with information and guidance for exercise play. The participant handout can be found in Attachment A.

Table 5. Attendee list

First Name	Last Name	Agency
Owen	Hasson	MoDOT
Michael	White	MoDOT
Mike	Foppe	MoDOT
Kenneth	Birke	MoDOT
Mark	Flauter	Florissant Valley Fire Protection District
Sam	Stephens	City of St. Louis
John	Walk	St. Louis Fire Department
John	Wheadon	St. Louis County, Missouri
Jeff	Abel	Government of Illinois
Jenni	Hosey	MoDOT
Athena	Scones	MoDOT
Rick	Bennett	WSP
Michael	Ruddy	Missouri Department of Natural Resources
Brian	Umfleet	MoDOT
Andrew	Blevins	Mercy
Andrea	Pye	Mercy
Bryan	Rosinski	Missouri Department of Natural Resources
Michael	Dolde	WSP
Tawanda	Bryant	MoDOT
Scotty	Melton	MoDOT
Kevin	Vogel	MoDOT
Michelle	Forneris	MoDOT
Brandon	Keller	IDOT
Henry	Brown	Univ. of Missouri
Daeyeol	Chang	Univ. of Missouri
Praveen	Edara	Univ. of Missouri

Traffic Modelling for Earthquake Project Overview

Praveen Edara gave an overview of the Identification of a Response and Rescue Network for the St. Louis Region (aka Traffic Modelling for Earthquakes) research project. The presentation can be found in Attachment B.

Overview of ShakeCast, Traffic Planning Resources, Other New Tools

Mike White (MoDOT) gave an overview of tools that are being used and developed by MoDOT. The presentation can be found in Attachment C.

Brief overview of agency plans

Each participating agency was given approximately five minutes to summarize related agency earthquake plans. The following provides a summary from each agency.

MoDOT SL District Traffic

- Ingress is main concern.
- Signal timing: need to look at egress routing, used to look at ingress (help coming in) for earthquake.
- Maintaining connectivity is a main challenge.
- TMC: communicate to people who don't know what route to take. How can we make them aware, typically something people don't talk about. We need a better communication plan. This needs to be better than a bad weather plan. More than "be prepared for bad weather and closed roads".
- (Communications over large area went down in Nebraska from T-1 line outage.)
- Need to be prepared, this will be huge.
- Boots on the ground.
    - How to get the job done with limited resources, getting the resources together.
    - Getting primary routes inspected.
    - How do we talk to field staff?
    - Resource management.
- Customer calls needing information: what is MoDOT going to do?
- Arterial congestion issues.
- EOC resource management, tracking it, what's available?
- What buildings are open, communication.
- Civil air patrol cooperative training, need to keep this going.

Hospitals/EMS/Healthcare

- Supply chain routes: what roads can be used to resupply and how long will it take?
- Flooding and other natural disasters is focus of plans.
- Real time information for supply chain routes for delivery routing.

- Pharmacy/drug supply concerns. (There is a warehouse in Springfield.)
- Three trauma centers in region C all have good comms - they have alternate communications (3 - 4 options deep), includes Sat Comms, amateur radio.
- There's a whole structure within state EOCs for BEOCs (business EOCs) for them to fit into disasters, and we are probably missing a lot of that, but we are working on how best to fit those in so that information can be passed on to those human impact/lifeline business.
- We've got business continuity plans, evacuation plans, etc., but there needs to be a best way to put this information together.
- Would it help to have a hub for transportation plans so those transportation plans can be shared out? Teams?

St. Louis County

- They have sent people to MoDOT EOC instead of having MoDOT at County EOC.
- Earthquake may be different from other responses.

St. Louis County Fire

- Need a plan for local response – incoming and outgoing help.
- Talking to locals, where do they go, who does this?
- They will be coordinating with MoDOT to see what is closed, open, and then check arterial routes, and put it all together.
- They feel MoDOT as ESF#1, is ultimately responsible for those ingress and egress routes, but getting the information up to us to be able to make decisions, and then passing that information back down is a gap.

State Emergency Management Agency (SEMA)

- Evacuees to other side of the state/country for shelter: one stop shop from first aid, food water, whatever to get folks to other side of state. Where do we put a consolidated site? Still working on best locations.
- There is a full-scale exercise next year.
- The companies who build natural gas pipelines are telling us it will be years before they can get the infrastructure back if it is hit bad enough.
- You'd have to explain to people that they may have to leave their house for over a year before infrastructure is back up and running.
- Schools won't be available to communities for 1 ½ years.
- A lot of the new tools can be built on to ESRI map layers in real time, and a good way to send out information. If there's an active map layer across the state, that's very useful.

MoDOT St. Louis TMC

- Communicating to people what they can do, what they can't do, how they should evacuate and how long they need to plan for, it's not something that they really talk about even in schools that try to run drills or help families plan.
- We may also have to look how we are going to function if we don't have our natural resources, power, or people to be able to function.
- MoDOT relies heavily on our devices, cameras, communication, apps, Not having those to be able to send information, to be able to do our jobs, can be an issue. Powerlines, fiber optic cables, and issues that affect them should be thought about. Signals, timing, infrastructure that relies on it.
- Bridge inspector is thinking about how they are even going to get their people out to inspect the bridge to see if the route is even open. How will we stay in communication with his folks and how are his folks going to let him know those resources are open or not?
    - Tracking what's deployed out into the field. Who is out there with what equipment.
- SAVE Coalition for bridge inspection?
- Staffing issues for TMC.
- St. Louis has statewide coverage at night.

MoDOT Safety

- They will be part of the response.

MoDOT Research

- One of the research projects is using artificial intelligence and machine learning, and how we can apply AI to all the data sets that we get and communicate it out so we don't have to go through it as a human and let the machines can take care of disseminating that information.
- How can we get the info out on one format?

MoDOT Central Office

- Get the info to the response community first.
- How do we help agencies know where good locations are to set up sites?
- How do we organize this IM structure.
- Internal policy.
- Can share ShakeCast map in KML format?
- Who pays?
- GETS card may be another backup communication.

Department of Natural Resources

- Spill line: great communication with MoDOT.

- There are Pipeline Association of MO (PAM) meetings – need to attend, engage pipelines.
- Work with LEPC (Local Emergency Planning Commissions).
- LEP Districts also.

St. Louis City Fire

- Can we get out of the fire house, are units functional?
- Rely on City public works to help them out on routes.
- Look at situational awareness, develop response teams i.e. human services, engineering.
- Has resources to bear in the city - 43 fire departments but in the city, they are fairly self-sufficient.
- Radio units shared between the hospital and Fire/EMS.
- FirstNet stays up – is reliable (as demonstrated at large events such as “pride fest”).
- Build map layers (real-time) map layers for a “LIVE” look at what’s happening right now.
- How do we communicate what the local FD’s see, get that information up to SEMA, and then SEMA can get it back out to the public?

Illinois Department of Transportation (IDOT)

- Three C’s: communications, coordination, and cooperation.
- Doing these seminars and workshops are part of that, ongoing meeting and coordinating is important. Being prepared like this can help you easier to adapt to all hazards.
- Use NIMS.
- Don’t really know exactly what’s going to happen, be flexible and ready.
- Incorporate ground level operations into plan.
- Keep lines of communication open with partners, other support functions.

Presentation of Earthquake Scenario

Rick Bennett presented the earthquake scenario for the exercise, discussion points and instructions for breakout discussions. The presentation can be found in Attachment D.

Breakout Modules

The breakout modules were structured as follows.

Module 1: Situation Awareness and Assessment – In general, how will the traffic situation affect initial situational awareness development. Traffic situational awareness (2-3 Breakout groups with facilitators).

Module 2: Critical Resources – In general how will the traffic situation affect the movement of initial critical resources – e.g. emergency medical, fire, PD, SAR, food/water, critical infrastructure clearance/repair (2-3 Breakout groups with facilitators).

Breakout Session Notes

The following provides summary notes of the breakout sessions as developed and briefed out by each group.

Module 1, Group 1

Question 1, Gridlock

- No power = no method to communicate.
- No fiber = darkness.
- Texting may still be functional.
- Strategically positioned on I-55, I-64.
- Answering public phone calls, maintenance calls, situational awareness calls.
- Restoring power is a priority!
- Critical MoDOT buildings have backup generators (~3 days functionality).
- Dedicated helicopter for situational awareness, damage assessment.

Question 2, Planning Assumptions

- Drones for bridge damage assessment.
- Critical to communicate with news agencies, crowd sourcing apps.
- MOSWIN use.
- Uncertainty of epicenter location.
- What time of the year is this happening?

Question 3 Planning Gap

- Access points for logistics and people (e.g. local airports).

Module 1, Group 2

Question 1, Gridlock

- Priority routes will be impacted first.
    - Need to keep them open.
    - Limited resources.
    - 12-72 Hours of initial impact.
- Communication
    - Fire depts. may know first – how to pass the information.
    - Power outage map from Ameren – help know where congestion might be.
    - Boots on the ground are the best source of information.
- Crowd source data if cell service.
- Where to set up potential sources/sites of distribution.

- Weather, games, other factors?
- Generators?
- Shift changes for hospitals.
    - Just in time supply chain.
    - Anything elective is suspended.
- Hospitals could be bogged down with minor medical injuries from earthquake.
- Staff may stay on site because they cannot get out.
- MOUs.
- Alternate care sites.

Question 2, Planning Assumptions

- Maybe not a lot of injuries, but structure impacts.
- Time expectations.
- Have a centralized IAP for situational awareness.
- COOP.
    - IDOT employees not mandated to come in for earthquake response.
    - Residency requirements.

Question 3 Planning Gap

- Refreshing MOUs – 2 years schedule?
- Finance/admin.
- Communications and cooperation between disciplines.
- What each discipline can and cannot do and communication of capabilities.
- Plans for sheltering employees.
- Just-in-time vs. mission critical supply deliveries.
- Resource access.
- Situational awareness.

Module 1, Group 3

Question 1 Gridlock

- Responders need to get to the scene to address the concern.
- TMC relies heavily on telecommunications: what's causing the congestion, to see what issue is going on and how to address it.
- Police responding to issues can get field information and pass on to dispatch for routing.

Question 2 Planning Assumptions

- Civil unrest may flair up quicker than anticipated, this happened in Hurricane Katrina.

- The timing of this earthquake (in the afternoon rush-hour) most people are heading home, this will add to urgency to people trying to get home and check on family & household concerns.

Question 3 Planning Gap

- Is 3hrs – 4hrs for residents to start evacuating after an earthquake 'true' & reasonable? The group thought 6hrs – 7hrs would be a more realistic assumption. Folks need to check on their family and house first, maybe make arrangements with family or friends on where they can stay out of the area and then gather stuff to evacuate. At that time, it may be dark when they actually leave, resulting in even more travel/congestion issues.
- An earthquake in the SL region may leave the 'island effect' separating St. Louis County/City from heading West through St. Charles or other counties due to river bridges.
- Responders may not be in the county where they are employed, and needed to be in order to inspect and respond when the earthquake happens. They may not be able to get to their county of employment.
- MONG does not move fast. The earliest you may expect them for assistance would be in two (2) weeks.
- Continuity of operations (COOP): is your stand-in (next-in-line/2ndary) able to step in to your role, if you are taking care of your personal 'family' needs and unable to respond to your job/agency?
- Study was conducted that revealed 2/3rds of responders would NOT show up if a catastrophic incident happened until they are certain that their family needs are being taken care of.
- Travel issues such trying to navigate around traffic on the shoulder or on right-of-way. Issues such as water main breaks could cause ground to become too soft for fire trucks to navigate over resulting in disabled response vehicles.
- Agencies may need to partner with law enforcement to get a good sit-rep.
- Would need good reliable updates on power resources, utility service updates. Accuracy would only be as good as what is being supplied by other agencies or utilities to you.

Module 2, Group 1

Question 1 Movement of Critical Resources

- Slower response from emergency responders (logistics).
- Using other resources like aerial support for traffic diversion and less congested area.
- Using other modes of transportation (bikes/metro rail).

Question 2 Planning Assumptions

- Time of resources to arrive.
- Expenses needed – fuel/general expenses along with digital world cash/credit.
- Public misinformation.
- Traffic device/sign/structure impacts.

Question 3 Planning Gaps

- Logistical storage and backups.
- Establish communications with local businesses for supply.
- Having plan B.
- Planned/coordinated command.
- Resources already in place/hard copy.

Module 2, Group 2

Question 1 Movement of Critical Resources

- Just-in-time vs critical.
  - Lifeline/medical supplies.
- Where are the supplies coming from and how far away?
- Mutual aid.
- Would be forced to find less than ideal routes that would delay deployment/emergency response.
- 24-72 hours for situational awareness assessments.
- How to make routes for emergency resources only – having to make repairs to even get in.
- Forward operating bases.

Question 2 Planning Assumptions

- Expectations may need to adjust.
- Relaying information for public.
  - Carful to give enough without creating mass hysteria.
  - Vetted info.
  - PIO in region is really good and cooperates well – continue those relationships.

Question 3 Planning Gaps

- Mutual aid.
- Planning – everyone will be vying for the same resources.
- Key people may change – institutional knowledge.

Module 2, Group 3

- Slow down response.
- Require a lot more coordination.
- Delay medical attention – critical issues.
- Fire response may not happen.
- Prioritize response (pick and choose) – life safety vs environmental.
- COOP for elected officials – city, county, etc.

- Jurisdictional authority on removal and access.
- Responders needs for food, water, etc.
- Government employee support, also.

Key Points Summary

Rick Bennett facilitated a summary of key points from the entire exercise summarized as follows.

- Communications is a common discussion point.
- Communications things that work:
    - 800 MHz, VHF agency radios, Starcom (IL).
    - FirstNet (AT&T first responder system).
- Pipelines need to be part of the planning and response.
- Delayed response times – understanding the reality with traffic congestion issues.
- Other modes could come into play.
    - Trains.
    - Bikes.
    - Peds.
- Public expectations – work to set these realistically.
    - Use the public information resources – "JIC".
- Mutual aid is important – between regions and disciplines.
- Awareness of vulnerable people and what is required. (This is not just an urban issue, can also happen in rural areas).
- Signal timing on arterial routes will likely need to be adjusted for the earthquake scenario.
- Everybody (responders and the public) needs food, water, medical, aka basic needs.

What's Next Discussion

What's Next Discussion (Mike White) – also served as hot wash and closing comments.

- Summary of Items.
- Continue development of Common Operating Picture.
- Next meeting – late March/April.
    - MOU agreements.
    - NIMS org.
    - Review priority routes.
    - Ingress/egress routes.
    - Mental health CISM.
    - Resource management/logs.
    - Planning timelines.
- Who to invite:
    - MO School Board.
    - Nursing homes.
    - Ameren/utilities.

    - Law enforcement.
    - PAM.
    - EMS.
    - Red Cross.
    - City/county DOT.
    - Elected officials.
    - FirstNet.
    - MOSWIN.
    - ARES.
    - Emergency Comm. Committee (Shannon Icloos).
    - Port.
    - Air.
    - Rail.
    - Bi-state development.
    - Motor Carriers.
    - Businesses – critical.
- Develop Plans Library.

Attachment A: Exercise Handout

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Earthquake Response Tools for Transportation TTX

Participant Handout

September 21, 2023 | Chesterfield, MO

Purpose and Scope

The "Identification of a Response and Rescue Network for the St. Louis Region" MoDOT research project is developing refined anticipated traffic impacts in the St. Louis area following a major New Madrid Seismic Zone earthquake as well as processes for predicting traffic impacts based on various assumptions and scenarios.
The purpose of this tabletop exercise is to develop a realistic traffic impact scenario and engage various key stakeholders in discussion based on a simulated real-world response. It is anticipated that the outcomes of this exercise will assist MoDOT, local law enforcement, local emergency management, other key agencies in planning and preparing for a major earthquake event.

Exercise Overview

A major earthquake of magnitude 7.5 occurred at 3PM on a weekday. AT 5PM damage has been reported over the entire eastern part of Missouri to bridges and roadways. Traffic issues in St. Louis are being reported indicating heavy congestion on many routes. The St. Louis area is experiencing outages of telecommunications and power.

Objectives

Mission Area	Core Capability	Objective
Protection	Planning	Help MoDOT staff and key stakeholders develop an understanding of traffic issues following an earthquake event and how the traffic challenges may influence response.

Mission Area	Core Capability	Objective
Protection	Planning	Gain an understanding or how traffic congestion will affect elements of agency plans; situational awareness/damage assessment, shelter activation locations and resources, local emergency responder deployments, etc. (Look at their plans to see what is likely to be challenged by traffic problems at a relatively high level, appropriate to a one-day TTX). Evaluate efficacy of MoDOT's response plan related to traffic. Develop injects to highlight traffic challenges to their response, such as: Post incident bridge inspection. Traffic incident response challenges focused on MoDOT priority routes. TMC limitations, such as outages of freeway detectors, traffic cameras, DMS. Accessibility of MoDOT crews to assess any damage and remove debris. Ingress of external support resources.
Response	Critical Transportation	Gain an understanding of initial internal critical resource movement including fire, medical, PDs, infrastructure owners such as MoDOT, Ameren (power), Spire (nat. gas), pipelines and access to critical facilities such as hospitals, shelters, grocery/drug stores, etc. Gain an understanding of the impact to ingress of external critical resources starting with emergency medical, search and rescue, food, fuel, etc.
Response	Critical Transportation	Understand the realities of earthquake evacuation related to real time traffic issues.
Response	Public Information and Warning	Evaluate existing public information tools related to traffic information following an earthquake event.
Response	Situational Assessment	Identify situational awareness/damage assessment challenges related to traffic issues. Understand the potential traffic issues following an earthquake, particularly the worst case scenario of an earthquake occurring near a peak period on a weekday.

St. Louis Earthquake Tabletop Exercise 9/21/2023

Exercise Schedule

0730 – 0800	Registration
0800 – 0830	Welcome and Introductions
0830 – 0915	Traffic for Earthquake Project Overview (Praveen Edara)
0915 - 0945	Overview of Shakecast, Traffic Planning Resources, Other New Tools (Mike White)
0945 - 1015	Brief overview of agency plans - 5 minutes each – what are you going to do (Agency Reps)
1015 - 1030	Presentation of exercise scenario (Rick Bennett)
1030 – 1045	Break
1045 – 1200	Module 1: Situation Awareness and Assessment – In general, how will the traffic situation affect initial situational awareness development. Traffic situational awareness (2-3 Breakout groups with facilitators)
1200 - 1215	Module 1 Group Brief outs
1215 – 1315	Lunch
1315 – 1430	Module 2: Critical Resources – In general how will the traffic situation affect the movement of initial critical resources – e.g. emergency medical, fire, PD, SAR, food/water, critical infrastructure clearance/repair (2-3 Breakout groups with facilitators)
1430 – 1445	Module 2 Group Brief outs
1445 – 1500	Break
1500 – 1530	Key points, common issues, interagency coordination items. Common Operating Picture Issues – Put the pieces together, identify dependencies, overlaps, needed coordination pieces, resource gaps. (Rick Bennett)
1530 – 1600	Hot Wash, Closing Comments. (Mike White)

Exercise Ground Rules

The following exercise implementation guidelines and rules apply to all Participants:

- The exercise is a safe place to discuss all issues associated with the exercise's scenario and objectives.
- Everyone's feedback is equally valuable.
- There are no wrong answers.
- Participants are encouraged to discuss additional or alternative options and solutions.
- Respond based on your knowledge of current plans and capabilities.
- Assume cooperation and support from other responders and stakeholders.
- Participants should allow the Facilitator to facilitate.
- Don't fight the scenario.

Exercise Assumptions

In order to ensure that exercise events progress in a semi-realistic manner and that all objectives are achieved during the exercise play, the following assumptions have been made:

- Participants are well-versed in their agencies' jurisdiction, responsibilities, response, and planned interface/coordination with other agencies.
- Participants respond in accordance with existing plans and procedures. In the absence of written procedures, Participants apply their individual initiative to satisfy response requirements.
- Participants participate for the entire duration of the exercise.
- Time compression and/or jumps may be necessary to allow all organizations the opportunity to achieve their objectives.
- For the purposes of this tabletop exercise the scenario is only one example, the discussion does not have to be restricted to this specific scenario.

Participant Feedback

After the completion of this exercise, please fill out this survey to provide us with your feedback:
https://exis.tsa.dhs.gov/Survey.aspx?ID=611615

Participating Stakeholders

BJC
City of St. Louis
East West Gateway Council of Governments
Florissant Valley Fire Protection District
Jefferson County
Mercy
Missouri Department of Natural Resources, Environmental Emergency Response Section
MoDOT
St. Louis County
State of Illinois
University of Missouri
Warren County
WSP

I-STEP Background

Background

The Transportation Security Administration's (TSA) Intermodal Security Training and Exercise Program (I-STEP) provides exercise, training, and security planning tools and services to the transportation community. The program focuses on the security nexus of the intermodal transportation environment, serving mass transit, freight rail, pipe line, port and intermodal, highway and motor carrier, and aviation modes. Working in partnership with the transportation modes, I-STEP enables security partners to:

- Enhance security capabilities – Strengthen plans, policies, and procedures; clarify ro les and responsibilities; validate planning needs; and strengthen grant proposals
- Build partnerships – Develop relationships with regional transportation players and other stakeholders.
- Gain insights in transportation security – Network wi th peers to gain a deeper understanding of security lessons learned and best practic es.

I-STEP is the only Federal exercise program to focus on the security nexus of the intermodal transportation environment. As a result, the program reduces risk to individual systems as well as the entire transportation network. I-STEP aligns to TSA's Transportation Systems Sector-Specific Plans (TSSSP) under the National Infrastructure Protection Plan (NIPP). The office of Policy, Plans, and Engagement (PPE) manages this program.

The Exercise Information System (EXIS) portal guides users through a step-by-step exercise planning process to develop their own specific security exercise. EXIS is an intuitive system providing a variety of exercise planning and evaluation tools as well as lessons learned and best practices from the DHS Transportation Systems Sector and other aligned user communities. Lessons learned and best practices from exercises and training events along with intelligence information help shape transportation security policy and guidance. Go to: https://exis.tsa.dhs.gov to receive an account and use the tool.

I-STEP Programmatic Goals

- Develop a comprehensive transportation security exercise program
- Serve as a training resource for TSA security partners
- Foster information sharing/collaboration among security partners
- Provide support services to TSA modal representatives

Contact Information

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Participant Notes

Attachment B: Slides on Scenario Modeling

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Identification of a Response and Rescue Network for the St. Louis Region

Sponsor: Missouri DOT

St. Louis Tabletop Exercise

1

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Progress Update

I. Scenario Generation

II. Demand Creation

III. Simulation Results - Road Network Performance

2

Scenario Generation

- Scenarios created by varying evacuation demand, road network, and time of earthquake occurrence.
- Residents assumed to evacuate to one of the super zones outside the St. Louis metro region (4 located in Missouri, 3 in Illinois)
- Two different occurrence times for earthquake (EQ): 7 am and 4 pm
- Residents in Missouri, would evacuate to super zones in the west.
- Residents in Illinois, would evacuate to super zones in the north.
- Demand is generated for 3,003 zones and are distributed to the super zones based on proximity, using the Gravity Model.

3

List of Scenarios

- Scenario 0: Base network, normal daily demand
- Scenario 1: Base network, 100% demand (EQ occurs at 7 am)
- Scenario 2: Base network, 50% demand (EQ occurs at 7 am)
- Scenario 3: Base network, 30% demand (EQ occurs at 7 am)
- Scenario 4: Base network, 100% demand (EQ occurs at 4 pm)
- Scenario 5: Base network, 50% demand (EQ occurs at 4 pm)
- Scenario 6: Base network, 30% demand (EQ occurs at 4 pm)

4

List of Scenarios (continued)

- Scenario 7: Damaged network, 100% demand (EQ occurs at 7 am)
- Scenario 8: Damaged network, 50% demand (EQ occurs at 7 am)
- Scenario 9: Damaged network, 30% demand (EQ occurs at 7 am)
- Scenario 10: Damaged network, 100% demand (EQ occurs at 4 pm)
- Scenario 11: Damaged network, 50% demand (EQ occurs at 4 pm)
- Scenario 12: Damaged network, 30% demand (EQ occurs at 4 pm)

- Six baseline scenarios and six damaged network scenarios
- 2 networks x 3 demands x 2 EQ times = 12 scenarios (plus one baseline)

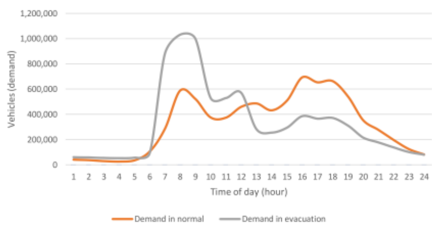
5

Demand Creation

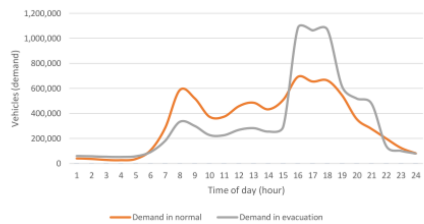
- St. Louis evacuation survey was used to generate evacuation demand
  - 56% of demand was assigned within 3 hours of earthquake occurrence
  - 26% of demand was assigned within 3 to 6 hours
  - Remaining 18% equally distributed from 6 to 24 hours

6

Demand Curves – how traffic is loaded onto the network



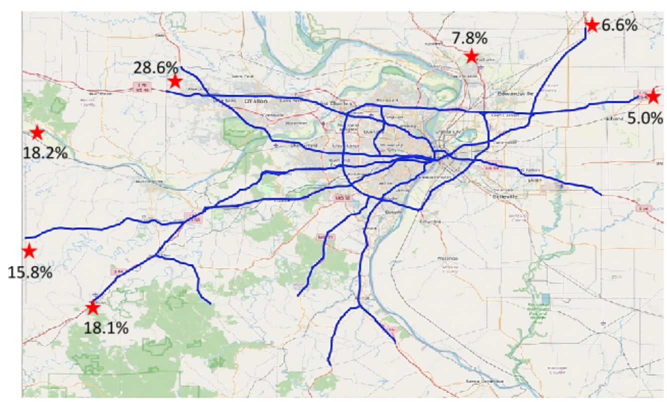
Earthquake Occurrence at 7 A.M.



Earthquake Occurrence at 4 P.M.

7

Distribution of Demand to Super Zones



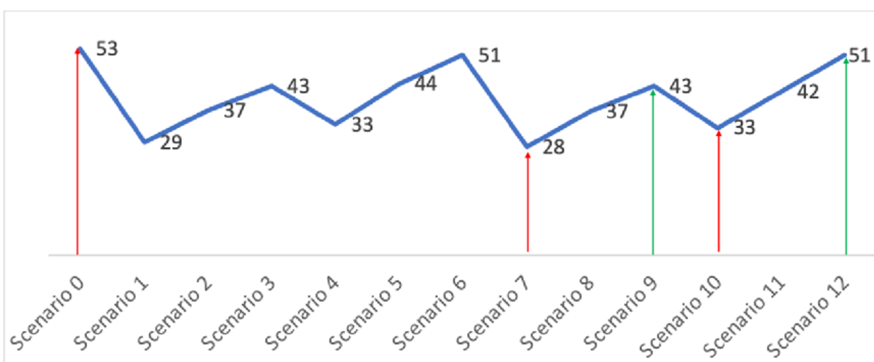
8

Simulation Results – Average Speeds (mph)

Scenario	AM	MidDay	PM	NightTime	24-hour Average
Scenario 0	51.66	54.39	50.40	54.99	52.86
Scenario 1	24.17	26.28	30.84	34.17	28.87
Scenario 2	32.01	35.19	38.67	42.81	37.17
Scenario 3	38.84	41.90	44.35	47.91	43.25
Scenario 4	37.30	39.51	24.63	32.21	33.41
Scenario 5	45.49	46.79	42.86	40.58	43.93
Scenario 6	53.11	53.71	46.93	50.90	51.16
Scenario 7	22.42	24.89	30.31	33.60	27.81
Scenario 8	31.63	34.58	38.62	42.86	36.92
Scenario 9	38.41	41.95	44.50	48.17	43.26
Scenario 10	37.02	39.28	22.70	31.67	32.67
Scenario 11	44.58	41.63	42.84	38.62	41.92
Scenario 12	53.44	54.03	46.68	51.26	51.35

9

Average Speed across Network (mph)



10

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AM Scenarios Comparison – Speed Maps

Baseline

Scenario 7 (100% demand)

Scenario 8 (50% demand)

Scenario 9 (30% demand)

- 60-80 mph
- 40-60 mph
- 20-40 mph
- 0 - 20 mph

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PM Scenarios Comparison – Speed Maps

Baseline

Scenario 10 (100% demand)

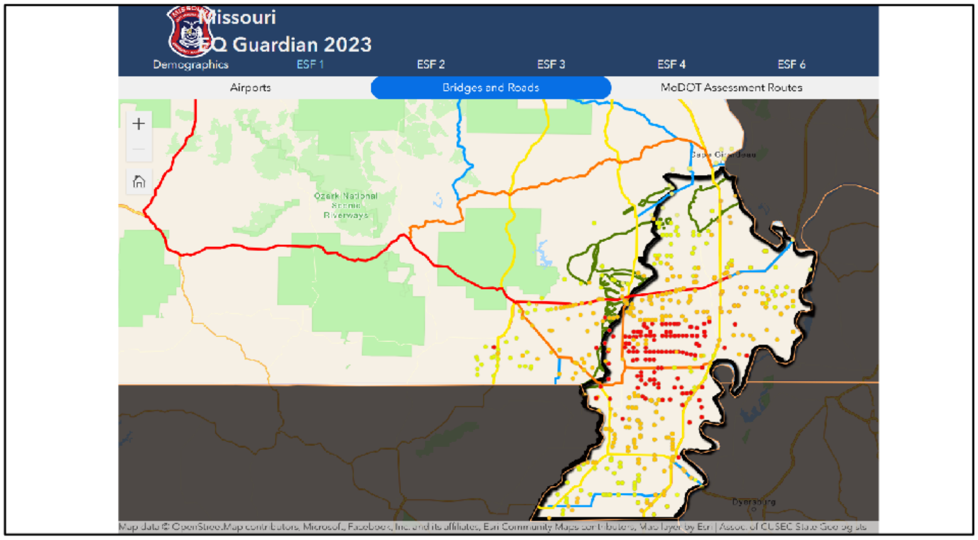
Scenario 11 (50% demand)

Scenario 12 (30% demand)

- 60-80 mph
- 40-60 mph
- 20-40 mph
- 0 - 20 mph

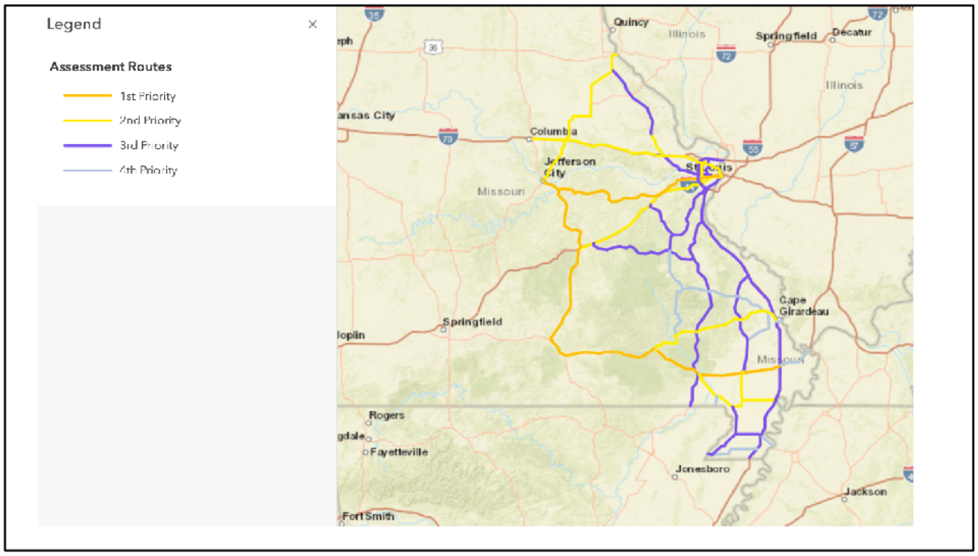
12

Attachment C: Evacuation Exercise Slides

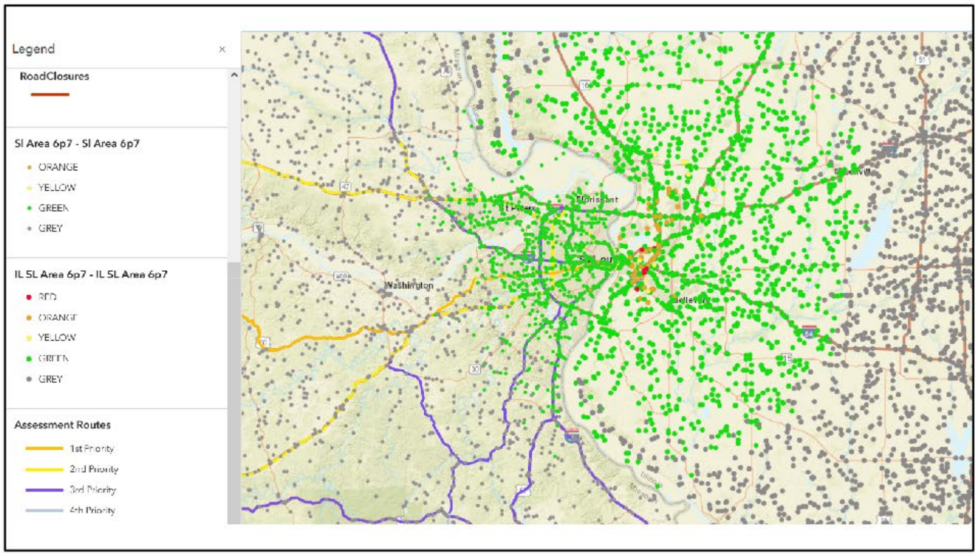


MoDOT has joined several states in supporting a USGS project called ShakeCast. ShakeCast takes data from the National Bridge Inventory and creates a priority list for bridge inspections after an earthquake. MoDOT receives this report approx. 10 minutes after a 3.5 magnitude or greater earthquake. The model pictured above is the inspection priorities for the 7.5m earthquake on the northern most New Madrid fault. Having this data a few minutes after an earthquake allows MoDOT to focus our resources to inspect bridges in the area most likely to sustain damage. Also noted on this picture are our inspection priority routes explained in the next slide. This data is being viewed through a new Situational Awareness view that was developed by SEMA's GIS staff.

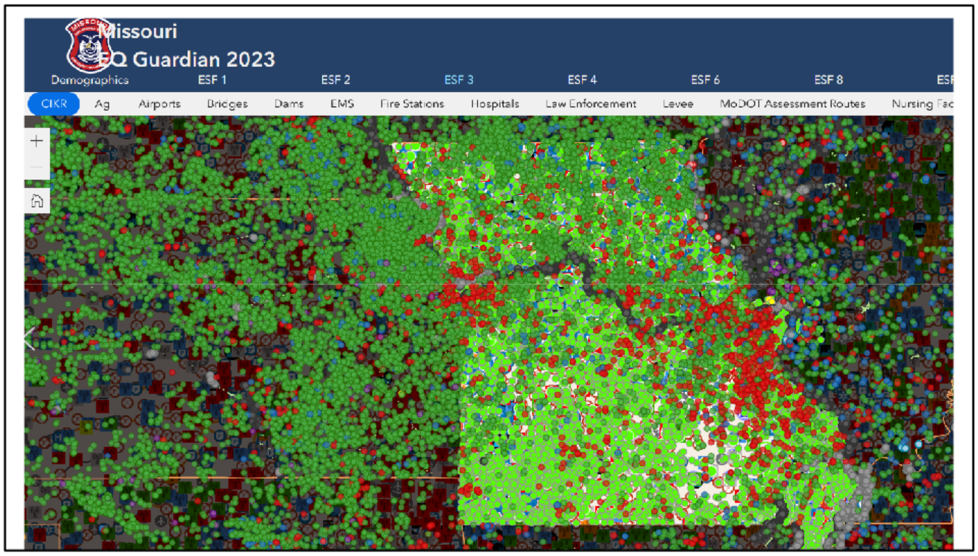
1



MoDOT developed priority routes that we will focus our resources for initial bridge inspections. These routes were assessed for the level of earthquake resilient features as well as the number of bridges that may be impacted. MoDOT
will prioritize inspections these roadways. MoDOT's earthquake plan triggers bridge inspections for any earthquake of magnitude 5.0 or greater. We will also re-inspect all bridges after each 5.0 or greater aftershock.



This map represents a model depicting a 6.7 magnitude earthquake just to the east of St. Louis in IL. The dots represent the priority of inspection from red being the highest priority to green being the lowest priority and grey noting bridges
that would not be impacted at a level requiring inspection.



The Missouri State Emergency Management Agency's GIS staff have developed a situational awareness viewer that has data layers for the Emergency Support Functions that are staffed at SEMA.. As you see in the heading above this layer has multiple points tied to critical infrastructure and key resources. The color coding will be able to be changed depending on the capability of the resource. For instance bridges can be coded red for closed, yellow for needs inspection or green for open . This system provides a high level of situational awareness across all response resources. We are testing the system during an October 2023 earthquake exercise at SEMA and are putting a workgroup together to further refine it.

Attachment D: Slides from Earthquake Evacuation Scenario

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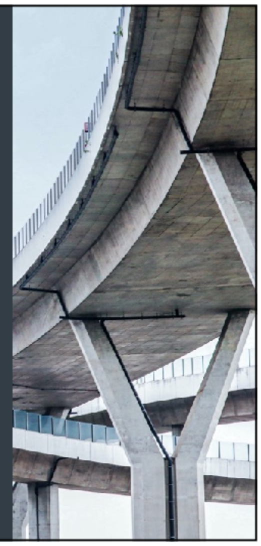
Tabletop Exercise

9/21/2023



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Exercise Objectives

Planning

Help MoDOT staff and key stakeholders develop an understanding of traffic issues following an earthquake event and how the traffic challenges may influence response.

Gain an understanding or how traffic congestion will affect elements of agency plans at a relatively high level:

- Situational awareness/damage assessment.
- Shelter activation locations and resources.
- Local emergency responder deployments, etc.

Evaluate efficacy of MoDOT's response plan related to traffic. Consider:

- Post incident bridge inspection.
- Traffic incident response challenges focused on MoDOT priority routes.
- TMC limitations, such as outages of freeway detectors, traffic cameras, DMS.
- Accessibility of MoDOT crews to assess any damage and remove debris. Ingress of external support resources.

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Exercise Objectives

Situational Assessment

Identify situational awareness/damage assessment challenges related to traffic issues.

Understand the potential traffic issues following an earthquake, particularly the worst-case scenario of an earthquake occurring near a peak period on a weekday.

Public Information and Warning

Evaluate existing public information tools related to traffic information following an earthquake event.

3

Exercise Objectives

Critical Transportation

Gain an understanding of initial internal critical resource movement related to traffic issues including:

- Fire, Medical, PDs,
- Infrastructure owners such as MoDOT, Ameren (power), Spire (nat. gas), pipeline operators
- Access to critical facilities such as hospitals, shelters, grocery/drug stores, etc.

Gain an understanding of the impact to ingress of external critical resources starting with emergency medical, search and rescue, food, fuel, etc.

Understand the realities of earthquake evacuation related to real time traffic issues.

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Scenario

A major earthquake of magnitude 7.5 occurred at 3PM on a weekday. AT 5PM damage has been reported over the entire eastern part of Missouri to bridges and roadways. Traffic issues in St. Louis are being reported indicating heavy congestion on many routes. The St. Louis area is experiencing outages of telecommunications and power.

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Scenario

General Injects for Discussion

Earthquake response plans have been activated at various levels; federal, state, local.

The state EOC and most County EOCs in the eastern 1/3 of Missouri are activated.

Situational assessment activities are under way. Field units have made reports, however some areas cannot be accessed due to traffic congestion. Those dependent on cell phone communications are having difficulty making calls and sending/receiving text communications. Two-way radio systems are generally functional, but dispatchers are heavily loaded handling emergency calls and situational awareness is secondary priority.

Emergency response units, police, fire, medical are overwhelmed with emergency call response.

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Scenario

General Injects for Discussion (Cont.)

Infrastructure operations including MoDOT, Ameren UE, Spire, Missouri American Water, Metropolitan Sewer District and local agencies and others are also overwhelmed with reports of damage.

National news outlets are calling; how much damage has occurred, are the agencies responding and what are they doing, what are recommendations to the public, should they be evacuating?

The State Emergency Operations Center has advised that they are fully operational and are asking for situation reports from each County by 9PM.

AM Scenarios Comparison – Speed Maps

Baseline

Scenario 7 (100% demand)

Scenario 8 (50% demand)

Scenario 9 (30% demand)

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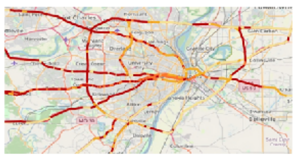
PM Scenarios Comparison – Speed Maps

Baseline

Scenario 10 (100% demand)



Scenario 11 (50% demand)

Scenario 12 (30% demand)

- 60-80 mph
- 40-60 mph
- 20-40 mph
- 0 - 20 mph

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Module 1

Situation Awareness and Assessment – In general, how will the traffic situation affect initial situational awareness development.

Discussion Questions:

How will traffic congestion issues affect your development of situational awareness?

Are there planning assumptions that need to change related to situational awareness?

Are there planning gaps for your agency, are there changes needed in your plans?

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Module 2

Critical Resources – In general how will the traffic situation affect the movement of initial critical resources – e.g., emergency medical, fire, PD, SAR, food/water, critical infrastructure clearance/repair

Discussion Questions:

How will traffic congestion issues affect your anticipated movement of critical resources?

Are there planning assumptions that need to change related to critical resources?

Are there planning gaps for your agency, are there changes needed in your plans?

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Thank you

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