2025 Transportation Technology Tournament

ROUTE OPTIMIZATION FOR ACCELERATED RESPONSE (ROAR)

Intelligent Tiger Systems

Drew Davis, Jacinta Fritz, Chase Kesner,
Amelia Strozier, and Eleanor Waldron

Project Name:	ROAR: Route Optimization for Accelerated Rescue		
Team Name:	ITS: Intelligent Tiger Systems		
Team Members:	*Name:*	*Age:*	*Pursued Institutional Degree:*
	Drew Davis	22	Bachelor of Science in Civil Engineering (BSCE), Bachelor of Arts (BA); University of Memphis
	Jacinta Fritz	22	Bachelor of Science in Mechanical Engineering (BSME); University of Memphis
	Chase Kesner	28	Master of Science in Civil Engineering (MSCE); University of Memphis
	Amelia Strozier	22	Bachelor of Science in Biomedical Engineering (BSBME); University of Memphis
	Eleanor Waldron	22	Bachelor of Science in Electrical Engineering (BSEE); University of Memphis
Academic Advisors:	*Name:*	*Profession:*	
	Dr. Stephanie Ivey	Professor with the Department of Civil Engineering, Associate Director of Transportation & Logistics; University of Memphis	
	Dr. Aaron Robinson	Associate Professor with the Department of Electrical & Computer Engineering; University of Memphis	
Sponsors:	Herff College of Engineering; University of Memphis		
	National Operations Center of Excellence (NOCoE)		
Abstract:	The University of Memphis commencement ceremony takes place at the FedEx Forum in Memphis, Tennessee to recognize the academic achievements of graduating students, which causes significant traffic congestion and travel delays twice a year. Within a twelve-hour time frame, three consecutive graduation ceremonies take place with over 2,800 diplomas being distributed and an unregulated number of guests being allowed to celebrate the success of the graduates. While current efforts to cope with the abnormal influx of congregating people include Memphis City Police manually directing traffic, such efforts are focused solely on pedestrian safety. Thus, the increase in traffic congestion which poses a significant challenge to the efficient response of emergency personnel in the event of an emergency requiring outside aid at the FedEx Forum is an unsolved problem. The following report proposes an Intelligent Transportation Systems (ITS) solution for effectively routing emergency response vehicles during congested commencement traffic through the utilization of dynamic barriers, Dynamic Message Signs (DMS), Transit Signal Priority (TSP), and Global Positioning System (GPS) tracking. The dynamic barriers will be permanently installed on pre-determined emergency response routes and, under normal conditions, will be left open. In the event of an emergency, the dynamic barriers will implement a system of sensors and GPS tracking to permit route access to emergency response vehicles only. Through DMS, public traffic currently on the route will be directed to exit the route, and traffic seeking to enter the route will be informed about current route closures and directed accordingly.		
Date:	May 7th, 2025		

ACKNOWLEDGEMENTS

The team would like to specially thank Dr. Stephanie Ivey and Dr. Aaron Robinson for their dedicated mentorship and encouragement. Additionally, the team would like to acknowledge the Memphis City Police Department as well as the University of Memphis Commencement Office for their support and data. Finally, the team would like to thank both the National Operations Center of Excellence (NOCoE) and the United States Department of Transportation (USDOT) for their guidance and for hosting the Transportation Technology Tournament.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PROBLEM DESCRIPTION

Background

Twice a year, in May and in December, the FedEx Forum in Memphis, Tennessee, hosts the University of Memphis commencement. Within less than eight hours, three different, consecutive ceremonies representing the university's thirteen different colleges take place to recognize the academic achievements of over 2,800 students receiving their bachelor's, master's, or doctorship degrees. In addition to the number of graduates attending, the university's total commencement attendance can reach well over 200,000 people due to the unregulated number of guests being invited to celebrate the success of their graduates (*University of Memphis*, 2024). On average, for every graduate attending, an additional six to ten guests will attend commencement (*Commencement Office*, 2025). As a result of such an abnormal influx of people congregating at one location and at one time, traffic congestion and wait times on roadways around the FedEx Forum can be severe.

Current Management Practices

Current methods implemented to cope with the abnormal influx of vehicular traffic resulting from the atypical increase in congregating people attending the University of Memphis commencement at the FedEx Forum are near nonexistent. While the Memphis City Police Department does manually direct some traffic during commencement operations, such efforts are focused primarily on pedestrian safety rather than on alleviating traffic congestion.

Solution Requirements

The severe traffic congestion and prolonged wait times created by the abnormal influx of people congregating during the University of Memphis commencement poses a significant challenge to the efficient response of emergency personnel responding to an emergency requiring outside aid at the FedEx Forum. Additionally, with no management practices currently being implemented to combat such atypical traffic patterns, a system of effectively routing emergency response vehicles in an efficient and safe manner in the event of an emergency at the FedEx Forum is needed. The following report proposes an Intelligent Transportation Systems (ITS) solution for effectively routing emergency response vehicles during congested commencement traffic through the utilization of dynamic barriers, Dynamic Message Signs (DMS), Transit Signal Priority (TSP), and Global Positioning System (GPS) tracking.

Stakeholders

While numerous stakeholders have been considered, the following are those identified as high-impact stakeholders:

General Public: Memphis residents, tourists, and event attendees (including, but not limited to, graduates and their family and friends, as well as university faculty and venue staff) will all be impacted by the Intelligent Tiger System's ROAR implementation. Not only will the general public directly contribute to the increase in congestion during special events, but they will also be required to adjust to changes in traffic flow and temporary lane closures in the event of an emergency.

Transportation Authorities: Region 4 Traffic Management Center (TMC) will be responsible for controlling, coordinating, and monitoring ITS roadway equipment, such as DMS and dynamic barriers as well as the already-present Closed-Circuit Television (CCTV) and TSP. Memphis Area Transport Authority (MATA) and Tennessee Department of Transportation (TDOT) may also see some impacts stemming from ROAR.

Planning Organizations: Memphis Metropolitan Planning Organization (Memphis MPO) and City of Memphis Office of Emergency Management (OEM) will be valuable resources in the planning and implementation of ROAR, as they are the organizations responsible for planning and managing emergencies.

Law Enforcement: Memphis Police Department (MPD), Shelby County Sheriff's Office (SCSO), and Tennessee Highway Patrol (THP) will be important partners in ensuring that drivers comply with the dedicated Emergency Vehicle (EV) lanes.

Emergency Responders: Because the primary focus of ROAR is to optimize route efficiencies for large-scale medical emergencies at the FedEx Forum, the major first responders that will be impacted by the proposed system will be those from the fire and medical departments. These emergency responders will be impacted by having known and specified routes to take when emergencies occur at the FedEx Forum during a special event. These stakeholders should see an increase in ease of navigation, allowing for lower stress levels in route and safer driving to and from the location of the emergency. Additionally, emergency dispatchers will also be impacted by the proposed system and will have additional responsibilities in coordinating the activation of the dedicated EV lanes in the event of an emergency. Finally, while the proposed system is dedicated to route optimization for medical and fire first responders, expanding the implementation of ROAR to include other emergency services, such as police, could be easily performed.

Study Area Challenges

The team reached out to local fire stations, police precincts, and hospitals to provide typical emergency response statistics and vehicle incident data but were informed that this data is not available to the public. The team also contacted the City of Memphis for traffic data during planned special events; unfortunately, this data is not collected in the project's area of interest. This made the pre-determined route selection challenging. As for the challenges of the area itself, the convergence of both infrastructure and traffic creates high congestion and safety concerns for the commencement attendees and the emergency responders. As seen in *Figure 1*, the narrow, one-directional, three-lane configuration of the B.B. King Boulevard, coupled with the single lane on S 4th Street, constrains the capacity for motorized traffic around the FedEx Forum. Since the commencement day consists of three times, 10:00 AM, 1:30 PM, and 5:30 PM, there would be a consistent flow of both incoming and outgoing traffic. Unauthorized parking on side streets between the FedEx Forum and Beale Street further constricts already limited roadways, and the shared bicycle lanes on Linden Avenue create additional conflict between cyclists and motorists during high-volume periods.

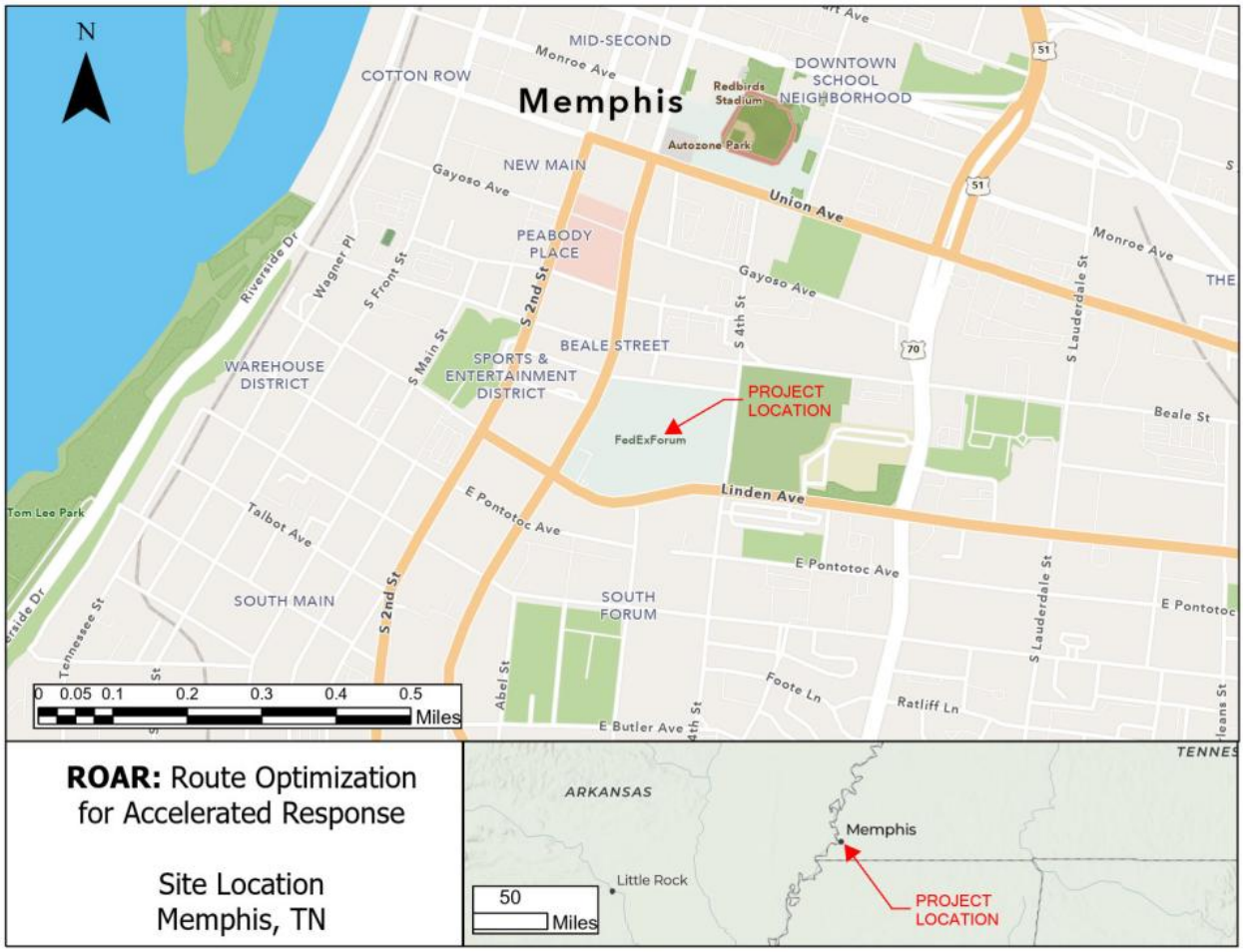

Figure 1: Site Location Overview

Additional Resources

In determining the vehicle-to-vehicle and vehicle-to-infrastructure communication requirements of the ROAR system, the team contacted a local fleet vehicle tracking company, LBTechnology. To determine the current methods implemented by the FedEx Forum to alleviate commencement traffic congestion, the team contacted the Memphis City Police Department (MCPD). The University of Memphis Commencement Office provided data concerning numbers and attendance for the commencement ceremony.

PROPOSED SOLUTION

To optimize the response efficiency of Emergency Medical Services (EMS) in the event of an emergency at the FedEx Forum requiring outside aid during congested commencement traffic, ROAR proposes to implement a system of dynamic barriers placed on certain predetermined Emergency Response (ER) routes that will restrict the access of these routes in the event of an emergency to Emergency Vehicles (EV) only by using a combination of Global Positioning System (GPS) tracking and sensors. As a result, through the combination of Transit Signal Priority (TSP) implementation and dynamic barriers, the predetermined routes will remain congestion-free, which will decrease EV response time and increase

patient survival outcomes. Public transport will be alerted and directed according to temporary route closures through Dynamic Message Signs (DMS). The following subsections highlight the details of the proposed system.

Background and Implementation

Dynamic Barriers:

A dynamic barrier is an automated gate system that is utilized to control and to direct the flow of vehicle traffic. Using a combination of ultrasonic and infrared sensors, the automated barriers will detect the presence of a vehicle and send the collected information to a control system (Selvakumar et al., 2023, p. 1295). The control system will then process the received information and, based upon preprogrammed algorithms, will send a signal to the motor of the automated barrier to either open or close the automated gate as required (Chandrappa et al., 2023, p. 1). While current dynamic barrier applications include railroad crossing gates and automatic toll booths, ROAR's proposition to implement dynamic barriers on mainstream roads to reserve designated lanes for Emergency Vehicles (EVs) is a novel field that is almost completely untouched (Selvakumar et al., 2023, p. 1295; Chandrappa et al., 2023, p. 1). Indeed, through the implementation of ROAR, dynamic barriers will be strategically and permanently installed on predetermined Emergency Response (ER) routes or designated lanes. Under normal, non-emergency conditions, the barriers will remain open, and traffic will flow normally. In the event of an emergency requiring outside aid at the FedEx Forum, however, the emergency operator who receives the emergency call will coordinate with the Transportation Management Center (TMC) to switch the interconnected dynamic barrier system to its Emergency Mode. Under the Emergency Mode, the dynamic barriers will automatically close, and public transport currently on the predetermined routes will be directed through DMS to exit the route. At the same time, TSP will automatically go into effect to further prioritize the efficient passage of EVs. By utilizing the barriers' built-in ultrasonic and infrared sensors along with the EVs' GPS enterprise tracking systems, the dynamic barriers will be able to track the location of EVs and open the gates for EV passage only. After the EV has passed through the gate, the gate will reclose, preventing public traffic from passing through. Additionally, because the automated gate systems have been placed incrementally along the routes, as soon as the EVs have safely passed through a section between barriers, the barriers will automatically reopen, permitting normal traffic to flow. The time during which the routes or lanes will be closed to public traffic will be limited, resulting in minimal traffic disruption. *Figure 2* depicts a mockup of a potential automated gate system setup.

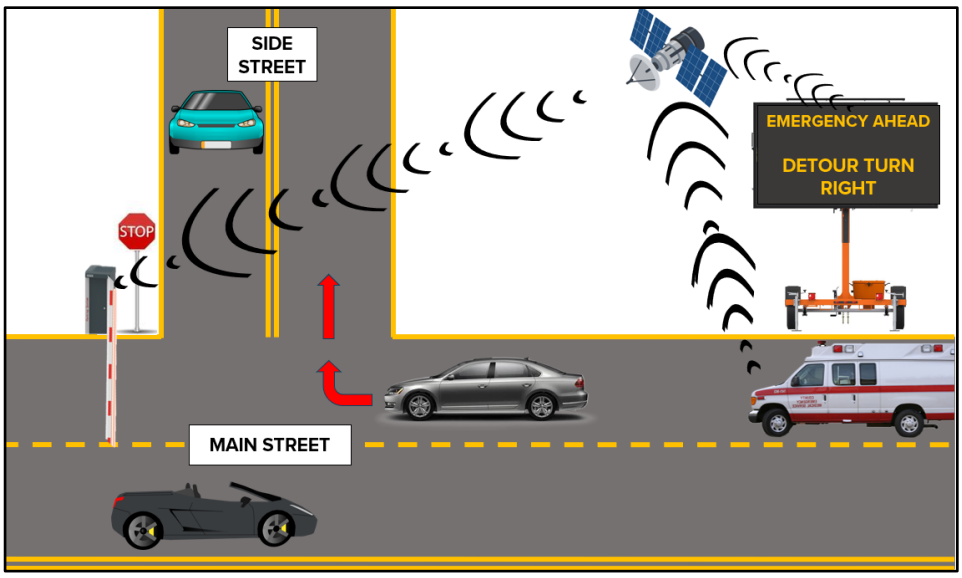

Figure 2: Schematic of a Proposed Dynamic Barrier Configuration

Predetermined Emergency Response (ER) Routes:

For each predetermined ER route, two distinct locations were selected for each service: fire-fighter and hospital. From there, one route from each service location was selected based on optimizing efficiency while also avoiding bottleneck roadways. Additionally, to minimize the implementation costs of purchasing and installing the automated gate system, careful consideration was taken to merge as many ER routes as possible to minimize the number of dynamic barriers and DMS that would have to be procured, installed, and maintained. A high-level overview of the selected fire and hospital predetermined ER routes is depicted in *Figure. 3.* The details of the predetermined ER routes for the Main St. and Mississippi Blv. Fire Stations are highlighted in *Figures 4-5,* respectively. The details on the predetermined ER routes for Le Bonheur as well as the Regional One hospital are outlined in *Figure 6.*

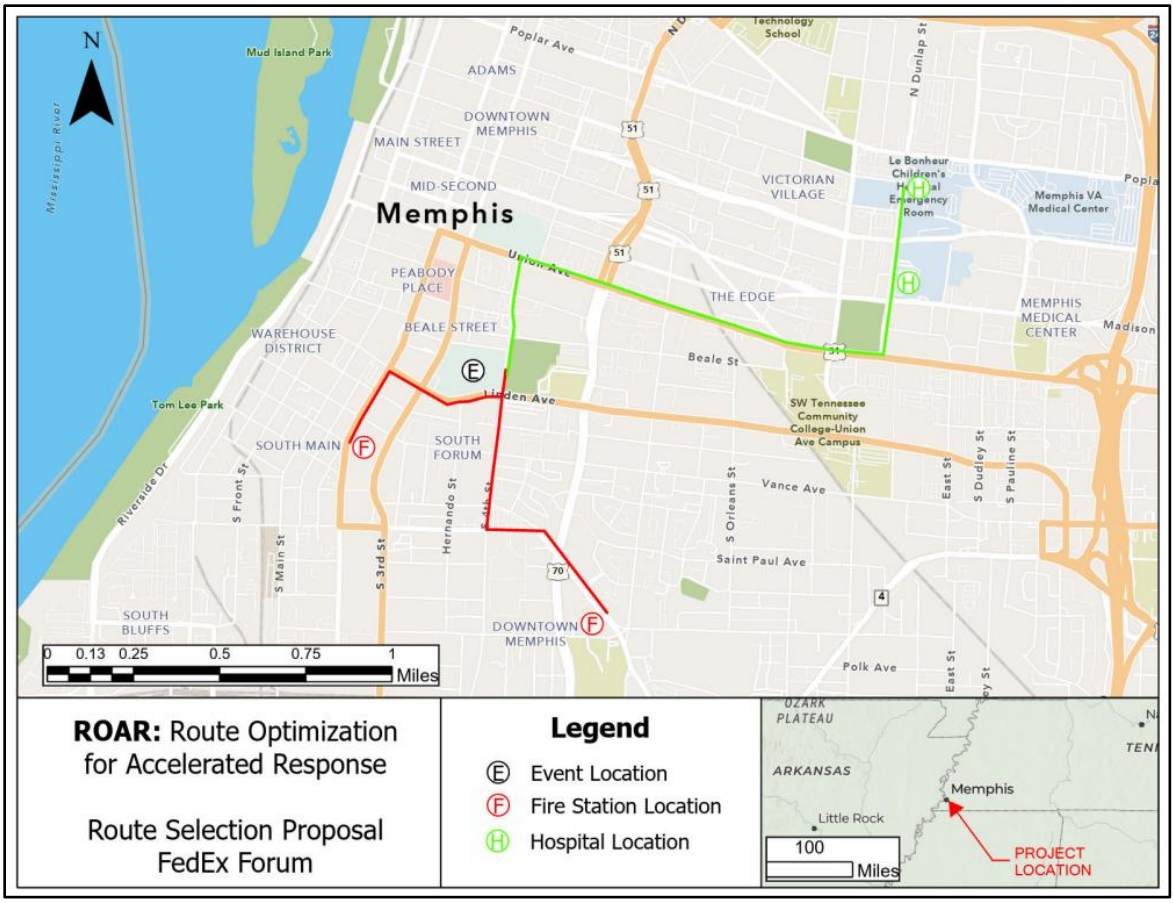

Figure 3: High-Level Overview of Predetermined ER Routes

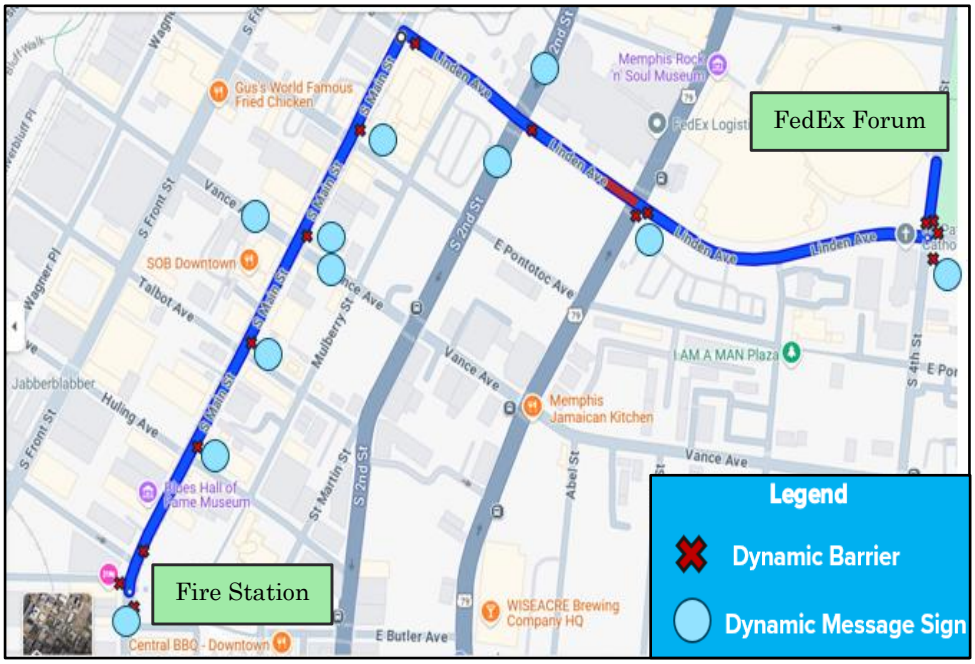

Figure 4: Main Street Fire Station Predetermined Emergency Route

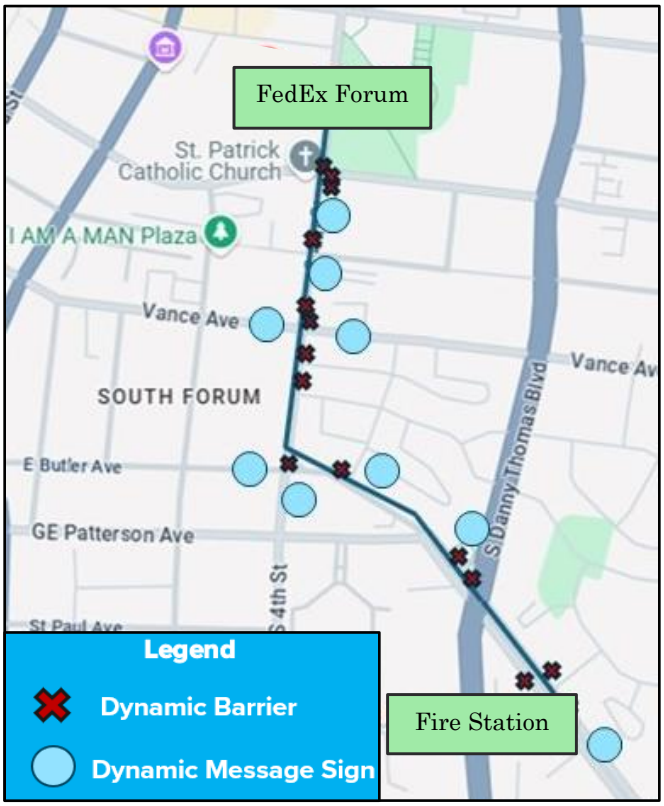

Figure 5: Mississippi Blvd. Fire Station Predetermined Emergency Route

Figure 6: Le Bonheur and Regional One Predetermined Emergency Routes

Transit Signal Priority (TSP):

Transit Signal Priority is the process of utilizing traffic signal timing to prioritize certain vehicles. There are two types of TSP currently used: intrusive traffic signal preemption and non-intrusive traffic signal preemption. Intrusive preemption, upon detecting the presence of the prioritized vehicle will automatically change the signal light that is in the direction of the oncoming prioritized vehicle green. Non-intrusive preemption, however, lengthens or shortens traffic signal color phases in order to prioritize certain vehicles (Zhong & Chen, 2022, pp. 19482). ROAR proposes a system that uses currently existing TSP technology at signal light intersections to implement both intrusive and non-intrusive preemption to prioritize EVs and to decrease implementation fees by minimizing the number of dynamic barriers needed. Once the TMC has switched the interconnected dynamic barrier system to its Emergency Mode, through non-intrusive preemption, each signal light in the direction of the oncoming EV will automatically lengthen the green phase. Thus, the movement of public traffic currently on the predetermined ER route will be prioritized. However, through the combination of closed dynamic barriers and DMS, traffic currently on the emergency route will be directed off the ER route. As a result, even before the EV arrives, traffic currently traversing the predetermined ER route will be able to easily maneuver off the predetermined route, leaving the ER route clear for EVs. Additionally, through a combination of intrusive and non-intrusive preemption, once the traffic signal detects an approaching EV, it will automatically turn the signal light that is in the direction of the EV green. Once the EV has passed, the traffic signal timing will transition into a brief restoration stage to rebuild normal roadway dynamics and then resume normal operations. Finally, in a case where a driver making a right-on-red may inhibit EV mobility, a dynamic barrier will be installed in order to prevent any drivers from making a right-on-red during emergency conditions.

Global Positioning System (GPS):

In order to coordinate the opening and closing of dynamic barriers according to EV needs, ROAR requires a Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication system between the dynamic barriers and the EVs. The optimal system does not require a major overhaul to existing vehicles, rather, it uses existing technology or properties of the average vehicle to decrease up-front costs. ROAR will implement a GPS system via an enterprise tracking device that is readily available, standardized, functions with all EVs, and automatically collects data on vehicle maintenance, use, speed, and location, which will be very beneficial both to the City of Memphis as well as to Region 4 TMC. The data collection and transmission system will consist of a simple GPS collection and cellular transmission device that plugs into the On-Board Diagnostics 2 (OBD2) system via a port beneath the steering wheel. The bulk of the data collection will be performed by the built-in OBD2 system (Liu, 2012, p. 607).

Dynamic Message Signs (DMS):

Currently implemented widely across the United States, DMS digitally displays messages to drivers and can be linked to a TMC so that live updates on traffic conditions and route information can be disseminated quickly. ROAR will utilize a system of DMS installed incrementally on the ER routes or designated lanes to inform public traffic of temporary route or lane closures due to emergency conditions and to direct traffic currently on the ER routes to exit or pull over as soon as is safely possible. Under non-emergency conditions, the DMS will display warnings that the route or lane is a designated emergency lane and is subject to temporary closure. To see the details on DMS placement along the predetermined routes, please see *Figures 4-6*.

Potential Challenges

Dynamic Barriers:

Two major challenges in implementing dynamic barriers are driver inattentiveness and gate system malfunction. The inattention of drivers can result in the arms of the automated gate systems being hit which has the potential to result in property damage both to the arm of the automated gate as well as to the vehicle and to the vehicle's occupants. To overcome such an issue, an automatic re-hinging and resetting automated gate system will be implemented in ROAR. Upon being hit, the automatic re-hinging gate system will simply swing out of the way and reset itself if there are no obstructions. Additionally, by constructing the boom, or arm, of the gate system from a light, more deformable material like carbon fiber wrapped in a coating of polystyrene foam rather than a metallic material as most booms are currently manufactured from, the physical boom of the gate will be much more impact resistant. Indeed, such an automated gate system like the BL261 Toll currently manufactured by Automatic Systems® has an impact resistance of up to 50 miles per hour (*Patented Swing-Off*, 2021). Thus, by utilizing such a system neither the system itself nor the motorist or the motorist's vehicle will withstand any harmful effects due to driver inattentiveness. Additionally, if the automated gate system malfunctions and the dynamic barrier does not open for an EV, the EV can safely force its way through the barrier system without inflicting any damage on either the system, the vehicle, or the motorist.

Transit Signal Priority (TSP):

Integrating TSP into ROAR does present one major concern: the potential disruption to general traffic flow. Prioritizing EVs can delay cross-traffic, particularly in areas with high traffic volume. To overcome this issue, ROAR will implement a system of both intrusive and non-intrusive preemption. While intrusive preemption can guarantee a green light for an EV unlike non-intrusive preemption, intrusive preemption is also more disruptive to normal traffic flow than non-intrusive preemption (Zhong & Chen, 2022, pp. 19482-19487). Thus, through a combination of intrusive and non-intrusive preemption coupled with a transitionary timing phase focused solely on efficiently restoring normal roadway dynamics after the EV has passed, ROAR will have minimal traffic disruption effects while still prioritizing EVs.

Global Positioning System (GPS):

One potential challenge of implementing ROAR's enterprise GPS tracking system utilizing OBD2 is the collaboration that would need to take place between the fleet vehicle tracking team and the City of Memphis' GIS team in creating a custom program that meets both ROAR system and data collection requirements. However, through clear and respectful communication, such an issue can easily be addressed and all requirements from both parties can be met. Also, because the OBD2 system is primarily intended to aid with identifying vehicular mechanical issues, the available data collected by OBD2 is limited. However, through carefully coupling OBD2 and GPS, the data collection range can be expanded to collect data useful to the transportation industry such as vehicle speed and location.

Dynamic Message Signs (DMS):

One potential challenge of implementing DMS in ROAR is finding suitable spots to place the DMS. Since much of the downtown area is dense, finding spots to place the DMS that will not block

sidewalks, roadways, or private property could prove challenging. However, not only were the ER routes carefully selected with such a potential issue in mind, but also, because the DMS will be temporary, disruption due to DMS placement will be minimal.

PROPOSED CONCEPT OF OPERATIONS (CONOP)

High-Level Physical Architecture

Implementation of ROAR to optimize EV route efficiency necessitates collaboration and coordination between the ITS Roadway Equipment and multiple departments such as the Emergency Management Center and the TMC as well as the general public. A high-level schematic of the physical architecture of ROAR is depicted in *Figure 7*.

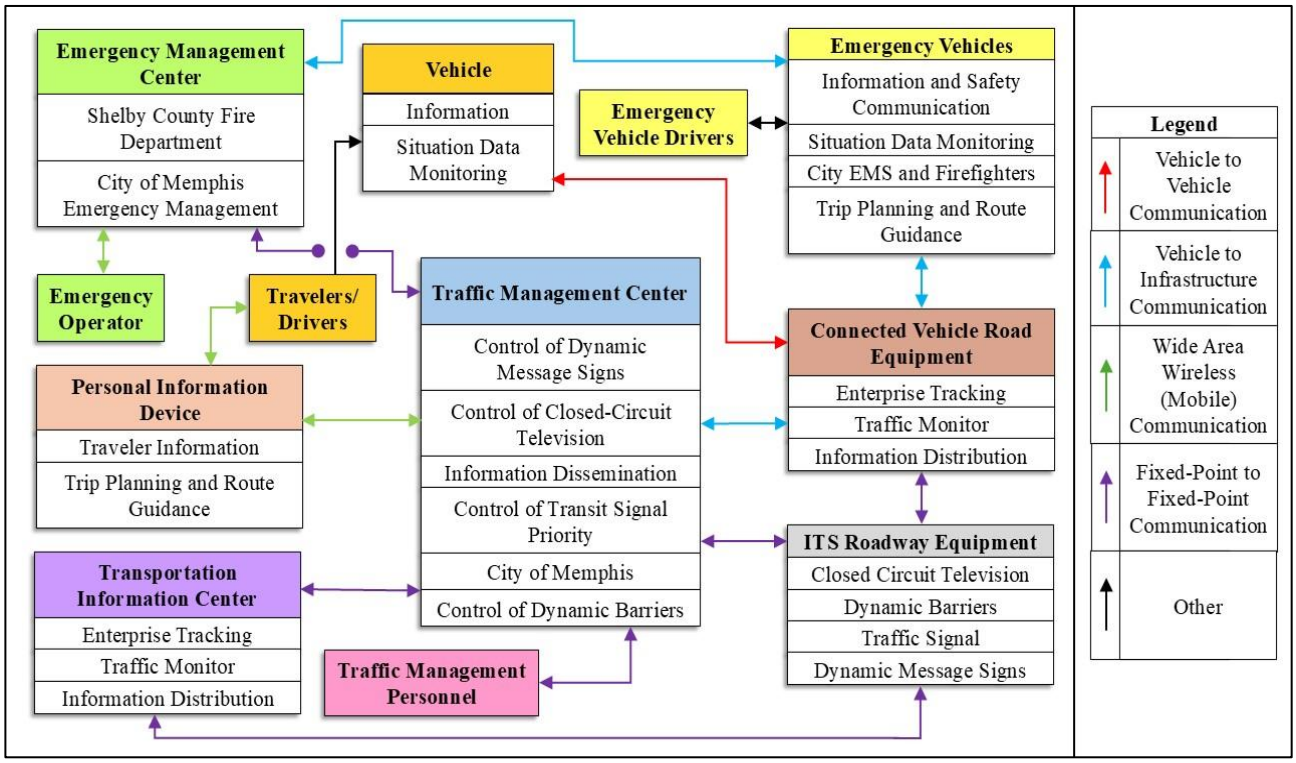

Figure 7: ROAR High-Level Physical Architecture Schematic

High-Level Functional Architecture

The physical architecture of ROAR depicted in *Figure 7* is comprised of twenty-six functional objects which are outlined and explored in *Table 1*.

Table 1: ROAR High-Level Functional Architecture

Physical Object	Functional Object	Description
Traffic Management Center (TMC)	Control of Dynamic Message Signs (DMS)	Oversee displayed DMS messages to alert Travelers/Drivers of route conditions promptly
	Control of Closed-Circuit Television (CCTV)	Monitor, collect, and analyze CCTV live footage for traffic congestion and malfunctioning barriers
	Information Dissemination	Disseminate roadway conditions, route closures, detours, and emergencies to the public
	Control of Transit Signal Priority (TSP)	Oversee TSP timing and programming for optimization of EV route efficiency
	City of Memphis	City of Memphis GIS team
	Control of Dynamic Barriers	Oversee installation, programming, and maintenance, coordinating closures, TSP, and DMS alerts
Traffic Management Personnel	-------	Perform all duties of the TMC
Transportation Information Center	Enterprise Tracking	Monitor the location of EVs and transmit EV information to TMC
	Traffic Monitor	Third-party applications such as Waze commonly report live traffic data to the TMC
	Information Distribution	Inform TMC concerning ITS Roadway Equipment status
ITS Roadway Equipment	Closed-Circuit Television	Monitor and record activity within a given area
	Dynamic Barriers	Open or close based on TMC programming & control
	Traffic Signal	Change colors to direct the flow of traffic according to TSP
	Dynamic Message Signs	Inform Travelers/Drivers of route conditions from TMC
Connected Vehicle Road Equipment	Enterprise Tracking	Collect location data of EVs and transmit EV data to ITS Roadway Equipment
	Traffic Monitor	Use data from third-party applications such as Waze to monitor traffic around the situation
	Information Distribution	Inform drivers of road conditions and route closures
Emergency Management Center (EMC)	Shelby County Fire Department	Respond to emergencies following ROAR protocol
	City of Memphis Office of Emergency Management (OEM)	Plan emergency protocol for special events
Emergency Operator	-------	Receive emergency calls, dispatch first responders, and coordinate with the TMC to implement ROAR
Emergency Vehicles (EV)	Information and Safety Communication	Obtain info from the EMC
	Situation Data Monitoring	Receive info from the EMC regarding the FedEx Forum emergency
	City EMS and Firefighters	Follow ROAR routes to efficiently respond to emergency
	Trip Planning and Route Guidance	Follow routes and emergency protocols set by the Office of Emergency Management (OEM) and ROAR
Emergency Vehicle Drivers	-------	Include the first responders from the fire station as well as from the hospital
Travelers/Drivers	-------	Include the public traveling on the predetermined ER routes and those nearby routes affected by ROAR
Vehicle	Information	Vehicles using third-party applications such as Waze will report traffic and safety to other vehicles
	Situation Data Monitoring	Third-party applications such as Waze will monitor traffic congestion and safety
Personal Information Device	Traveler Information	Collect data from Travelers/Drivers through third-party applications
	Trip Planning and Route Guidance	Obtain data from the TMC to make route decisions

ANTICIPATED IMPACTS

ROAR by reserving predetermined, optimal-efficiency first responder routes for EVs will not only decrease response times and healthcare fees, but it will also increase patient survival outcomes and EV safety. The following subtopics highlight in detail the anticipated benefits of ROAR.

Health Benefits

In the event of an emergency, every second counts. Particularly during a life-threatening emergency, such as cardiac arrest, patients are 2.4 times less likely to survive if the response time of emergency personnel is greater than 8 minutes (Bürger et al., 2018, p. 423). In fact, by decreasing ER time by just two minutes, the probability of patient survival increases by approximately 10% (Holmén et al., 2020, p. 3). Following, the proposed solution seeks to cut EV response time and increase patient survival outcomes by offering a system of optimal routes that are congestion-free despite increased commencement traffic and are reserved in the event of an emergency for EVs only. Utilizing route optimization for EVs to reduce response time has been found effective by the Texas Department of Transportation, where ER route optimization resulted in a median decrease in EV response time by 11 minutes (*ITS Technology*, 2024, p. 29).

Operational Benefits

By designating a set of predetermined, optimal ER routes for EVs that will be restricted to EVs only in the event of an emergency, ER dispatch and response time will be simplified and streamlined. By streamlining the response process and creating traffic-free routes for EVs to take in the case of an emergency at the FedEx Forum, the response time for such emergencies will decrease, which will increase operational process efficiencies and decrease patient fatalities.

Safety Benefits

By blocking access to the predetermined ER routes in the event of an emergency to public traffic, the proposed solution offers traffic-free routes for the efficient and safe passage of EVs. In the event of an emergency, EVs are preempted from following normal traffic regulations due to the need for speed. Such preemption, while decreasing response time and increasing patient survival, comes at the cost of causing roadway confusion and endangering EV drivers. Since 1994, Emergency Service Vehicle Incidents (ESVI), such as vehicle collisions, in the U.S. have resulted in well over 450 deaths. For firefighters, ESVI is the second leading cause of fatality (*ITS Technology*, 2024, p. 11). Thus, the proposed solution supports EV safety by creating designated routes or lanes clear of public traffic and reserved for ER vehicle passage only in the event of an emergency.

Mobility Benefits

By offering traffic-free routes, the proposed solution will enhance the efficient response of ER vehicles. Additionally, by utilizing TSP to prioritize EVs, the mobility and efficiency of ER will be further increased, which will result in reduced EV response times. Such positive results for the proposed solution can be predicted from previous TSP implementations. Indeed, by implementing a TSP system that combines both intrusive and non-intrusive preemption, EV travel time can be reduced by 62.58%. Additionally, because such a system automatically extends the green light phase in the direction of the oncoming EV prior to the EV's arrival, the proposed TSP system effectively combats ER route

congestion by allowing traffic currently on the ER route to clear (Zhong & Chen, 2022, pp. 19484-19488). Additionally, because the EV routes or designated lanes will be closed off to public traffic in the event of an emergency in small segments and for short periods of time, the disruption to normal traffic flow due to EV activity will be minimized, which will support streamlined public vehicle movement.

Economic Benefits

By reducing ER time and, thereby, increasing patient survival outcomes, the proposed solution has the potential to offer significant economic advantages. Not only can the timely response of emergency responders decrease hospitalization and other healthcare fees for patient treatment by preventing the worsening of patient conditions but also, by offering treatment sooner, rapid ER can result in better patient outcomes with decreased recovery times and increased complete-recovery rates. As a result, due to renewed individual productivity and decreased healthcare fees, every one minute decrease in ER time has the potential to annually save roughly $48 million dollars (Jaldell et al., 2014, p. 555). Additionally, through rapid ER, property-damaging as well as life-threatening events, such as a fire, can be more efficiently and effectively dealt with. Within just thirty seconds, a small fire can double in size to a large one (Li et al., 2016, p. 193). Therefore, decreasing the response time of EVs has the additional economic benefit of preventing excess property damage.

Environmental Benefits

By reducing ER vehicle travel time along with optimizing route efficiency, the proposed solution will result in less fuel consumption which will conserve natural resources. Additionally, due to decreased travel time, the carbon footprint left by the exhaust of the EVs will be reduced along with the other hazardous waste fumes emitted by combustion engines. As a result, the air quality in Memphis will be protected.

Other Benefits and Risks

Because the implementation of ROAR would include the permanent installation of the dynamic barriers on the predetermined ER routes along with the interconnected GPS enterprise tracking system and the TSP, such a solution can be utilized at all FedEx Forum events, not just the bi-annual University of Memphis commencement. Indeed, the FedEx Forum hosts numerous other high-attendance events such as Memphis Grizzlies games, National Basketball Association playoffs, world boxing championships, and top-star concerts (*History*, 2015). Thus, after the initial installation, the proposed solution can be implemented in the event of an emergency requiring outside aid at any planned special event hosted by the FedEx Forum. Additionally, because the GPS enterprise tracking system is connected to the OBD2 system, ROAR offers the potential for valuable transportation data collection.

REFERENCES

Bürger, A., et al. (2018). The Effect of Ambulance Response Time on Survival Following Out-of-Hospital Cardiac Arrest. *Deutsches Arzteblatt international*, *115*(33-34), 541–548. https://doi.org/10.3238/arztebl.2018.0541

Commencement Office. (2025). Memphis.edu. https://www.memphis.edu/commencement/

Chandrappa, S., et al. (2023). An IOT-Based Automotive and Intelligent Toll Gate Using RFID. *SN Computer Science*, *4*(2). https://doi.org/10.1007/s42979-022-01569-0

Holmén, J., et al. (2020). Shortening Ambulance Response Time Increases Survival in Out-of-Hospital Cardiac Arrest. *Journal of the American Heart Association*, *9*(21), e017048, 1-24. https://doi.org/10.1161/JAHA.120.017048

History. (2015, August 12). FedExForum - Home of the Memphis Grizzlies. https://fedexforum.com/about-our-house

ITS Technology Use Case Library - ITS America. (2024, August 21). ITS America, 1-72. https://itsa.org/technology-use-case-library/

Jaldell, H., et al. (2014). Time is money, but how much? The monetary value of response time for Thai ambulance emergency services. *Value in health: the journal of the International Society for Pharmacoeconomics and Outcomes Research*, *17*(5), 555–560. https://doi.org/10.1016/j.jval.2014.05.006

Li, J., et al. (2016). Experimental Study on Vertical Fire Spread of Thin Hanging Combustibles. *Procedia Engineering*, *135*, 189–196. https://doi.org/10.1016/j.proeng.2016.01.107

Liu, J., et al. (2012). A remote on-line diagnostic system for vehicles by integrating OBD, GPS and 3G techniques. *In Practical Applications of Intelligent Systems: Proceedings of the Sixth International Conference on Intelligent Systems and Knowledge Engineering, Shanghai, China, Dec 2011 (ISKE2011)* (pp. 607-614). Springer Berlin Heidelberg.

Patented Swing-Off and Automatic Reseating System. (2021). Automatic Systems-International. https://www.automatic-systems.com/news/systeme-de-degondage-regondage-automatique-brevete/

Selvakumar, R., et al. (2023). Design and development of artificial intelligence assisted railway gate controlling system using internet of things. *The Scientific Temper*, *14*(04), 1295-1300. https://doi.org/10.58414/SCIENTIFICTEMPER.2023.14.4.35

University of Memphis to Hold Spring Commencement May 4. (2024). Memphis.edu.

https://www.memphis.edu/mediaroom/releases/2024/april/2024-may-commencement.php

Zhong, L., & Chen, Y. (2022). A Novel Real-Time Traffic Signal Control Strategy for Emergency Vehicles. *IEEE Access*, *10*, 19481–19492. https://doi.org/10.1109/access.2022.3149920