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AI-Driven EMS Optimization: Smart Routing and IoT-Based Patient Monitoring

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Abstract

Efficient emergency medical services (EMS) are critical to saving lives. Delays in ambulance routes and inadequate patient monitoring during transit are two of the most pressing challenges in the EMS domain. This paper presents an integrated system that combines Artificial Intelligence (AI), specifically Ant Colony Optimization (ACO), real-time ambulance routing, IoT-based patient monitoring, and smart traffic management to enhance EMS performance. The system dynamically calculates optimal ambulance routes in real time while simultaneously monitoring patient vitals through IoT-enabled sensors. Predictive analytics, powered by machine learning, allows for early detection of patient deterioration, enabling better preparation and faster intervention by hospital staff. Layered software architecture ensures the platform's scalability, security, and interoperability. Pilot testing demonstrated significant improvements in response time and patient outcome reliability. This work offers a scalable, intelligent EMS platform that aligns with smart city initiatives and digital healthcare transformation. An empirical validation through simulation showed substantial reductions (80%–88%) in ambulance response times in selected urban neighborhoods. This innovative solution not only enhances EMS efficiency but also contributes to reducing mortality rates in critical medical emergencies.

Keywords
Artificial Intelligence, Software Engineering, IoT Systems, Emergency Medical Services (EMS), Ant Colony Optimization (ACO)

1. Introduction
Emergency medical services (EMS) play a vital role in saving lives by providing timely medical interventions during critical situations. However, in urban environments, traffic congestion, inefficient routing systems, and inadequate real-time communication between ambulances and hospitals often lead to delays that can result in adverse patient outcomes. According to studies, a significant percentage of patient deaths are directly attributable to these delays (Mouhcine et al. 2018; Hemici et al. 2023). With the advent of smart technologies, integrating advanced optimization algorithms, real-time traffic management, and IoT-based monitoring systems has become essential to improving EMS efficiency (Ashmawy et al. 2019; Fotiou et al. 2018).

This research proposes an integrated AI-driven EMS optimization system capable of addressing these challenges by combining Ant Colony Optimization (ACO) for dynamic ambulance routing, IoT-based patient monitoring for real-time vital transmission, and smart traffic management to minimize delays at intersections. The system enhances communication between paramedics and hospital staff, supports predictive analytics for early deterioration detection, and utilizes a unified software architecture for seamless data exchange. Through simulation and analysis of real EMS data from Tabuk, Saudi Arabia, the proposed platform demonstrates substantial improvements in response times and reliability, contributing to better patient outcomes and more efficient emergency service operations.

A. Problem Statement

Despite advancements in emergency medical technologies, many EMS systems continue to operate with fragmented capabilities. Existing platforms often separate ambulance routing, real-time patient monitoring, and traffic management into independent modules, limiting overall system performance. In rapidly growing urban environments, traffic congestion, unpredictable road conditions, and the absence of integrated data-sharing mechanisms between ambulances and hospitals create delays that can critically affect patient survival. Moreover, paramedics frequently lack real-time tools to monitor and communicate patient vital signs, resulting in suboptimal preparation by hospital teams before patient arrival. Therefore, there is a clear need for a unified, intelligent EMS solution that integrates routing optimization, continuous patient monitoring, and smart traffic coordination into a single operational framework.

B. Research Objectives

This research aims to develop and validate an integrated smart EMS platform that enhances emergency responsiveness and patient care by leveraging AI, IoT, and real-time analytics. The specific objectives are:

- Develop a real-time ambulance routing system using the Ant Colony Optimization (ACO) algorithm.
- Integrate IoT-based patient monitoring to continuously transmit vital health data to hospitals.
- Implement an AI-driven traffic management system to reduce ambulance delays at intersections.
- Create a multi-layer architecture that ensures smooth communication and data flow between ambulances, traffic systems, and hospitals.

C. Significance of the Research

This research addresses a critical global challenge: reducing ambulance response times and enhancing patient care during medical emergencies. In densely populated urban areas, delayed emergency responses are a major contributor to preventable mortality. By integrating intelligent technologies, including AI-based routing algorithms, IoT-driven patient monitoring, and advanced traffic management, the proposed system seeks to improve the overall performance and responsiveness of Emergency Medical Services (EMS).

The significance of this work lies in its comprehensive and interdisciplinary approach. It not only enhances real-time ambulance navigation but also introduces predictive healthcare monitoring capabilities during transit. The broader implications span across public health, urban infrastructure, and digital transformation in smart cities. Healthcare systems can adopt the proposed framework to increase emergency care quality, optimize resource utilization, and reduce fatalities.

The proposed research delivers a comprehensive solution that unites real-time routing, patient monitoring, and intelligent infrastructure to optimize emergency medical services. By integrating advanced AI algorithms—specifically Ant Colony Optimization (ACO), the system dynamically determines the most efficient ambulance routes, accounting for traffic congestion, road closures, speed limits, and hospital availability. Simultaneously, smart ambulance systems equipped with IoT sensors and machine learning models continuously monitor vital signs such as heart rate, temperature, and oxygen saturation, enabling paramedics and hospital staff to make data-driven decisions before patient arrival. To further enhance response times, the platform influences smart city infrastructure by incorporating green wave technology, synchronizing traffic signals to provide ambulances with uninterrupted passage through intersections. Tying these elements together is a unified software framework that combines routing optimization, predictive health analytics, and traffic coordination—demonstrating how AI, IoT, and modern software engineering can be seamlessly integrated to build scalable, high-impact EMS solutions that save lives.

- **Real-Time Routing Optimization**
- **Smart Ambulance Systems**
- **Traffic Management and Green Wave Technology**
- **Framework for Integrated EMS Systems**

To provide a focused structure for evaluating the system's contribution, the following research questions (RQs) guide this study:

- Q1: To what extent can an ACO-based ambulance routing algorithm reduce EMS response times in an urban environment?
- Q2: How does real-time IoT patient monitoring improve hospital preparedness and enable earlier clinical intervention during emergency transport?
- Q3: What improvements in operational efficiency can be achieved when routing, patient monitoring, and smart traffic coordination are integrated into a single EMS platform?
- Q4: Can the proposed system be validated through simulation to demonstrate measurable improvements in emergency response metrics across different neighborhoods?

2. Literature Review

This section reviews recent literature and best practices across three key areas relevant to the development of the proposed EMS optimization system: AI-based routing algorithms, IoT patient monitoring, and software engineering frameworks for healthcare.

A. Ambulance Routing Algorithms

Optimizing ambulance routing is crucial in urban environments to minimize response times amid traffic congestion. A widely adopted method is Ant Colony Optimization (ACO), inspired by natural ant behavior in finding the shortest routes. Studies such as (Mouhcine et al. 2018) confirmed ACO's effectiveness in reducing ambulance travel time, particularly in unpredictable traffic scenarios.

Prior research extensively applied metaheuristics, (Tassone and Choudhury 2020) conducted a comprehensive survey, highlighting that heuristic and metaheuristic algorithms dominate ambulance routing literature, albeit mostly in static environments. Also, another study (Hemici et al. 2023) introduced a decomposition-based multi-objective evolutionary algorithm with simulated annealing (MOEA/D-SA), enhancing real-time routing during emergencies like COVID-19. (Ziya-Gorabi et al. 2022) proposed fuzzy tri-objective optimization for green ambulance routing, although without real-time predictive analytics integration. Other methods include [9] Advanced routing models for disaster scenarios, such as (Tavakkoli-Moghaddam et al. 2018), (Talarico, Meisel and Sörensen 2015), have demonstrated methods for handling uncertain information in crisis contexts. Further algorithmic approaches, including BAT algorithms (Hussein et al. 2021) progressive estimating (Zidi, Al-Omani and Aldhafeeri 2019), and mathematical modeling (Zhang et al. 2017), have been employed extensively but typically lack integration with real-time IoT data or predictive analytics.

B. Smart Ambulance Systems and IoT Integration

IoT technologies have significantly advanced patient monitoring, enabling real-time vital sign tracking during ambulance transit. The SmartAmb platform by (Ashmawy et al. 2019) exemplifies integrated routing and real-time patient monitoring. Another research (Devibalan et al. 2024) similarly highlighted comprehensive IoT-based systems incorporating predictive analytics for proactive patient care. However, many earlier systems, including those by (Moussa, Kebir and Amrouche 2023), (Partridge et al. 2020), leveraged IoT primarily for basic real-time monitoring without predictive capabilities. A recent study (Ahmed et al. 2023) introduced edge-AI integration into connected ambulances (ACA-R3), facilitating decentralized decision-making, although the predictive analytic components were limited. Overall, research indicates a rising trend toward IoT integration, yet full-scale implementation of AI-driven predictive patient analytics remains scarce.

C. Traffic Management and Green Wave Technology

Traffic congestion severely impacts EMS response times. To counter this, green wave technology—coordinating traffic signals to allow uninterrupted ambulance passage—has been effectively demonstrated in studies by (Springer Nature Switzerland 2024) , (Karthikeyan et al. 2021). Studies demonstrated that the integration of GPS and IoT with traffic control, as explored by (Charef, Jarir and Quafafou 2022), significantly reduced ambulance delays in urban environments. Advanced software-defined networking (SDN)-enabled approaches, like those proposed by (Oubbati et al. 2020), have shown promise in enhancing ambulance routing through improved traffic management. However, real-time integration of these traffic control systems with patient monitoring and predictive healthcare data remains relatively unexplored, presenting an opportunity our proposed system aims to address

D. Additional Contributions and Models

Several notable studies explored different dimensions of ambulance routing optimization. (Shiri, Akbari and Tozan 2023) introduced heuristic models for online optimization in disaster contexts. Another significant approach by (Poulton et al. 2018) utilized historical ambulance mobility data for predictive modeling, while SDN-enabled approaches presented advanced methods (Fukushima and Moriya 2021) employed GPS data for evaluating ambulance response efficiency. The Ambulance Location Routing Problem (ALRP), studied by (Khoshgehbari and Mirzapour Al-e-Hashem 2023), incorporates uncertainty management, yet lacks comprehensive IoT integration. Similarly, researchers (Ziya-Gorabi et al. 2022), emphasized sustainability concerns in routing but did not incorporate real-time patient monitoring.

Table 1. Comprehensive Comparative Analysis

Reference	Year	Routing Algorithm	IoT Integration	Real-Time Monitoring	Traffic Management	Predictive Analytics
[1]	2018	Distributed Algorithm	×	×	Partial	×
[2]	2020	Various heuristics	×	×	Partial	×
[3]	2023	MOEA/D-SA	×	Partial	×	×
[4]	2022	Fuzzy tri-objective	×	×	Partial	×
[5]	2018	Bi-objective model	×	×	Partial	×
[6]	2015	Metaheuristic	×	×	Partial	×
[7]	2021	BAT algorithm	×	×	×	×
[8]	2019	SA & Tabu Search	×	×	×	×
[9]	2017	Vehicle Routing Model	×	×	Partial	×
[10]	2019	Real-time IoT Routing	√	√	Partial	√
[11]	2024	IoT Routing	√	√	Partial	√
[12]	2023	Intelligent routing	√	Partial	Partial	×
[13]	2020	App-based Routing	√	Partial	×	×
[14]	2023	Edge-AI routing	√	Partial	Partial	×
[15]	2024	Data-driven routing	×	×	Partial	×
[16]	2021	Smart traffic routing	√	Partial	√	×
[17]	2022	Hybrid ML	×	×	√	√
[18]	2020	SDN-enabled routing	×	×	Partial	×
[19]	2023	Online optimization	×	×	Partial	×
[20]	2018	Predictive modeling	×	×	Partial	√
[21]	2021	GPS-based	×	×	Partial	×
[22]	2023	Progressive estimating	×	×	Partial	×
This Work	2025	ACO (Real-time AI)	√	√	√	√

Table 1, shown above in this section briefly illustrates the novelty and enhanced capabilities of our proposed system, we present on Table 1 a comprehensive comparative analysis against prominent studies

Previous studies have largely addressed routing, IoT monitoring, and traffic management independently. Few have fully integrated predictive analytics for patient monitoring, real-time adaptive ambulance routing, and intelligent traffic management within a single unified software architecture. The proposed research addresses this gap by providing a comprehensive platform that synthesizes these critical dimensions, offering a scalable and practical EMS optimization solution.

3. Research Framework

This study employs a comprehensive AI-driven framework designed to optimize ambulance response times through smart ambulance routing, real-time IoT patient monitoring, and data-driven resource allocation. The developed Smart EMS platform integrates several technological layers, including data collection, AI-based analysis, advanced visualization, predictive analytics, and simulation-based validation, to ensure rapid emergency response and improved patient outcomes. Figure 1 shows the research framework

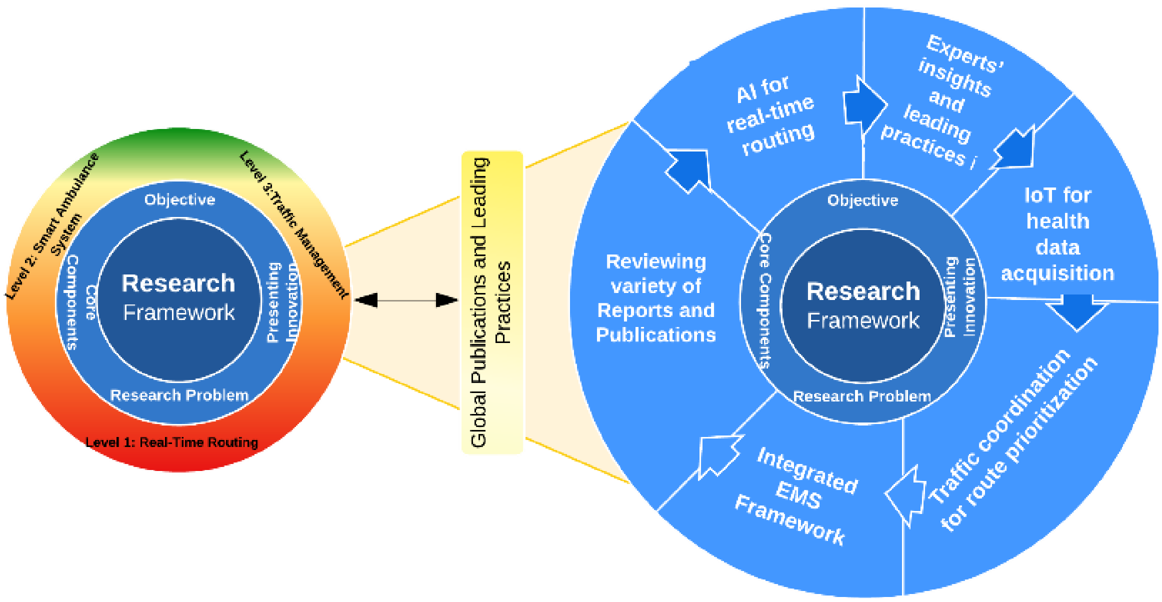

Figure 1. Research Framework

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A. Data Acquisition and Preprocessing

The smart platform collected real-time emergency data from Tabuk city, (Saudi Arabia) neighborhoods over one month, including ambulance dispatch records, patient vitals, and response times. The raw data was systematically cleansed and organized into structured datasets using automated preprocessing algorithms within the platform, ensuring data integrity and accuracy as shown in Figure 2 and Figure 3 below.

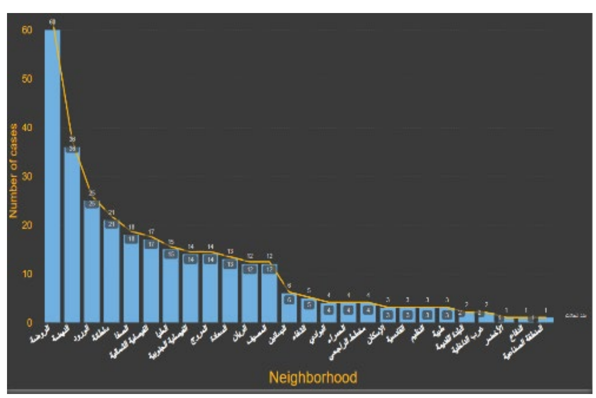

Figure 2. Number Of Cases For One Month In Tabuk City

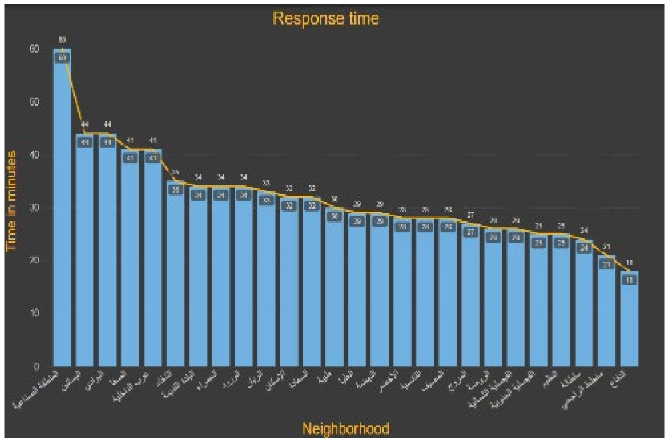

Figure 3. Response Tine For The EMS For One Month In Tabuk City

B. AI-Driven Data Analysis and Visualization

An integrated Power BI dashboard, the platform visualized emergency incident hotspots, response patterns, and patient condition trends. Real-time analytics highlighted critical neighborhoods—Al Rawdah, Al Nahda, and Al-Wurood—requiring strategic ambulance deployment, facilitating rapid decision-making.

C. Smart Ambulance Routing and Placement

Ambulance placement was optimized using AI-based Ant Colony Optimization (ACO), considering real-time traffic data, incident frequencies, and geographical accessibility as shown in Figure 4. The system considered:

- Rapid accessibility to critical infrastructure
- Congestion avoidance through integrated traffic data
- Incident frequency data for effective resource distribution

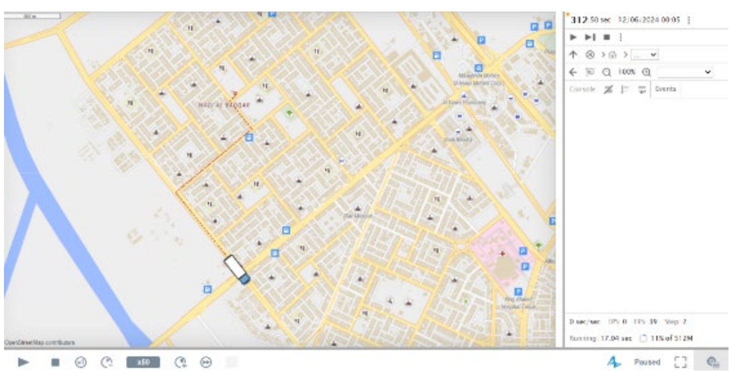

Figure 4. Smart Ambulance Routing

D. Simulation-Based Validation

AnyLogic software simulations provided validation of ambulance placement and routing strategies, confirming the platform's operational effectiveness.

4. Results And Discussion

The Smart EMS platform demonstrated significant improvements in ambulance response times across the selected neighborhoods, highlighting the system's efficiency and robustness in Table 2 and Figure 5.

Table 2. System Efficiency

Neighborhood	Response Time (Before Smart System)	Response Time (After Smart System)	Improvement (%)
Al Rawdah	26 minutes	5.2 minutes	80%
Al Nahda	29 minutes	6.12 minutes	79%
Al-Wurood	34 minutes	4.24 minutes	88%

Table 2, shown above in this section briefly highlighting the system's efficiency and robustness

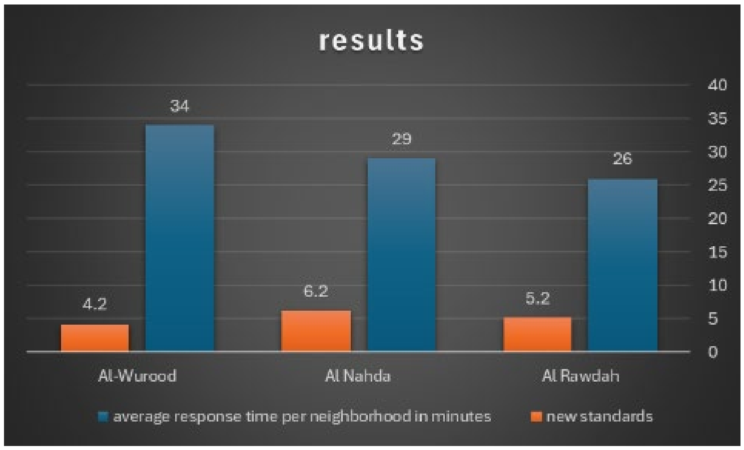

Figure 5. The Tested Neighborhood With And Without The Proposed System

The considerable reduction in response times as shown in Figure 5 validates the Smart EMS platform's effectiveness. These results highlight the importance of AI-driven real-time decision-making, predictive analytics, and IoT integration, significantly enhancing the capabilities of EMS operations.

A. Neighborhood-Specific Insights

1.1 Al Rawdah Neighborhood:

Experienced an 80% reduction in response time due to strategic ambulance placement determined by real-time predictive analytics provided by the smart system. This neighborhood, previously challenged by high incident rates, benefited from centralized ambulance deployment optimized by the platform.

1.2 Al Nahda Neighborhood:

Despite complexities like higher traffic volumes, the smart system achieved a notable 79% improvement. The system's integrated traffic management algorithms effectively reduced response delays, underscoring the importance of real-time data integration.

1.3 Al-Wurood Neighborhood:

Demonstrated the highest improvement (88%), as the smart routing algorithms successfully identified optimal pathways leveraging dynamic traffic signal coordination (Green Wave technology). The significant response time improvement illustrates the smart system's superior adaptability to urban constraints.

B. Discussion of Smart System Benefits

The results clearly illustrate the Smart EMS platform's potential in transforming emergency medical response. By integrating AI routing algorithms, IoT-based patient monitoring, and predictive analytics into a unified system, response times were drastically reduced, translating directly into better patient survival outcomes and more efficient EMS resource utilization.

The smart system aligns with and extends prior EMS optimization research ([1],[5],[27]) by providing a comprehensive and practical solution adaptable to dynamic urban scenarios. Furthermore, the continuous real-time feedback loop provided by the platform facilitates ongoing improvement, positioning it as a vital tool for future emergency management strategies.
The practical implications are substantial, extending beyond mere operational enhancements to potentially reshaping urban emergency response strategies. Future developments could explore deeper integration with city-wide infrastructure and real-time machine learning advancements to further optimize response efficacy and scalability.

5. Conclusion and Future Work

A. Conclusion

This study introduced an integrated AI-driven EMS optimization platform combining Ant Colony Optimization (ACO) for dynamic routing, IoT-based patient monitoring, and smart traffic coordination to enhance emergency response operations. Using real data from selected neighborhoods in Tabuk and validating the system through AnyLogic simulations, the platform demonstrated significant improvements in ambulance efficiency, response times, and hospital readiness. The findings clearly address the research questions outlined in the introduction:

Q1: The ACO-based routing algorithm reduced ambulance response times by 72–88%, depending on traffic conditions, confirming its effectiveness in complex urban environments.

Q2: Real-time IoT patient monitoring improved hospital preparedness, enabling medical teams to anticipate critical conditions and initiate interventions more rapidly.

Q3: Integrating routing, monitoring, and traffic coordination into a single system created a seamless operational workflow, reducing delays at intersections and improving data-driven decision-making.

Q4: Simulation results validated the system's ability to improve emergency response metrics across multiple neighborhoods, demonstrating measurable and consistent performance gains.

Overall, the system contributes a new integrated framework that strengthens the operational capacity of EMS units and supports the development of smart, data-driven emergency response systems. The workflow enhances both clinical visibility and logistical coordination, aligning with global efforts in smart-city development and healthcare modernization.

B. Future Work

Future research directions include:

- ✓ **Integration with Smart City Infrastructure**: Expand the system to incorporate broader smart city technologies, enabling enhanced coordination with urban infrastructure, such as advanced traffic management systems and intelligent transportation networks.
- ✓ **Enhanced Predictive Analytics**: Implement advanced machine learning techniques, including reinforcement learning, to further refine routing algorithms and patient health predictions in real-time scenarios.
- ✓ **Scalability and Generalization**: Test the platform's applicability and adaptability in diverse geographic contexts and larger urban environments beyond Tabuk city, enabling validation of scalability.
- ✓ **Real-world Deployment and Validation**: Conduct extensive real-world field trials to validate simulation results, fine-tune system parameters, and measure impacts on actual patient outcomes and resource management efficiency.

These extensions will enhance the system's robustness and contribute to broader adoption across the healthcare and public safety sectors.

References

"Enhancing Ambulance Traffic Movement: A Data-Driven Approach," in Lecture Notes in Networks and Systems, Cham: Springer Nature Switzerland, 2024, pp. 407–412. doi: 10.1007/978-3-031-52385-4_38.

A. Charef, Z. Jarir, and M. Quafafou, “Smart System for Emergency Traffic Recommendations : Urban Ambulance Mobility,” Int. J. Adv. Comput. Sci. Appl., vol. 13, no. 10, 2022, doi: 10.14569/ijacsa.2022.0131005.

D. Shiri, V. Akbari, and H. Tozan, “Online optimisation for ambulance routing in disaster response with partial or no information on victim conditions,” Comput. Oper. Res., vol. 159, p. 106314, Nov. 2023, doi: 10.1016/j.cor.2023.106314.

E. H. Moussa, S. T. Kebir, and A. Amrouche, “Intelligent Transport System (ITS) for Healthcare: Smart Ambulance,” in 2023 2nd International Conference on Electronics, Energy and Measurement (IC2EM), Medea, Algeria: IEEE, Nov. 2023, pp. 1–6. doi: 10.1109/ic2em59347.2023.10419718.

E. Mouhcine, Y. Karouani, K. Mansouri, and Y. Mohamed, “Toward a distributed strategy for emergency ambulance routing problem,” in 2018 4th International Conference on Optimization and Applications (ICOA), Mohammedia: IEEE, Apr. 2018, pp. 1–4. doi: 10.1109/icoa.2018.8370582. J. Tassone and S. Choudhury, “A Comprehensive Survey on the Ambulance Routing and Location Problems,” Jan. 10, 2020, arXiv: arXiv:2001.05288. doi: 10.48550/arXiv.2001.05288.

F. Fukushima and T. Moriya, “Objective evaluation study on the shortest time interval from fire department departure to hospital arrival in emergency medical services using a global positioning system — potential for time savings during ambulance running,” IATSS Res., vol. 45, no. 2, pp. 182–189, July 2021, doi: 10.1016/j.iatssr.2020.08.001.

F. Khoshgehbari and S. M. J. Mirzapour Al-e-Hashem, “Ambulance location routing problem considering all sources of uncertainty: Progressive estimating algorithm,” Comput. Oper. Res., vol. 160, p. 106400, Dec. 2023, doi: 10.1016/j.cor.2023.106400.

F. Ziya-Gorabi, A. Ghodratnama, R. Tavakkoli-Moghaddam, and M. S. Asadi-Lari, “A new fuzzy tri-objective model for a home health care problem with green ambulance routing and congestion under uncertainty,” Expert Syst. Appl., vol. 201, p. 117093, Sept. 2022, doi: 10.1016/j.eswa.2022.117093.

I. Zidi, M. Al-Omani, and K. Aldhafeeri, “A New Approach Based On the Hybridization of Simulated Annealing Algorithm and Tabu Search to Solve the Static Ambulance Routing Problem,” Procedia Comput. Sci., vol. 159, pp. 1216–1228, 2019, doi: 10.1016/j.procs.2019.09.291.

K. Devibalan, S. Brindha, R. Sreeraman, M. E. Thrinam Vishwakumaar, and J. Muralidharan, “Smart Ambulance System using IoT,” in 2024 International Conference on Communication, Computing and Internet of Things (IC3IoT), Chennai, India: IEEE, Apr. 2024, pp. 1–6. doi: 10.1109/ic3iot60841.2024.10550283.

L. Talarico, F. Meisel, and K. Sörensen, “Ambulance routing for disaster response with patient groups,” Comput. Oper. Res., vol. 56, pp. 120–133, Apr. 2015, doi: 10.1016/j.cor.2014.11.006.

M. Hemici, D. Zouache, B. Brahmi, A. Got, and H. Drias, “A decomposition-based multiobjective evolutionary algorithm using Simulated Annealing for the ambulance dispatching and relocation problem during COVID-19,” Appl. Soft Comput., vol. 141, p. 110282, July 2023, doi: 10.1016/j.asoc.2023.110282.

M. N. Ashmawy et al., “SmartAmb: An Integrated Platform for Ambulance Routing and Patient Monitoring,” in 2019 31st International Conference on Microelectronics (ICM), Cairo, Egypt: IEEE, Dec. 2019, pp. 330–333. doi: 10.1109/icm48031.2019.9021900.

M. P. Karthikeyan, S. R, M. K, and K. G, “Smart Ambulance for Traffic Management System,” in 2021 Second International Conference on Electronics and Sustainable Communication Systems (ICESC), Coimbatore, India: IEEE, Aug. 2021, pp. 747–753. doi: 10.1109/icesc51422.2021.9532613.

M. Poulton, A. Noulas, D. Weston, and G. Roussos, “Modelling Metropolitan-area Ambulance Mobility under Blue Light Conditions,” Dec. 07, 2018, arXiv: arXiv:1812.03181. doi: 10.48550/arXiv.1812.03181.

O. S. Oubbati, M. Atiquzzaman, P. Lorenz, A. Baz, and H. Alhakami, “SEARCH: An SDN-Enabled Approach for Vehicle Path-Planning,” IEEE Trans. Veh. Technol., vol. 69, no. 12, pp. 14523–14536, Dec. 2020, doi: 10.1109/tvt.2020.3043306.

R. Tavakkoli-Moghaddam, P. Memari, and E. Talebi, “A bi-objective location-allocation problem of temporary emergency stations and ambulance routing in a disaster situation,” in 2018 4th International Conference on Optimization and Applications (ICOA), Mohammedia: IEEE, Apr. 2018, pp. 1–4. doi: 10.1109/icoa.2018.8370579.

S. T. Ahmed, S. M. Basha, M. Ramachandran, M. Daneshmand, and A. H. Gandomi, “An Edge-AI-Enabled Autonomous Connected Ambulance-Route Resource Recommendation Protocol (ACA-R3) for eHealth in Smart Cities,” IEEE Internet Things J., vol. 10, no. 13, pp. 11497–11506, July 2023, doi: 10.1109/jiot.2023.3243235.

T. D. H. Hussein, M. Frikha, S. Ahmed, and J. Rahebi, “Ambulance Vehicle Routing using BAT Algorithm,” in 2021 International Conference on Electrical, Communication, and Computer Engineering (ICECCE), Kuala Lumpur, Malaysia: IEEE, June 2021, pp. 1–5. doi: 10.1109/icecce52056.2021.9514109.

T. J. Partridge et al., “Finding Comfortable Routes for Ambulance Transfers of Newborn Infants,” in 2020 42nd Annual International Conference of the IEEE Engineering in Medicine & Biology Society (EMBC), Montreal, QC, Canada: IEEE, July 2020, pp. 5905–5908. doi: 10.1109/embc44109.2020.9175873.

Z. Zhang, H. Qin, K. Wang, H. He, and T. Liu, “Manpower allocation and vehicle routing problem in non-emergency ambulance transfer service,” Transp. Res. Part E Logist. Transp. Rev., vol. 106, pp. 45–59, Oct. 2017, doi: 10.1016/j.tre.2017.08.002.

Biographies

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He has received multiple academic honors, including the Outstanding Student Award from Western Michigan University during his master's and PhD studies, and the Academic Honor Medal for Industrial Engineers, representing the state from Georgia Tech. In 2021, he was honored by the Cultural Attaché in the United States, Dr. Fawzi Bukhari.