The Review Of
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Artificial Intelligence Applications For Decision Support And Response Time Optimization In The Saudi Red Crescent Authority

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Abstract

Artificial intelligence (AI) has become an essential component of modern emergency medical services (EMS), offering advanced capabilities that enhance decision-making, improve operational efficiency, and reduce overall response times. Recent global studies demonstrate that AI-supported applications—such as machine learning–based demand forecasting, natural language processing (NLP) for call triage, and dynamic routing algorithms—significantly improve dispatch accuracy, optimize ambulance distribution, and strengthen situational awareness in high-pressure environments. These technologies also support EMS teams by facilitating early recognition of critical conditions and improving resource allocation during peak demand.

Within Saudi Arabia, the Saudi Red Crescent Authority (SRCA) has undertaken substantial digital transformation initiatives aligned with Vision 2030, including the adoption of geospatial intelligence, unified emergency reporting platforms, and automated operational dashboards. Despite these advancements, there remains a scarcity of empirical research evaluating AI's real-world impact on SRCA operations, particularly regarding dispatch performance, triage accuracy, and response time optimization. This integrative review synthesizes evidence from studies published between 2020 and 2025 to assess the role of AI in global EMS systems and explore its applicability within the Saudi context.

Findings from 48 eligible studies indicate that AI-driven tools can reduce dispatch and routing times by 10–40%, improve triage accuracy by up to 28%, and enhance demand prediction precision with error margins below 10%. However, challenges persist, including data interoperability, workforce readiness, ethical considerations, and the need for context-specific model adaptation. The review highlights the critical opportunity for SRCA to implement and evaluate AI-enabled solutions to strengthen decision support, optimize ambulance operations, and improve patient outcomes nationwide.

Overall, AI represents a transformative pathway for advancing prehospital emergency care. Strategic investment in localized AI development, pilot testing, and longitudinal evaluation is essential for enabling SRCA to achieve world-class EMS performance and support national health transformation objectives.

Keywords Artificial intelligence; Emergency Medical Services; Saudi Red Crescent Authority; Decision support systems; Response time optimization; Machine learning; Predictive analytics; Emergency dispatch; Triage accuracy; Dynamic ambulance routing; Vision 2030.

Introduction

Artificial intelligence (AI) has become a cornerstone of modern emergency medical services (EMS), offering new capabilities to enhance decision-making, resource allocation, and operational efficiency. As global EMS systems increasingly rely on data-driven tools, AI-enabled applications—such as predictive analytics, machine learning–based dispatch systems, and automated triage algorithms—have demonstrated measurable improvements in prehospital care outcomes and response times. In high-demand environments, these technologies support rapid prioritization of emergency calls, optimize ambulance deployment, and reduce delays that can directly influence patient survival and clinical outcomes (Alshammari et al., 2024; Li et al., 2023).

Within Saudi Arabia, the Saudi Red Crescent Authority (SRCA) has made significant strides toward integrating digital transformation in alignment with Vision 2030's national goals for enhancing healthcare quality, efficiency, and accessibility. The Authority's operations involve a high volume of emergency calls, geographically diverse service regions, and increasing population demands—all of which underscore the need for advanced technological solutions. AI applications offer transformative potential in this context by improving real-time situational awareness, forecasting demand surges, and supporting evidence-based operational decisions. Recent advancements in the Kingdom's digital health infrastructure, including unified EMS platforms, geospatial analytics, and IoT-enabled monitoring, further position SRCA to capitalize on AI-driven enhancements (Ministry of Health, 2024; SRCA, 2023).

Despite these advancements, gaps remain in understanding how AI can be optimally integrated into emergency response workflows and how such integration translates into measurable improvements in response times, decision accuracy, and overall EMS performance. Existing studies highlight the promise of AI-supported dispatch algorithms, automated incident classification, and predictive modeling for ambulance positioning; however, empirical evaluations within the Saudi context remain limited. As SRCA continues its trajectory toward advanced digital transformation, assessing the current evidence on AI applications for decision support and response time optimization becomes essential for guiding policy, operational improvements, and future system design.

This study aims to synthesize recent research on AI-driven decision support tools and response time optimization strategies within EMS, with a particular focus on their relevance and applicability to the Saudi Red Crescent Authority. By examining global and regional evidence, this review

provides insights into how AI can strengthen SRCA's mission of delivering timely, high-quality emergency medical care across the Kingdom.

Literature Review

1. Artificial Intelligence in Emergency Medical Services (EMS)

AI has increasingly shaped the evolution of emergency medical systems worldwide by enabling faster, data-driven decision-making and enhanced operational efficiency. EMS agencies have adopted machine learning (ML), deep learning, and predictive analytics to improve triage accuracy, anticipate call volumes, and optimize ambulance utilization. International research shows that AI-driven platforms significantly reduce diagnostic uncertainty, accelerate dispatch processes, and support accurate early recognition of critical cases such as cardiac arrest, stroke, and trauma (Zhang et al., 2024; Chen & Li, 2023). AI-enabled decision support systems also assist EMS personnel in interpreting real-time physiological data collected through wearable sensors and remote monitoring devices, improving prehospital assessment and on-scene decision-making.

2. AI for Demand Prediction and Resource Allocation

Predictive models represent one of the most impactful AI applications in EMS. These tools analyze historical dispatch records, weather data, seasonal trends, and geographical patterns to forecast emergency call distribution. Studies have demonstrated that AI-powered demand forecasting improves the positioning of ambulances, reduces idle time, and decreases average response intervals (Rahman et al., 2024). Advanced geospatial algorithms further allow EMS agencies to identify "high-risk hot zones," enabling dynamic ambulance relocation during peak periods. These capabilities support efficient resource deployment and minimize delays during unexpected surges in demand—a critical component of high-performing EMS systems.

In the context of large metropolitan areas, AI-driven dynamic routing systems integrate real-time traffic conditions, road closures, and incident data to recommend the fastest routes. When combined with automated dispatch algorithms, these systems reduce human error while balancing workload between stations and crews (Kumar et al., 2023). Such data-driven models contribute to more equitable service distribution and improved EMS accessibility.

3. AI-Supported Dispatch and Call Classification

Emergency medical dispatch is a complex process requiring rapid decision-making under uncertainty. AI-powered call classification tools analyze caller speech patterns, keywords, background noise, and historical patterns to identify call severity and appropriate response levels. Research has shown that natural language processing (NLP) systems can classify emergency calls more accurately than traditional manual protocols, especially in cases involving incomplete or unclear information (Lee et al., 2024). These systems reduce over-triage and under-triage rates, thereby improving deployment efficiency and ensuring the right level of care reaches patients faster.

In addition, AI-based triage models help dispatchers prioritize life-threatening events earlier, improving survival outcomes for time-sensitive conditions such as cardiac arrest and major trauma. Automated prompts and decision trees also support less experienced dispatchers, reducing variation in decision quality and enhancing patient safety.

4. AI for Response Time Optimization

Response time is one of the most widely recognized indicators of EMS performance. AI systems enhance response times by integrating predictive analytics, real-time monitoring, and dynamic resource management. Studies conducted in high-density urban environments have demonstrated that AI-based station allocation and route optimization systems can reduce response times by 15–30% (Hernandez et al., 2024). Machine learning–based models assess factors such as call urgency, traffic flow, and ambulance availability to recommend the most efficient deployment strategy.

AI-powered dashboards also provide supervisors with live performance metrics, enabling rapid adjustments when delays are detected. These tools improve situational awareness and support proactive decision-making, helping EMS managers anticipate bottlenecks before they affect response times.

5. Artificial Intelligence Adoption in the Saudi Red Crescent Authority (SRCA)

Saudi Arabia has invested heavily in digital transformation within EMS, positioning SRCA as a leader in adopting advanced technologies in the region. As part of Vision 2030 initiatives, SRCA has launched smart platforms that integrate GIS-based incident tracking, automated dispatching, and unified digital records (Saudi Red Crescent Authority, 2023). The Authority also uses AI-supported tools for monitoring fleet performance, analyzing emergency call patterns, and improving coordination across regions.

Despite these advancements, current literature reveals a gap regarding empirical evaluations of AI implementation specifically within SRCA's operations. Most studies highlight the potential benefits of AI in the Saudi EMS context but emphasize the need for localized research to understand practical challenges, data integration barriers, and outcomes related to patient safety and quality of care (Alshammari et al., 2024).

6. Identified Gaps in the Literature

A review of the existing evidence reveals several gaps:

1. Limited Saudi-specific empirical studies examining AI effectiveness in SRCA operations.
2. Insufficient analysis of integration challenges, including data quality, interoperability, and workforce readiness.
3. Lack of standardized metrics for measuring the impact of AI on response time, decision accuracy, and patient outcomes.
4. Minimal longitudinal evaluations of AI systems after implementation.
5. Limited assessment of AI's role in rural and remote Saudi regions, where delays may differ significantly from urban areas.

These gaps underscore the need for research that systematically evaluates AI's role in decision support and response time optimization within SRCA, considering the Kingdom's unique geographic, demographic, and operational contexts.

Methods

This review adopted an integrative literature review approach to synthesize contemporary evidence on artificial intelligence (AI) applications for decision support and response time optimization in emergency medical services (EMS), with a particular focus on the Saudi Red Crescent Authority (SRCA). The methodology was designed to capture the breadth of AI technologies applied within EMS systems globally, while identifying their relevance, feasibility, and potential integration into SRCA's operational framework.

Search Strategy

A comprehensive search was conducted across major scientific databases—PubMed, Scopus, Web of Science, IEEE Xplore, and ScienceDirect—to retrieve relevant studies published between January 2020 and January 2025. These years were selected to ensure the inclusion of the most recent AI advancements following global digital transformation trends in EMS.

Search terms were combined using Boolean operators and included:

- "artificial intelligence" OR "machine learning" OR "deep learning" OR "prediction model"
- "emergency medical services" OR "EMS" OR "prehospital care"
- "decision support" OR "dispatch" OR "triage"
- "response time" OR "ambulance deployment"
- "Saudi Red Crescent Authority" OR "Saudi EMS"

Reference lists of included studies and relevant systematic reviews were also screened to identify additional eligible publications.

Inclusion and Exclusion Criteria

Studies were included if they met the following criteria:

1. Published in peer-reviewed journals between 2020–2025.
2. Focused on EMS, prehospital care, or ambulance services.
3. Evaluated or described AI, machine learning, predictive analytics, or algorithm-based systems.
4. Explored outcomes related to decision support, triage, dispatching, or response time optimization.
5. Written in English.

Studies were excluded if they:

- Focused on non-EMS hospital settings only.
- Examined purely theoretical AI models without EMS application.
- Were conference abstracts, commentaries, or non–peer-reviewed sources.
- Did not assess or describe operational outcomes relevant to EMS.

Study Selection Procedure

All retrieved records were screened in several steps.

1. Title and abstract screening was conducted to exclude irrelevant studies.
2. Full-text review followed for all remaining articles to confirm eligibility based on inclusion criteria.
3. Studies selected for final inclusion were those that provided empirical data, modeling insights, or implementation evaluations relevant to AI in EMS.

The process ensured that the included studies represented high-quality and up-to-date contributions to the field.

Data Extraction and Synthesis

A structured data extraction matrix was developed to record the following key variables from each study:

- Study aims and design
- Geographic setting
- AI techniques used (e.g., NLP, ML, deep learning, predictive modeling)
- Operational area targeted (dispatch, routing, triage, call classification, ambulance positioning)
- Outcomes measured (e.g., response time reduction, accuracy improvement)
- Relevance to SRCA and Saudi Vision 2030

Extracted data were synthesized using a thematic analysis approach, grouping findings into major AI application domains such as predictive analytics, automated dispatch, triage systems, and operational optimization.

Quality Assessment

The methodological quality of the included studies was assessed using appropriate appraisal tools:

- Mixed Methods Appraisal Tool (MMAT 2018) for mixed-method and qualitative studies.
- Joanna Briggs Institute (JBI) Critical Appraisal Checklists for quantitative studies.
- TRIPOD criteria for prediction and machine learning model evaluations.

Studies rated as low quality were excluded or used with caution during interpretation.

Ethical Considerations

This review utilized publicly available peer-reviewed literature and therefore did not require institutional ethical approval. All data were handled responsibly, with proper referencing and adherence to academic integrity principles.

Results

A total of 48 studies met the inclusion criteria and were analyzed. The literature demonstrated substantial global interest in applying artificial intelligence to optimize emergency medical services. Four major themes emerged: (1) AI for call classification and triage**,** (2) predictive analytics for demand forecasting and resource allocation**,** (3) AI-enhanced dispatch and route optimization, and (4) operational performance improvements, including response time reduction**.** Although global evidence is well-developed, research specific to Saudi Arabia remains limited.

1. AI for Call Classification and Triage

Twelve studies evaluated the use of AI-powered triage and call classification tools. Most used natural language processing (NLP) or deep learning models to analyze caller speech, textual descriptions, or historical incident data. Across these studies, AI systems consistently outperformed traditional manual triage protocols in identifying high-acuity emergencies.

Key Findings

- AI systems improved triage accuracy by 15–28% compared to standard dispatcher assessments (Lee et al., 2024).
- NLP models demonstrated high sensitivity in detecting critical cases such as cardiac arrest, stroke, and severe trauma.
- Automating triage reduced dispatcher workload and decreased call-processing times by an average of 12–18 seconds per call**,** a valuable gain in life-threatening scenarios.

No Saudi-based study directly evaluated AI-supported triage tools within SRCA, indicating a clear opportunity for future local implementation research.

2. Predictive Analytics for Demand Forecasting and Resource Allocation

Fifteen studies assessed predictive models designed to forecast EMS call volumes, geographic incident distribution, and optimal ambulance placement. Machine learning algorithms, including random forests, gradient boosting, and LSTM neural networks, were commonly used.

Key Findings

- Predictive models accurately forecasted demand with error margins as low as **5–10%** (Rahman et al., 2024).
- Hot-spot prediction maps enabled proactive ambulance deployment in high-risk zones.
- AI-driven resource allocation reduced idle ambulance time and improved readiness during peak incidents.
- Some models incorporated external variables (traffic, weather, events), improving predictive accuracy.

These findings demonstrate strong applicability to SRCA, particularly in densely populated regions like Riyadh, Jeddah, and the Eastern Province.

3. AI-Enhanced Dispatch and Route Optimization

Thirteen studies focused on AI-driven dispatch systems and dynamic routing technologies. These tools leveraged real-time geospatial data, traffic conditions, and fleet availability to determine the fastest ambulance dispatch and route.

Key Findings

- AI-based dispatch algorithms reduced dispatch decision-making time by **20–35%** compared to manual methods (Kumar et al., 2023).
- Dynamic routing systems decreased travel times by **10–30%** in urban environments.
- AI-driven load-balancing strategies reduced overburdening of specific stations.
- Integration of real-time traffic feeds contributed significantly to response time improvements.

Although SRCA uses GIS-supported dispatch platforms, no published empirical evaluation was found assessing AI-based routing or dispatching within the Kingdom.

4. AI and EMS Operational Performance (Including Response Time Reduction)

Eight studies evaluated overall operational improvements resulting from AI integration across dispatch, triage, and predictive analytics systems.

Key Findings

- Combined AI interventions led to 10–40% faster response times in high-activity regions (Hernandez et al., 2024).
- Machine learning–based dashboards improved situational awareness, enabling managers to reallocate resources rapidly.
- AI systems reduced non-essential dispatches and improved decision accuracy, contributing to performance efficiency.
- In some systems, AI significantly reduced geographic inequities by improving coverage in underserved or remote areas.

However, the literature also highlighted barriers such as limited data interoperability, model transparency concerns, and challenges with personnel training.

5. Evidence Specific to the Saudi Context

Only three studies indirectly related to Saudi Arabia were identified:

1. A descriptive analysis highlighting SRCA's adoption of digital platforms and GIS-based monitoring (SRCA, 2023).
2. A national review emphasizing the need for advanced technologies to improve EMS response times under Vision 2030 goals (Ministry of Health, 2024).
3. A modeling study recommending AI-supported analytics for improving ambulance coverage in Saudi urban regions (Alshammari et al., 2024).

None provided a direct empirical assessment of AI implementation within SRCA operations, underscoring a major research gap and opportunity for innovation.

Summary of Overall Evidence

Across international EMS systems, AI applications showed substantial positive impacts on:

- Decision accuracy
- Call triage precision
- Ambulance deployment efficiency
- Travel time reduction
- Resource utilization balance
- Predictive readiness for peak demand
- Overall response time improvement

Despite these advances worldwide, AI use within SRCA remains largely descriptive with no published empirical evaluations, highlighting a significant gap that future research should address.

Discussion

This review highlights the growing role of artificial intelligence in enhancing emergency medical services, especially in areas related to decision support, triage accuracy, predictive analytics, and response time optimization. The findings from international literature demonstrate that AI technologies have matured to a point where they can generate meaningful operational improvements, particularly in systems with high call volumes, complex urban environments, and dynamic resource demands. The positive impact of AI on EMS performance—ranging from faster dispatch decisions to improved routing and demand forecasting—provides compelling evidence for its potential applicability within the Saudi Red Crescent Authority.

AI Adoption and Implications for SRCA

The SRCA operates within a unique context characterized by rapid population growth, large geographic coverage, and increasing pressure to meet Vision 2030 efficiency and quality targets. The global evidence suggests that AI-driven decision support tools could meaningfully enhance SRCA operations by improving the speed and accuracy of incident classification and reducing the variability in dispatcher performance. Implementing NLP-based call analysis systems, for example, could help improve early recognition of high-acuity emergencies such as cardiac arrest, trauma, and stroke—conditions where every second is critical.

Predictive analytics tools offer additional value for SRCA by enabling proactive ambulance positioning and resource allocation. Given the geographic diversity of Saudi regions—from dense metropolitan cities to remote rural areas—AI-powered forecasting models could help address longstanding challenges in ensuring equitable response times across the Kingdom. Machine

learning models that incorporate real-time traffic feeds, weather data, and historical incident trends could provide SRCA with precise operational insights that are difficult to achieve using conventional methods.

Potential Operational Benefits

Across the international literature reviewed, AI-enabled systems consistently demonstrated improvements in EMS operational performance. The most significant benefits include:

- Reduced response times through dynamic routing and better ambulance distribution.
- Improved triage accuracy, resulting in fewer over-triage and under-triage cases.
- More efficient resource utilization, decreasing the burden on high-demand stations.
- Enhanced situational awareness, particularly when using AI-driven dashboards.
- Earlier detection of critical incidents, improving survival outcomes.

If adopted within the SRCA system, these benefits could translate into measurable advancements in emergency care quality, patient safety, and system responsiveness.

Barriers and Challenges

Despite the strong potential, several challenges must be addressed before AI can be systematically integrated into SRCA's emergency response system.

1. Data Integration and Quality

Most AI systems rely heavily on large, high-quality datasets. Variations in data collection practices, incomplete documentation, or lack of interoperability across platforms can hinder model accuracy. SRCA's transition to advanced AI systems will require robust data governance frameworks.

2. Workforce Readiness and Training

The successful adoption of AI technologies requires adequate training for EMS personnel, dispatchers, and supervisors. Concerns related to trust in AI recommendations, fear of job displacement, or unfamiliarity with technology must be proactively addressed through structured educational programs.

3. Ethical and Legal Considerations

AI-powered decision systems introduce concerns around algorithmic transparency, accountability, and patient privacy. Clear guidelines are needed to ensure that AI complements—rather than replaces—clinical and operational judgment.

4. Customization to the Saudi Context

Most existing AI models are developed in Western or Asian EMS systems. Saudi Arabia's unique geography, climate, population distribution, and cultural communication patterns require localized adaptation of AI algorithms to ensure relevance and accuracy.

Opportunities for Future Research

The lack of Saudi-specific empirical studies represents an important opportunity for researchers, policymakers, and SRCA leadership. Future investigations should focus on:

- Evaluating AI-triage tools using SRCA call data.
- Testing predictive analytics models in high-density Saudi cities.
- Implementing pilot programs for AI-driven dynamic routing in Jeddah, Riyadh, and Dammam.
- Assessing the impact of AI on dispatcher performance and decision accuracy.
- Identifying barriers to adoption from EMS personnel perspectives.

Longitudinal studies will also be essential for measuring sustained improvements after implementation.

Overall Interpretation

The global evidence collectively suggests that artificial intelligence represents a powerful enabler of high-performing EMS systems. For SRCA, AI adoption aligns directly with national health transformation goals and offers significant potential to improve efficiency, reduce response times, and elevate the quality of prehospital care. However, successful integration will require careful planning, investment in digital infrastructure, workforce training, and context-specific evaluation.

Conclusion

This review demonstrates that artificial intelligence has the potential to significantly advance emergency medical services by improving decision support, enhancing triage accuracy, and reducing response times. Global evidence consistently shows that AI-driven dispatch algorithms, predictive analytics, and automated triage systems offer measurable improvements in operational efficiency and patient outcomes. These technologies allow EMS agencies to better anticipate demand, optimize ambulance placement, and deliver faster, more accurate responses during emergencies.

For the Saudi Red Crescent Authority, the findings highlight a substantial opportunity to leverage AI in support of national health transformation goals under Vision 2030. Although SRCA has already made progress in digitalization through GIS-based platforms and integrated emergency reporting systems, the absence of empirical studies evaluating AI implementation within its operations points to a critical research and development gap. Integrating AI-driven solutions—such as NLP-based call classification, machine learning forecasting models, and dynamic routing systems—could meaningfully improve prehospital care delivery across Saudi Arabia.

However, realizing the full benefits of AI requires addressing challenges related to data quality, system interoperability, workforce readiness, and ethical considerations. Future efforts should focus on conducting localized evaluations, pilot implementations, and long-term studies to validate the performance of AI tools within the SRCA context.

Overall, artificial intelligence offers a promising pathway for optimizing emergency response, strengthening decision-making, and ensuring timely, high-quality care for patients across the Kingdom. Strategic investment in AI research, workforce training, and system integration will play a vital role in enabling SRCA to achieve world-class EMS performance and support the broader objectives of Saudi Vision 2030.

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