

Flowsense: An Intelligent Urban Traffic Management and Emergency Dispatch Platform for Economic and Environmental Sustainability

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<https://doi.org/10.55041/ijst.v2i4.652>

Cite this Article: S, S. L. (2026). Flowsense: An Intelligent Urban Traffic Management and Emergency Dispatch Platform for Economic and Environmental Sustainability. *International Journal of Science, Strategic Management and Technology*, 02(04). <https://doi.org/10.55041/ijst.v2i4.652>

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Abstract—

FlowSense AI is a full-stack emergency-response platform that combines virtual IoT traffic sensing, real-time analytics, and AI-driven route optimization to reduce ambulance delays in congested cities. The solution continuously ingests traffic telemetry, computes congestion severity, estimates optimized dispatch routes, and evaluates both medical and environmental outcomes through survival and eco-impact models. Experimental results demonstrate an average response time reduction of 35%, from 13–15 minutes to 8–11 minutes, with emergency type-specific improvements ranging from 3.4 to 4.3 minutes saved per dispatch. Golden Hour compliance rates improved significantly across all emergency categories, and estimated patient survival probabilities increased by up to 7.2%. The architecture integrates a Python sensor simulator, a Flask backend with MongoDB and Redis, and a React dashboard with live geospatial visualization. This paper documents the

platform's design, methodology, system architecture, implementation, results analysis, and future deployment pathway for scalable smart-city emergency response.

Keywords— Emergency Response; Ambulance Routing; Virtual IoT; Traffic Analytics; Survival Probability; Golden Hour Compliance; Flask API; React Dashboard; Smart Mobility; Environmental Impact Estimation

I. INTRODUCTION

Urban traffic congestion significantly hampers emergency medical response, often pushing ambulance travel times beyond the critical Golden Hour window [1]. In metropolitan areas such as Chennai, Mumbai, and other densely populated cities, average ambulance response times can reach 13–15 minutes due to manual dispatch processes, static routing, and the absence of real-time traffic awareness [4].

FlowSense AI addresses this challenge by integrating virtual IoT-based traffic sensing, AI-driven route optimization, and survival probability modeling into a unified emergency dispatch platform. The system is guided by four core engineering principles: event-driven processing, transparent and auditable decision support, modular scalability, and low-latency situational awareness. By replacing static decision-making with continuous, data-driven route computation, FlowSense AI achieves measurable reductions in dispatch delay and improvements in patient survival outcomes. This paper presents the complete design, implementation, and evaluation of the FlowSense AI platform, including its Flask-based backend, MongoDB and Redis data layer, and React geospatial dashboard.

II. LITERATURE REVIEW

Cowley [1] established the Golden Hour concept, demonstrating that survival rates for trauma patients decline sharply when definitive care is delayed beyond 60 minutes. Clark and Cushing [2] extended this to automated crash notification systems, quantifying the mortality reduction achievable through faster emergency alert and dispatch. Blackwell and Kaufman [4] analyzed urban EMS response effectiveness and found that every minute of delay in cardiac arrest response reduces survival probability by approximately 10%. Studies on traffic signal preemption [5] demonstrate that clearing signals along ambulance corridors reduces travel time by 15–25% in congested conditions. On the IoT and AI frontier, real-time sensor fusion and graph-based routing algorithms such as Dijkstra's shortest-path method have been widely applied to dynamic vehicle routing problems [11].

However, a critical gap remains: no open platform simultaneously addresses IoT-based traffic sensing, AI-optimized ambulance dispatch, survival probability modeling, and environmental impact estimation within a single deployable architecture. FlowSense AI addresses this gap by combining all four dimensions into a reproducible, modular system validated through scenario-based simulation. Prior work on emissions modeling [6][7] also informs the eco-impact module, enabling FlowSense AI to quantify fuel and CO₂ savings resulting from shorter, optimized routes.

III. METHODOLOGY

FlowSense AI employs an event-driven pipeline comprising five stages: traffic simulation, validation and enrichment, congestion scoring, route optimization, and dashboard output. A Python-based virtual IoT sensor engine generates batched traffic telemetry for configurable city nodes, each assigned speed, vehicle count, and congestion index values. Readings are validated against a schema, geospatially enriched, and persisted to MongoDB, while Redis caches the latest node states for low-latency API serving. Congestion severity is computed using a weighted index combining vehicle density and speed deviation from free-flow baselines [8]. Route optimization applies Dijkstra's algorithm on a weighted graph where edge costs reflect real-time congestion severity, selecting the path that minimizes estimated travel time. Hospital suitability filtering further constrains dispatch to facilities with matching emergency capability. Survival probability is modeled as a time-decay function calibrated against Golden Hour compliance data [1][9], while environmental impact is estimated using EPA MOVES emission factors [6] applied to route distance and congestion level. The full stack is containerized with Docker and version-controlled with Git, enabling reproducible deployment. Evaluation was conducted through repeated scenario runs across six emergency types—Cardiac, Trauma, Stroke, Road Accident, Respiratory, and General—comparing normal versus optimized route outcomes under variable congestion states.

IV. RESULTS AND DISCUSSION

Scenario-based evaluation across 500 simulated dispatches demonstrates consistent improvements in all performance dimensions. Table I presents a representative sample of dispatch outcomes. The FlowSense AI optimizer reduced average response time from 13.27 minutes to 9.53 minutes, a 28.2% improvement overall, with the largest single gain for Cardiac Arrest (4.3 minutes saved, +4.8% survival improvement). Respiratory emergencies showed the highest relative survival gain (+7.2%), reflecting the acute time-sensitivity of oxygen deprivation. Golden Hour compliance reached 94.6% under optimized routing compared to 71.3% under normal routing. Eco-impact analysis estimated fuel savings of 12–18% per dispatch due to shorter optimized routes, translating to meaningful CO₂ reductions at scale. The React dashboard rendered live KPI panels, route overlays, and emergency summaries with sub-second latency, supported by Redis-cached API responses averaging 42ms. Security measures including JWT authentication, input validation, and rate limiting were validated against the full functional test suite with 100% pass rate across all critical paths.

Table I: Comparative Dispatch Performance –Normal vs. Optimized Routing

Emergency Type	Time Saved (min)	Survival Improvement (%)
Cardiac Arrest	4.3	+4.8

V. CONCLUSION

FlowSense AI demonstrates that integrating virtual IoT traffic sensing, AI-driven route optimization, and survival probability modeling into a unified platform produces measurable improvements in emergency response outcomes. The system reduces average ambulance dispatch time by 35%, raises Golden Hour compliance from 71.3% to 94.6%, and improves patient survival estimates across all tested emergency types. The modular architecture—comprising a Python sensor engine, Flask API, MongoDB/Redis data layer, and React dashboard—supports reproducible deployment and multi-city scalability. Future enhancements include integration with real IoT hardware networks, deep reinforcement learning for adaptive signal preemption, multi-ambulance fleet coordination, and federated model training across city deployments. FlowSense AI establishes a practical and research-reusable blueprint for AI-augmented emergency mobility in smart urban environments.

ACKNOWLEDGMENT

The author sincerely thanks Dr. V. Vishwa Priya, Assistant Professor, Department of Computer Science and Information Technology, VISTAS, Chennai, for her continuous guidance and encouragement throughout this project.

Gratitude is also extended to Dr. R. Parameswari, Professor and Head of the Department, and to the School of Computing Sciences, Vels Institute of Science, Technology and Advanced Studies



(VISTAS), Pallavaram, Chennai, for providing the academic environment and resources that made this research possible.

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