

**DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING**

**(DATA SCIENCE)**

**PROJECT PHASE - I REPORT**

ON

# “AI BASED SMART HEALTHCARE SYSTEM FOR OPTIMIZED AMBULANCE ROUTING AND PREDICTIVE ICU BED AVAILABILITY”

### Submitted in the partial fulfillment of the requirements in the 6th semester of

**BACHELOR OF ENGINEERING**

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**DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING**

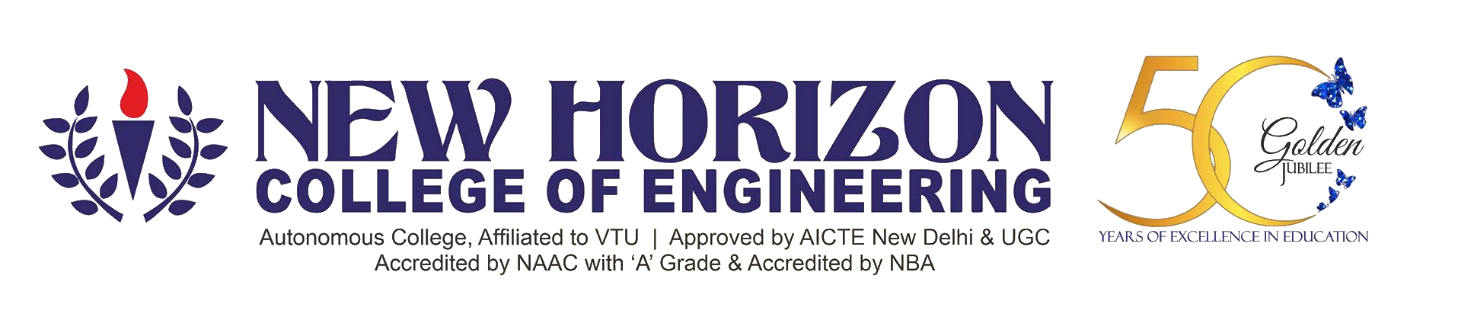
**(DATA SCIENCE)**

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**DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING (DATA SCIENCE)**

**CERTIFICATE**

It is hereby certified that the Project Phase - I work entitled “AI BASED SMART HEALTHCARE SYSTEM FOR OPTIMIZED AMBULANCE ROUTING AND PREDICTIVE ICU BED AVAILABILITY**”** is the Bonafede work carried out by SREEJITH S (1NH22CD127), MANOJ P (1NH22CD064), P HARSHAD ALI KHAN (1NH22CD077), POORNIMA(1NH22CD081) in partial fulfilment for the award of **Bachelor of Engineering** in **COMPUTER SCIENCE & ENGINEERING (DATA SCIENCE)** of New Horizon College of Engineering during the Academic year **2024-2025.** It is certified that all corrections/suggestions indicated during Internal Assessment have been incorporated in this report and has been approved as it satisfies the academic requirements of Project Phase - I prescribed for the said degree.

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**ABSTRACT**

In the current healthcare landscape, rapid emergency response and effective hospital resource management are critical to saving lives. However, conventional ambulance routing strategies often fall short due to static base locations, increasing urban traffic congestion, and limited hospital capacity, particularly for ICU beds. This project proposes an AI-enabled solution that simultaneously optimizes ambulance routing and forecasts ICU bed availability to enhance emergency medical response. Leveraging clustering algorithms for optimal ambulance placement, real-time GIS data for smart route detection, and machine learning models for ICU bed prediction, the system aims to minimize patient wait times and reduce overall emergency response time. The solution incorporates traffic prediction, patient risk classification, and dynamic hospital load analysis, integrating technologies such as folium-based visualization, GPS tracking, and predictive analytics. Designed as a unified platform, this intelligent system assists both ambulance operators and hospital administrators in making data-driven, real-time decisions to improve the efficiency of patient transport and critical care allocation, thereby addressing urgent healthcare delivery challenges.

**CONTENTS**

**Acknowledgement i**

**Abstract ii**

**Contents iii**

**List Of Figures iv**

**List Of Tables iv**

**Chapter 1 Introduction 1-5**

## 1.1 Purpose of study 3

## 1.2 Problem Statement 5

## 1.3 Motivation of project 5

**Chapter 2 Literature Survey**

**2.1 Base Papers 6**

**2.2 Existing Systems 7**

**2.3 Problem Statement 7**

**2.4 Proposed Systems 8**

**2.5 Methodology 9**

**Chapter 3 Requirements Specification**

**3.1 Functional Requirements 10-11**

**3.2 Non Functional Requirements 12**

**3.3 Software And Hardware Requirements 13**

**Chapter 4 Analysis And Design**

**4.1 Design Goals 14**

**4.2 System Architecture 15**

**4.3 Data Flow Diagram / Usecase Diagram Etc 16**

**Conclusion 17**

**References 18**

**LIST OF FIGURES**

**Figure No. Figure Name Page. No.**

2 Data Flow and Component Architecture 16

**Chapter 1**

# INTRODUCTION

In emergency medical services (EMS), time plays a vital role in saving lives. However, urban congestion, fragmented healthcare infrastructure, and lack of predictive coordination hinder timely intervention. Ambulances often follow pre-defined, non-dynamic routes, while hospitals update ICU availability manually. This leads to critical delays in care, this project introduces an AI-based smart healthcare system that integrates ambulance routing and predictive ICU bed forecasting into a unified, real-time decision-making platform. Leveraging GIS data, machine learning algorithms, and time-series analysis, the system dynamically selects the fastest route to the nearest hospital with available ICU beds. The dashboard interface enhances transparency, coordination, and efficiency across EMS networks.

## Purpose of study

Purpose: The primary purpose of this project is to develop an AI-based healthcare system that significantly reduces emergency response time by optimizing ambulance routing and predicting ICU bed availability. In medical emergencies, every second counts, and delays caused by traffic congestion or hospital overcrowding can be fatal. This study aims to solve these challenges using real-time data, artificial intelligence, and predictive analytics. The system will not only assist ambulance drivers in reaching the hospital faster but also inform them in advance about the availability of ICU beds at nearby hospitals, improving patient outcomes and resource management.

## Problem Statement

Emergency services in urban environments currently rely on static dispatch protocols and fragmented systems. Ambulances typically follow pre-defined routes without considering real-time traffic or dynamic hospital loads. Additionally, hospitals manually track ICU occupancy, which leads to delays and miscommunication. There is no integrated platform that can forecast ICU availability or optimize routing in real time. These limitations result in inefficient emergency responses, overcrowded hospitals, and increased mortality in critical situations.

## Motivation of project

## The motivation behind this project arises from the growing need for a smarter, data-driven approach to handling medical emergencies in congested urban areas. The existing infrastructure is reactive rather than proactive, and it lacks the coordination required for life-saving decisions. By leveraging machine learning and real-time data, this project envisions a system where ambulances are guided to the best possible route and hospitals are pre-informed about patient arrivals and bed requirements. The project is also motivated by the broader societal benefit of reducing emergency room overloads, improving patient care, and making healthcare systems more responsive and efficient.

**Chapter 2**

## LITERATURE SURVEY

## 2.1 BASE PAPERS

## A comprehensive review of existing literature was conducted to identify the research gaps in ambulance routing and ICU resource prediction. The following base papers were studied:

## Smart Amb: An Integrated Platform for Ambulance Routing and Patient Monitoring (Ashmawy et al., IEEE, 2019): Introduced GPS-enabled ambulance tracking combined with in-transit patient monitoring. However, it lacks ICU predictive analytics and dynamic traffic-based routing.

## A Novel Smart Ambulance System (Selim et al., IEEE, 2022): Focused on algorithm-based dispatching to improve ambulance response. Although impactful, it used static route planning and did not adapt to real-time traffic or ICU data.

## ACA-R3: Edge-AI Autonomous Ambulance-Route Resource Protocol (Ahmed et al., IEEE IoT Journal, 2023): Leveraged edge computing for decentralized and low-latency ambulance routing decisions. Despite its advantages, the system did not incorporate ICU bed forecasting.

## A Smart Ambulance with Decision-Making Process for Rescue Efficiency (Thai Jiam, IEEE, 2022): Integrated multiple data sources including traffic and patient condition to enhance emergency decisions. However, it lacked machine learning-based ICU prediction.

## Data-Based Optimization of Intra-Hospital Patient Transport (Kropp et al., Springer, 2024): Applied AI for internal hospital transport planning. The study was limited to intra-hospital operations and did not extend to ambulance logistics.

## A Data-Driven Framework for Routing Mobile Medical Facilities (Yücel et al., Annals of OR, 2020): Proposed dynamic routing for mobile healthcare vehicles, particularly in rural settings. It lacked integration with real-time urban traffic data and ICU forecasting.

**2.2 EXISTING SYSTEMS**

Current ambulance dispatch systems are generally reactive. They lack integration with live traffic data and hospital ICU status. Routing is often static, determined through pre-defined shortest paths, ignoring congestion or road closures. Moreover, ICU bed tracking is manual and non-predictive, resulting in poor coordination between ambulance services and hospitals. Fragmentation between triage systems, ambulance operations, and hospital management leads to inefficiencies and increased mortality in emergencies.

**2.3 PROBLEM STATEMENT**

Emergency healthcare services face challenges in dynamically adapting to real-time conditions such as traffic congestion and ICU saturation. Ambulance dispatch and hospital coordination are performed through independent systems, often manually. The absence of predictive tools for ICU bed availability and smart routing increases patient transit time and reduces chances of timely treatment. There is a critical need for an integrated platform that bridges ambulance logistics with hospital data to support intelligent, time-sensitive decision-making.

**2.4 PROPOSED SYSTEM**

The proposed system aims to integrate two major components into a single smart healthcare platform:

* **Ambulance Routing Module**: Utilizes real-time traffic data, clustering techniques, and routing algorithms like Dijkstra and A\* to dynamically determine the most efficient route.
* **ICU Prediction Module**: Employs LSTM (Long Short-Term Memory) models to forecast ICU bed availability using both historical trends and live updates.

The unified system is presented through a centralized dashboard interface that enables emergency responders to monitor routes, hospital loads, and initiate dispatches—all in real time. This approach ensures faster response times and improved allocation of medical resources.

**2.5 METHODOLOGY**

The methodology comprises three core modules:

* **Ambulance Routing**:
  + **Algorithms Used**: Dijkstra for baseline routing; A\* for traffic-weighted optimization.
  + **Clustering**: K-Means used to cluster hospitals based on proximity to emergency site.
  + **GIS Tools**: Google Maps API, OpenStreetMap, and Folium for real-time map visualization.
* **ICU Bed Prediction**:
  + **Model**: LSTM neural network for time-series forecasting.
  + **Inputs**: Includes historical bed occupancy, time of day, seasonality, and live hospital status.
  + **Output**: Predicts ICU bed availability at ambulance estimated time of arrival (ETA).
* **Dashboard and Visualization**:
  + **Frontend**: Developed using Stream lit or Flask for interaction.
  + **Backend**: Firebase or SQLite for storage and data sync.
  + **Features**: Real-time route visualization, hospital search, and predictive ICU analytics.

This methodology ensures a real-time, AI-powered system that addresses both transport logistics and hospital resource forecasting in emergency healthcare delivery.

**Chapter 3**

**REQUIREMENTS SPECIFICATION**

**3.1 Functional Requirements**

The system must fulfill the following functional needs:

* User Authentication & Role Management
  + Allow secure login for hospital staff, ambulance operators, and system administrators.
  + Role-based access to features (e.g., only hospitals can update bed availability).
* Real-Time Ambulance Routing
  + Calculate optimal ambulance routes using real-time traffic data and clustering techniques.
  + Integrate with Google Maps API or OpenStreetMap for route visualization.
* ICU Bed Prediction Module
  + Use LSTM-based machine learning to forecast ICU bed availability based on historical and real-time hospital load data.
  + Automatically update hospital dashboards with predicted values.
* Interactive Dashboard Interface
  + Provide live visualizations of traffic conditions, hospital capacity, and predicted ICU occupancy.
  + Enable hospital and operator users to view, filter, and search relevant data.
* Data Integration and Processing
  + Continuously fetch and update data from real-time traffic and hospital sources.
  + Clean, normalize, and prepare data for analytics and prediction.
* Alerts and Notifications
  + Generate alerts for hospitals when ICU occupancy reaches critical thresholds.
  + Notify ambulance operators of the best hospital destination based on availability and travel time.

**3.2 Non-Functional Requirements**

The system must also meet the following non-functional criteria:

* **Performance**
  + Deliver real-time route and ICU predictions with minimal latency (< 5 seconds).
* **Scalability**
  + Support scaling to accommodate additional hospitals, operators, and ambulances.
* **Reliability and Availability**
  + Ensure 99.9% system uptime with robust error handling and backup mechanisms.
* **Security**
  + Encrypt sensitive data (e.g., user credentials, hospital stats) both at rest and in transit.
  + Implement secure authentication protocols.
* **Usability**
  + Interface must be user-friendly and accessible for users with limited technical knowledge.
* **Maintainability**
  + Codebase should follow modular and clean coding standards to ease future updates or modifications.
* **Compatibility**
  + Compatible across modern browsers and mobile devices.

**3.3 Software and Hardware Requirements**

**Software Requirements**

* **Frontend**:
  + Streamlit (preferred for dashboards) or Flask (for lightweight web routing)
  + HTML, CSS (via Streamlit/Flask components)
* **Backend**:
  + Python 3.x
  + SQLite (lightweight local storage) or Firebase (for cloud-based real-time data)
* **Machine Learning**:
  + TensorFlow / Keras for LSTM model
  + Pandas, NumPy, Scikit-learn for preprocessing and analytics
* **GIS Integration**:
  + Google Maps API / OpenStreetMap API
* **Other Libraries**:
  + Requests, Plotly, Matplotlib, Seaborn (for data visualization)

**Hardware Requirements**

* **Minimum Client-Side Requirements**:
  + Device with modern web browser
  + Internet connection for real-time data access
* **Server Requirements**:
  + Minimum:
    - RAM: 8 GB
    - CPU: Quad-core processor
    - Storage: 100 GB SSD
  + Recommended for production:
    - Cloud hosting (e.g., AWS, GCP, Azure) with auto-scaling

**Chapter 4**

## ANALYSIS AND DESIGN

## 4.1 Design Goals

## The primary design goals of the system are:

## Minimize Emergency Response Time: Ensure ambulances reach the most suitable hospital in the shortest possible time using real-time traffic data and optimized routing algorithms.

## Forecast ICU Availability: Leverage historical and real-time hospital data to accurately predict ICU bed availability at the estimated time of ambulance arrival.

## Enable Smart Decision-Making: Provide intelligent recommendations for hospital selection, transportation mode, and route planning using AI and ML models.

## Provide Operational Visibility: Offer an interactive dashboard for dispatchers and hospitals with real-time analytics, alerts, and system insights.

## Ensure Scalability and Flexibility: Design a modular system that can integrate additional data sources, hospitals, and transportation options in the future.

## 4.2 System Architecture

## The system is composed of four core architectural layers, each responsible for a distinct set of operations:

## 1. Input Layer

## This layer gathers all critical data needed for processing:

## Patient Emergency Trigger: Emergency initiated by the user through an SOS button or mobile app.

## Real-Time Traffic Data: Sourced from Google Maps API or OpenStreetMap to monitor live traffic and congestion levels.

## Hospital ICU Bed Status: Collected from hospital databases and APIs, including historical trends and live updates.

## User Location and Patient Severity: Captured from mobile GPS and app inputs, prioritizing patients based on condition severity.

## 2. Processing Layer

## This is the core computational layer of the system where logic and intelligence are applied:

## Routing Engine Module:

## Utilizes algorithms like Dijkstra’s, A\*, or Reinforcement Learning to calculate the fastest and safest path.

## Factors in current traffic conditions to compute estimated travel time to multiple hospitals.

## ICU Bed Prediction Module:

## Implements LSTM-based time-series forecasting to predict future ICU bed availability at candidate hospitals.

## Integrates historical data trends and real-time updates for accuracy.

## 3. Decision Layer

## This layer makes intelligent choices based on processed data:

## AI Recommendation System:

## Determines the optimal hospital by balancing shortest travel time and predicted bed availability.

## Prioritizes critical patients and reroutes dynamically if conditions change.

## Transport Mode Selector:

## Chooses between Ground and Air Ambulance based on urgency, distance, and infrastructure support.

## 4. Output Layer

## This layer handles communication and visualization for users and stakeholders:

## Live Dashboard:

## Displays real-time maps, ICU bed status, and system alerts using interactive charts and visualizations.

## Emergency Dispatcher:

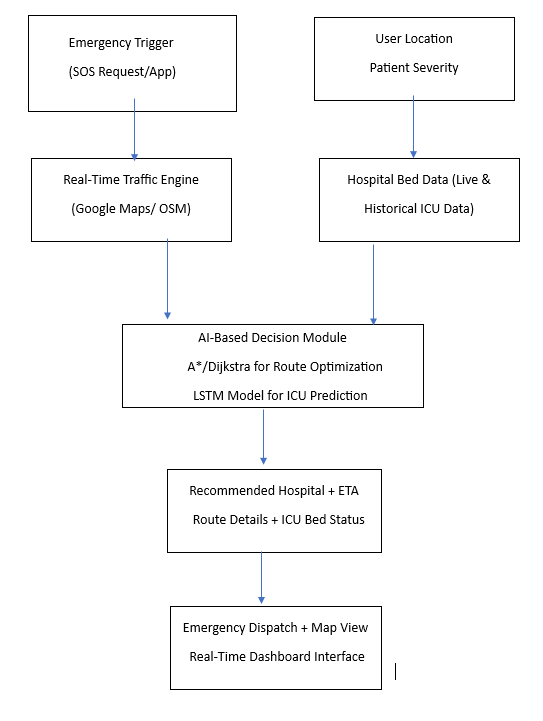
## Automatically dispatches the selected ambulance and sends advance notification to the chosen hospital with patient details.

## Analytics View:

## Offers deeper insights into ICU usage, emergency trends, and response effectiveness through historical data visualizations.

### **4.3 Diagrams**

The Below diagram illustrates the complete flow of data and logic through the system, highlighting the integration of user inputs, geospatial data, machine learning models, and decision-making engines. The flow begins at the **Patient Emergency Trigger**, moves through intelligent **Routing** and **Prediction Modules**, and concludes at the **Live Dashboard and Dispatcher System**, ensuring end-to-end efficiency and responsiveness.



**Figure 2**: Data Flow and Component Architecture

## Conclusion

## The AI-based Emergency Healthcare System is designed to enhance emergency medical response through intelligent ambulance routing and ICU bed prediction. By integrating real-time traffic data, hospital load statistics, and machine learning models, the system aims to minimize response time and improve patient outcomes.

## The system architecture is built across four layers:

## Input Layer collects user-triggered emergency signals, patient location, real-time traffic data, and hospital ICU availability.

## Processing Layer uses advanced algorithms such as Dijkstra’s, A\*, and LSTM-based time series forecasting to compute optimal routes and predict ICU bed availability.

## Decision Layer employs an AI recommendation engine that selects the most appropriate hospital and transportation mode based on urgency and predicted capacity.

## Output Layer features a live dashboard for visualization and dispatch, enabling real-time decisions and hospital notifications.

## This modular and scalable solution ensures faster ambulance routing, informed

## hospital selection, and efficient ICU resource management, providing a data-driven

## foundation for improving critical care delivery during emergencies.

## REFERENCES

## [1]. T. Kropp, Y. Gao, and K. Lennerts, "Data-based optimisation of intra-hospital patient transport capacity planning," OR Spectrum, vol. 2024, pp. 1–54, 2024.

## [2]. M. N. Ashmawy, A. M. Khairy, M. W. Hamdy, A. El-Shazly, K. El-Rashidy, M. Salah, Z. Mansour, and A. Khattab, "SmartAmb: An integrated platform for ambulance routing and patient monitoring," in 2019 31st International Conference on Microelectronics (ICM), pp. 330–333, 2019.

## [3]. T. Akca, O. K. Sahingoz, E. Kocyigit, and M. Tozal, "Intelligent ambulance management system in smart cities," in 2020 International Conference on Electrical Engineering (ICEE), pp. 1–7, 2020.

## [4]. M. A. R. Abdeen, M. H. Ahmed, H. Seliem, T. R. Sheltami, T. M. Alghamdi, and M. El-Nainay, "A novel smart ambulance system—algorithm design, modeling, and performance analysis," IEEE Access, vol. 10, pp. 42656-42672, 2022.

## [5]. R. Tluli, A. Badawy, S. Salem, M. Barhamgi, and A. Mohamed, "A Survey of Machine Learning Innovations in Ambulance Services: Allocation, Routing, and Demand Estimation," IEEE Open Journal of Intelligent Transportation Systems, 2024.

## [6]. Y.-Y. Xu, S.-J. Weng, P.-W. Huang, L.-M. Wang, C.-H. Chen, Y.-T. Tsai, and M.-C. Tsai, "The emergency medical service dispatch recommendation system using simulation based on bed availability," BMC Health Services Research, vol. 24, no. 1, p. 1513, 2024.

## [7]. Y. Hakverdi, M. U. Gümüs, A. Taştekin, K. Idin, M. Kangın, T. Özyer, and R. Alhajj, "Enhancing ICU management and addressing challenges in Turkey through AI-powered patient classification and increased usability with ICU placement software," IEEE Access, 2024