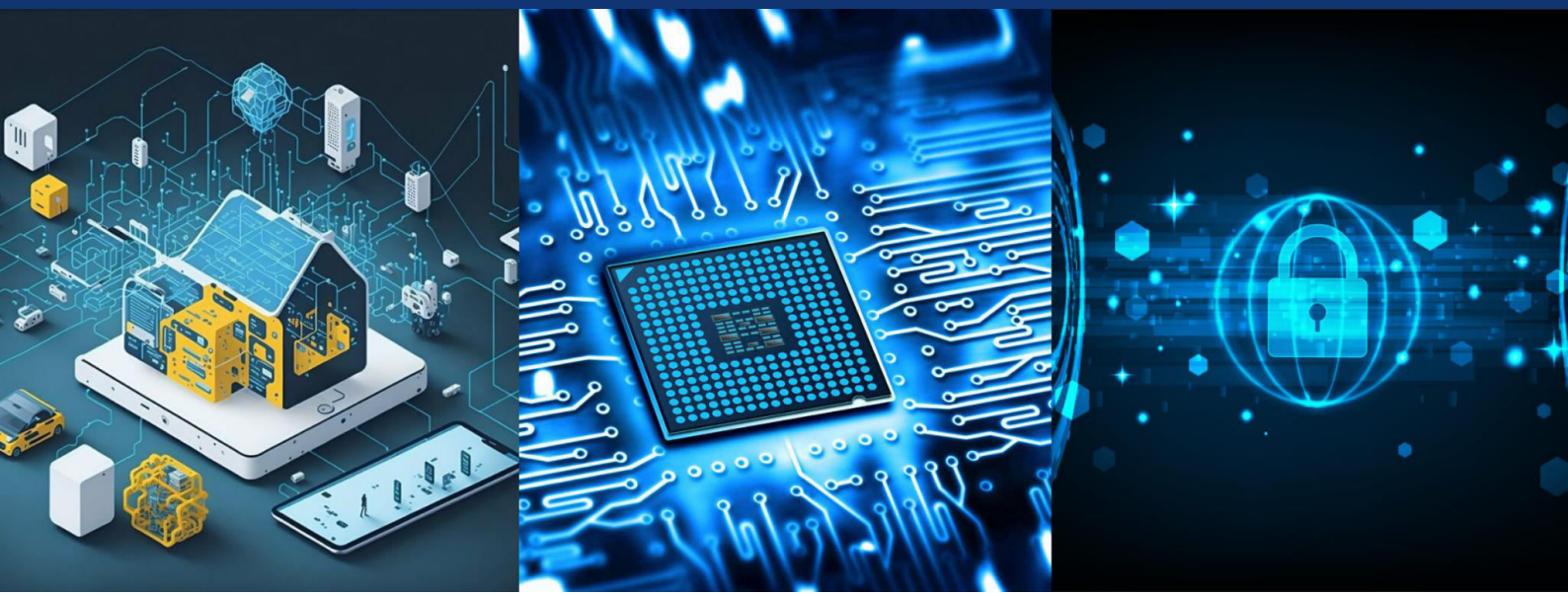
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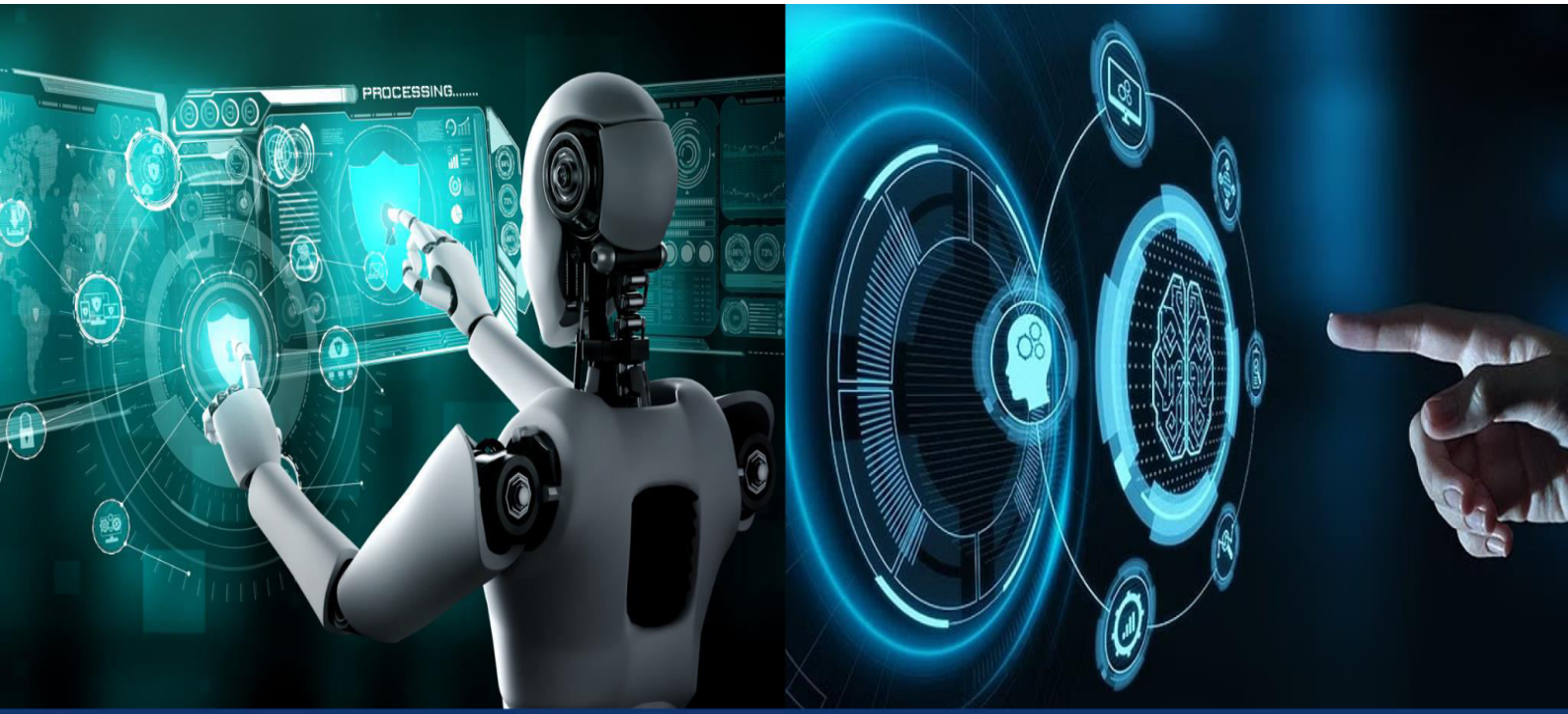
ISSN(O): 2320-9801

ISSN(P): 2320-9798



# International Journal of Innovative Research in Computer and Communication Engineering

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)




**Impact Factor: 9.927**

**Volume 14, Issue 10, October 2026**

© 2026 IJIRCCE | Volume 14, Issue 10, October 2026 DOI: 10.15680/IJIRCCE.2026.1410038

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 9.927| ESTD Year: 2013|

International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

# Arogya Vahini: AI-Based Smart Ambulance Routing System with Hospital Coordination and Traffic-signal Priority

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**ABSTRACT:** Timely ambulance services are affected by factors such as traffic congestion, route planning, and co-ordination between emergency providers and hospitals. Arogya Vahini is a web based Smart Ambulance Routing System with Hospital coordination. It handles emergency requests and provides features for better communication between patient, ambulance, driver and administrator. The system has various features like emergency request handling, GPS-based visualization of routes, estimated time to destination and distance, searching hospitals, notifications and voice assistance. A prototype based on the ESP32 microcontroller has been used for implementing traffic signals with LED`s Buzzer and SOS Button. An optimized route has been implemented using external route generation, A heuristic search as a bound and context aware decision making AI. Supabase has been set up as a data store for recording emergency workflows and route decisions. The routing agent returns the chosen route and the reasoning. Functional testing should be performed on the system to test route selection handling of road closures, fallback to providers, data storage and failure improvements in real world ambulance response times have not been made quantitatively.

**KEYWORDS**: Smart Ambulance System, Emergency Response, Hospital Coordination, GPS Based Routing, Traffic Signal Priority, Artificial Intelligence, A* Search, Context Aware Route Optimisation, Supabase.

## I. INTRODUCTION

Emergency medical services provide essential support during medical emergencies. However delays due to traffic, optimum path finding, and ambulance availability can cause inefficiencies in the process. Delays at junctions and lack of clear emergency information can cause further issues. An emergency system can be used to manage requests, identify optimum routing and improve co-ordination between emergency responders and hospitals. Traditionally emergency requests will be handled, ambulance allocation, path finding and hospital information will be done separately. As a result it can be difficult to track how an emergency request is processing. Using a web based system will allow emergency information to be organised and provide a structure for all involved (Patients, ambulances Drivers and Administrators).

This Paper introduces Arogya Vahini, a web based system for managing emergency requests with smart ambulance routing and hospital co-ordination. The system has three sections: Patient, Driver, Administrator. This allows emergency requests to be submitted, ambulance requests to be handled by the driver, emergency status, GPS path finding, ETA and Distance information, hospital search, notifications and voice support.

The route finding section has been designed using a heuristic search and context aware decision agent to provide an optimum path. An ESP32 prototype has been created to demonstrate emergency traffic light priority. The prototypes uses LED traffic lights, buzzer and manual SOS button to show that there is a priority light for the chosen direction. This is a prototype and doesn`t interact with actual traffic lights.

The Key contributions of this project are the creation and deployment of a web based emergency co-ordinator. The route finding section has updated to allow separation between generating and choosing a route. This means that alternative routes have been clearly considered based on contextual factors. Routes can be closed and validated. Supabase has been

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used to store information related to the emergency, such as the emergency setup, status, and route decisions. More testing will be required at a small scale to see how the system performs when scaled up. Live traffic coverage and direct connection on outside integration.

## II. RELATED WORK

Smart ambulance systems have been studied with the aim of optimising route planning, ambulance allocation, traffic control and information sharing to improve emergency situations. Previous work has shown the importance of aligning ambulance allocations to real time road conditions and health care needs. A systematic literature review was produced looking into emergency medical services, smart ambulance systems, patient health monitoring and traffic control.

This work covered how emergency medical services can utilise green corridors to allow ambulances to move freely and transmit patients health information to hospitals ahead of time [1]. A smart ambulance system was proposed which takes into account traffic conditions and hospital load levels to optimise ambulance allocation and routing [2]. The objective was to reduce ambulance response times, waiting times. The authors analysed their algorithm using both analytical analysis and simulation. This shows the benefit of aligning ambulance allocation and routing to real time traffic and hospital information [2]. An intelligent emergency information system was proposed to optimise ambulance allocation and routing [3]. This uses an optimisation algorithm which takes into consideration both parts of an ambulance journey. The first part being the ambulance moving to a patients location and the second part being transporting the patient to hospital.

This study also looked at how new information can impact ambulance allocation and routing. This includes new emergency requests and ambulance breakdowns. This study emphasises the importance of the inclusion of emergency information [3]. The studies above all have different objectives, optimisation algorithms and requirements. For advanced ambulance routing and allocation algorithms they may require real time information about traffic conditions, ambulance availability and hospital capacity. This poses an important problem to overcome in practice. Arogya Vahini solves this issue by providing a web based emergency coordination system. This contains modules to help with emergency requests, ambulance requests, emergency status and allows for route visualisation using GPS. It also provides ETA and distance information, search functionality for hospitals, notifications and voice assistance. The route optimiser uses a heuristic search algorithm with a specified graph containing roads. If this feature does not work then a basic route optimiser is also available. The decisions maker makes decisions based on the context of the situation using a decision maker which analyses possible routes given by different routing providers. A separate prototype has been made using an ESP32 to show how priority can be given to traffic signals for a specific direction using LEDs, buzzer and SOS button.

The AI search algorithm uses a classical algorithm to calculate the best partial path based on cost so far and heuristic estimates of future costs. The extra decision maker takes into account the context of the situation by using rules. This includes emergency priority, ETA of the route, distance of the route, how up-to-date the traffic information is and if there are any closures. This is a rule based AI decision maker with heuristic search. This does not mean a trained machine learning model has been used. Supabase has been used as a database to store information with controlled access.

## III. PROPOSED ALGORITHM

A. Design Considerations:

- Emergency Requests can be submitted via the patient module.
- Current Patient location can be obtained if location permission can be provided.
- Emergency requests can be accessed by drivers via the driver module.
- GPS data can be provided showing route, estimated time of arrival, and distance.
- Hospital search, notifications and voice assistant can be used.
- Administrator module can monitor and manage emergency requests.
- ESP32 hardware prototype can be used independently from deployed web application.
- LED signals can be used for traffic light display, buzzer, and a physical SOS button. This shows an emergency signal.

An improved version of the route optimiser can make requests to the pre-configured route provider for potential routes. The A corridor graph can be used for minimal fallback if no route is provided. the agent will take each potential route,

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validate them and apply any known closures and feasibility checks. The routes which are deemed to be feasible will have their score calculated based on context aware weights. This will return why the decision was made.

The emergency, status and route decisions will be stored in Supabase in the backend based on pre-configured options. Access policies will be applied based on authenticated roles. Functionality should be tested on the routing decisions, accessing the database and existing modules. However, there is no evidence of large scale validation.

B. Proposed Algorithm:

The purpose of the algorithm was to organise emergency requests and provide route assistance. The algorithm processes emergency requests, provides route assistance, context aware routing decisions, emergency status, and storing of relevant data. An independent hardware algorithm provides priority to traffic lights using an ESP32 controller.

Step 1: Emergency request processing

An emergency request will be submitted by the patient. If Location permission is provided the system will obtain the current location of the patient. The emergency request will be logged and processed by the driver module. Once the request has been reviewed and accepted by a driver, the request will follow the existing status logic.

Step 2: Route Assistance/Hospital Search

Once the Request has been accepted by a driver, route assistance can be provided. The location data will be used to display the route on the map with an estimated time of arrival and distance. Hospital search can also be used .Route decisions will be made by the route optimiser and context aware agent. The route optimiser will validate the start and end points, It will then make requests to the pre-configured route providers for potential drive routes(such as Google Routes and OSRM). Potential route data can include estimated time, distance, geometry and navigation. If the external providers do not provide a usable route, the optimiser will run A path finding algorithms with the pre-defined corridor graph if the start and end points fall within the corridor graphs geographic coverage, If no usable route can be found the system will return not available.

Step 3: Context Aware AI routing Decisions

The decision agent will process each potential route, considering estimated time, distance, emergency priority, traffic and how fresh it is. Known road closures will also be considered where possible. Any route with an invalid estimated time or distance will be removed. Any routes which are known to have closures metadata csn be matched. The remaining routes will be scored based on a configurable multiple cost. The lowest cost feasible route will be the original geometry and navigation from the original provider to show the actual route in the driver portal.

This can be represented with a formula:

Score(r)= (w _t T_norm(r)) + (w _d D _norm(r)) + (w _c C(r)).

Where T_norm(r) represents the normalised estimated travel time,

D_norm(r) represents normalised distance, and C(r) represents the traffic risk from the available data.

The weights depend on how high the priority of the emergency is, for critical emergencies, the estimated time could be weighted higher to priorities it, However, all routes must be feasible and safe, This represents a relative scoring and will not always guarantee the safest or best global route.

Care must be taken when considering the traffic data. Google routes will provide traffic aware estimates if set up correctly. OSRM will provide route geometry and time but cannot guarantee live traffic data. The delay will be calculated from average speed meaning it is just a proxy for live data. Matching around closures by road name is a basic precaution and may not work if road names are ambiguous or share a geometry. A stronger implementation should match verified closure segments or closure geometry.

Step 4. Emergency Status/ route Replanning

As the algorithm progresses, the status of the emergency request will be updated. The patient and admin modules will allow users to view availability request data. Accepted requests will be processed by drivers via the driver module. Notifications and voice assistant will be used. If significant changes occur in the GPS data or new traffic/closures data in received, the backend can request new potential routes, Route replanning should not cause too much change in routes and should keep the dispatcher in control. This will continue until the request is complete or closed.

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Step 5. Supabase Data Storage
Supabase has been configured to store the data for the application. This includes emergency requests, status change, and relevant route decision data based on the Projects schema. The backend should perform privileged actions on the database using credentials based on the environment.

Never expose the service role key in browser code. Row level policies should be added to limit access based on the authenticated user. This can include patient, driver and admin permissions. Route decision data may include the request id, route source, estimated time of arrival, distance, decision time, and short reason for decision Supabase is used as a storage for the applications data. It will not provide routes, live traffic or AI reasoning.

C. ESP32 Traffic Light priority Algorithm
The hardware prototype will show the emergency priority signal.
1. Initialise ESP32 controller, LED traffic lights, buzzer and physical SOS button.
2. Run traffic light sequence based on pre-configured settings.
3. Monitor physical SOS button.
4. If button is pressed run pre-configured emergency priority for selected direction.
5. Show the relevant signal using the LED and buzzer.
6. Continue monitoring button and run traffic light sequence based on pre-programmed behaviours.

The hardware prototype will demonstrate the idea behind priority for emergency traffic lights. This is independent from the deployed web application and does not directly control real traffic infrastructure.

## IV. PSEUDO CODE

Algorithm 1: Request Handling and AI optimized Routing
Step 1: Initialize application, backend, routing and database.
Step 2: receive emergency request from patient module.
Step 3: Get current patient location.
Step 4: Log emergency request into system and store authorized request Supabase.
Step 5: Send request to driver module.
Step 6: Driver can review and accept the request.
Step 7: Update emergency request status.
Step 8: Check origin and destination and request routing options from external routing services.
Step 9: Normalize the estimated time and distance and calculate cost of routes based on priority. Only use traffic information if it is available
Step 10: Select the cheapest valid option. Store route geometry, navigation, source and reason.
Step 11: Display routing information, ETA and distance in the driver dashboard.
Step 12: Store relevant information regarding routing decisions and status using backend and Supabse.
Step 13: If there has been a meaningful change in location or new routing/traffic information then re-plan the route.
Step 13: Provide hospital search, notifications and voice assistant functionality using the relevant modules.
Step 14: Administrator can view and manage the emergency process.
Step 15: If there are no valid routes then display “Not Available”. Request new options or for dispatchers to review.
Step 16: Finish

Algorithm 2: ESP32 Priority Signal
Step 1: Initialize ESP32, LED signals, buzzer and SOS button.
Step 2: Run the set traffic light sequence.
Step 3: Check if SOS button has been pressed then run the set emergency priority sequence.
Step 4: Display the priority status for the selected direction.
Step 5: Turn on buzzer based on the programmed controls.
Step 6: Continue running the set sequence based on the prototype logic.
Step 7: Repeat while the prototype is running.
Step 8: Finish the prototype has been turned off.

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## V. SIMULATION RESULTS

The Arogya Vahini system has been deployed and simulated on a small scale. The simulation focuses on verifying how well the software functions of the system work and the traffic signal prototype on the ESP32. The software includes functionality allowing users to make emergency requests, accept driver requests, track emergency status, and visualise their route using GPS. It also Provide ETA and distance information, searching for hospitals, notifications and voice assistance. The Gemini API is included so that the system has AI assisted interaction at a basic level. The optimised route functionality needs to be tested by verifying the route suggestions and the context aware decision making. This could involve multiple valid routes, one route matching a known closure, invalid ETA/distance, out of date traffic context, failed external provider, fallback coverage, and no valid routes. It should also be verified that the route chosen has the correct geometry and a Navigation Instructions in the driver portal and that the reason for choosing the route matches the actual context provided.

The hardware prototype includes the prioritisation of emergency signals through an ESP32 controller. There are LED traffic signals, a buzzer, and an SOS button. This allows for the demonstrate the prioritisation of emergency signals. Supa Base should be verified to ensure that the emergency and route decisions are being stored correctly. It should also be verified that row level security is being applied. The testing has shown that the functionality works as expected within the demonstration. However there is no quantitative data showing how well the system is performing, no large scale testing has been performed. no reduction in ambulance response times or ETA errors can be claimed. If ground truth data for journey times can be obtained then a controlled evaluation can be performed in the future go show hoe successful the route decision is (success rate). How many closures were avoided, how long it takes to make a request, and the mean absolute error in ETA. The current implementation should be seen as a working prototype within an academic setting. In the future the context aware decision agent could be compared to a baseline. This could be the first route returned by the provider or the shortest distance. The fallback should also be reported on as it has limited geographical coverage due to the predefined corridor graph being used.

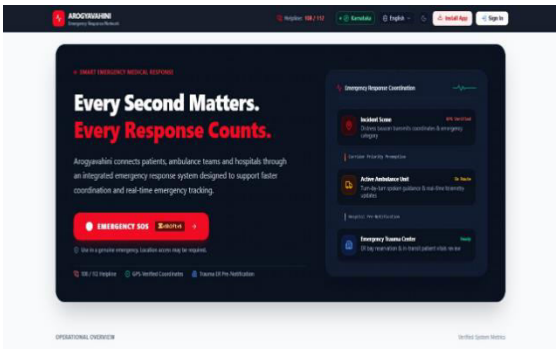



Fig. 1. Home Page of the Proposed Aarogya Vahini System

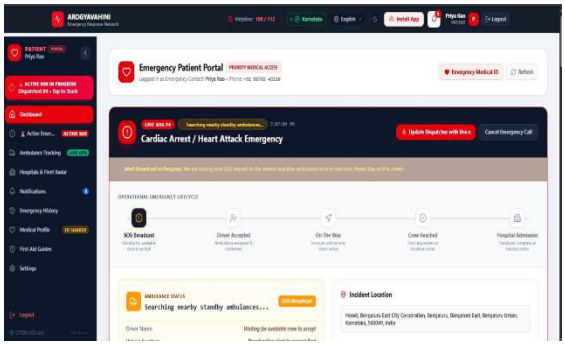



Fig. 2. Patient Emergency Request and SOS Interface

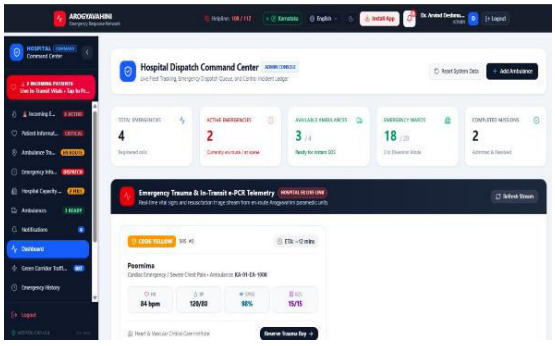



Fig. 3. Hospital Dispatch Centre Interface Confirmation Interface

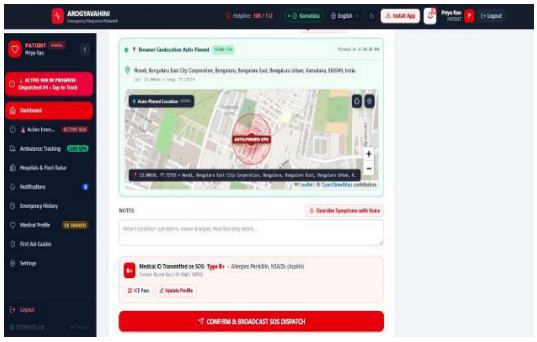


Fig. 4. GPS-Based Patient Location and SOS Dispatch

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Fig. 5. Physical Hardware Setup of the ESP32-Based Emergency

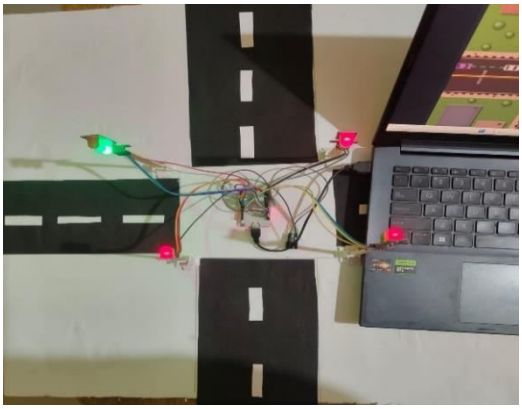


Fig. 6. Green Corridor Simulation for Emergency Vehicle Priority Traffic Signal Priority System

## VI. CONCLUSION AND FUTURE WORK

Aarogya Vahini is a software solution that can be used to manage ambulance requests, view the route, and coordinate with hospitals. There is also a prototype which uses hardware. Software includes a web app allowing patients to make emergency requests. Drivers can then manage the request. The software also includes viewing the route using GPS, time and distance estimates, alerts, a voice aid, and searching for hospitals. An optimised route is found using external route APIs such as Google Routes and OSRM. The routes are weighted based on time, distance and traffic factors. If there is no access to external route APIs we have implemented the A search algorithm using a defined city road corridor graph. We have also implemented enhancements to the route finding method based on context. This means the emergency, traffic information availability and known road closures are taken into consideration. Supabase was used as our database. The hardware component includes an ESP32 based traffic light prototype using LED lights, a buzzer and a physical SOS button. The software application and hardware were used to test the system on a smaller scale. However, the hardware is not connected to the web application. There is no evidence of large scale testing or evidence to show ambulance response times have been reduced. Future work includes implementing real time verified traffic information, better ambulance allocation, secure sharing of hospital information, connecting the software and hardware, and analysing the routes based on defined metrics of performance.

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