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Risk-Aware Smart Navigation System for Shortest and Safest Path Detection

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Abstract- The system uses a curated dataset of 70 documented accident locations from Visakhapatnam and the NH16 corridor. Current weather information is obtained from OpenWeatherMap and used in the risk calculation. Traffic information is obtained through the TomTom platform and shown as part of the current route information. The application also includes a TomTom interactive map, browser-based location detection, emergency facility search, voice narration, and a risk-score display.

The prototype was tested for route generation, distance calculation, accident handling, weather penalties, risk scoring, data loading, and disconnected routes. The results show that safety-related information can be included in a lightweight browser-based navigation application without a separate backend server. The system is intended as a regional decision-support prototype and does not claim to guarantee real-world road safety.

Functional testing covers route generation, distance calculation, accident handling, weather penalties, risk scoring, data loading, and disconnected-path conditions. The resulting prototype demonstrates how safety-related information can be incorporated into a lightweight browser-based navigation workflow without requiring a dedicated

backend. The system is intended as a regional decision-support prototype rather than a guarantee of real-world road safety.

Keywords- Risk-aware navigation, A* algorithm, safest path, shortest path, accident analysis, traffic analysis, weather-aware routing, TomTom Maps, OpenWeatherMap, GIS, smart transportation.

INTRODUCTION

Navigation applications are now widely used for daily travel. Most route planners give priority to shortest distance, estimated travel time, or a combination of the two. These measures are useful for improving travel efficiency, but they do not always show the safety conditions of the roads on the selected route. For example, a route may be shorter while passing through an accident-prone area or through a location affected by unfavorable weather or traffic conditions.

The Risk-Aware Smart Navigation System (RASNS) is designed to address this issue by treating route efficiency and route safety as separate objectives. The application provides a normal shortest route as well as a risk-aware route, allowing the user to compare the two and choose according to the situation. The safety-oriented route is calculated on a custom road graph using the A* search algorithm. Accident information and weather conditions are used to change the cost of the route.

The main contribution of this work is the practical integration of risk information into a regional navigation application rather than the development of a new shortest-path algorithm. The system uses 44 graph locations in the Visakhapatnam region and a curated dataset containing 70 documented accident locations across Visakhapatnam and the NH16 corridor. The safest route produced by the system should be understood as the route with the lowest calculated cost for the factors included in the model, and not as a guarantee that the route is objectively the safest in real-world conditions.

1. PROBLEM STATEMENT AND OBJECTIVES

Existing navigation applications can provide useful directions, but safety-related information is often left for the driver to consider separately. Historical accident information may be available, but it is not always included when a route is selected. Weather information may also be displayed without directly changing the route. The project therefore focuses on combining navigation and safety information in one web application and also providing basic emergency assistance.

The main objectives are: (1) to develop a browser-based navigation application for the Visakhapatnam region and NH16 corridor; (2) to implement A* on a custom 44-node road graph with risk-based cost adjustments; (3) to provide shortest-path and safest-path options; (4) to obtain and display current weather information; (5) to use accident-zone information during route selection; and (6) to provide emergency facility search and voice-assisted navigation.

These objectives follow the project implementation, which combines TomTom services, A* pathfinding, live weather information, accident data, and risk-aware route calculation.

2. RELATED WORK AND RESEARCH GAP

Previous research on risk-aware route planning has considered areas such as accident-aware routing, constrained path planning, accident hotspot analysis, and learning-based path search. The literature reviewed for this project includes studies using accident information and approaches that modify A* to consider safety-related factors. Some learning-based approaches also use estimated risk information to improve path selection and search efficiency.

The focus of RASNS is more practical and application-oriented. It provides a lightweight browser application for a defined regional road network and combines historical accident information with current weather and traffic context. Instead of using a machine-learning prediction model, the prototype uses explicit penalty values. This makes it easier to see how each risk factor changes the route cost and to explain the route selection process.

Approach	Primary emphasis	Risk information	Practical characteristic
Conventional shortest routing	Distance/time	Usually implicit or external	Fast and familiar
Accident-aware routing	Accident locations	Historical accident evidence	Safety-focused
Learning-assisted risk planning	Constrained/risk-aware search	Learned or modeled risk	Higher algorithmic complexity
RASNS	Shortest + modeled safest route	Accidents + weather + traffic context	Browser-based regional prototype

3. PROPOSED SYSTEM

RASNS uses a client-side architecture in which the user interface, application logic, project data, external services, and browser APIs work together. The main application files contain the interface and routing logic, while the accident dataset and road graph provide the internal data. External services are used for maps, routing, traffic, weather, and place search. Browser features provide location information, voice output, and periodic data updates.

Layer	Main components	Purpose
Presentatio	index.html, navigation.html, style.css	User interface and route visualization
Applicatior logic	JavaScript, A*, risk functions, API orchestration	Routing, scoring event handling
Data	andhra_accidents .json, road graph, coordinates	Regional accident an graph data
External API	TomTom, OpenWeatherMa	Maps, routes traffic, search weather
Browser API	Geolocation, SpeechSynthesis, timers	GPS, voic guidance, refresh

For the prototype, TomTom services are used for map display, routing, traffic flow, and place search. OpenWeatherMap provides current weather condition, temperature, humidity, wind speed, and pressure. The project also considers the usage limits of the selected external services.

4. DATA AND RISK MODEL

4.1 Accident Dataset

The accident data used in the system is historical and curated rather than a live accident feed. It is used to identify locations that have documented accident information and assign additional risk to the corresponding graph nodes. Therefore, the system can highlight known risk locations, but it cannot represent every accident or road hazard occurring at the current time.

4.2 Weather Model

Condition	Documented penalty	Interpretation
Rain	+15	Higher route cos under rain
Drizzle	+10	Moderate weather related cost
Mist	+12	Visibility-related caution
Clouds	+5	Lower weather related cost
Other / clear	0	No weather penalt in the documente model

4.3 Traffic Context

Traffic information is obtained from the TomTom traffic flow service using current-speed and free-flow-speed values. The prototype groups traffic conditions into levels such as Low, Moderate, and Heavy. The traffic condition is shown to the user and is also included in the risk-aware route cost. Since the information comes from an external service, its availability and accuracy depend on that service.

4.4 Composite Risk Indicator

The interface includes a combined risk indicator to give the user a simple view of the current route conditions. In the implemented model, accident presence, traffic severity, and weather severity contribute to the displayed risk score. The score is intended to act as an understandable warning indicator. It should not be treated as a statistically calibrated probability of a collision.

5. ROUTE OPTIMIZATION

5.1 Shortest Path

The shortest-path option uses the external routing service to obtain route geometry and travel-time information. It acts as the baseline route for comparison with the risk-aware path. This option mainly focuses on travel efficiency and does not apply the explicit safety penalties used by the risk-aware route.

5.2 Risk-Aware A* Search

The safest-path option uses the custom bidirectional road graph. Each graph node represents a regional location, and each connection has a base cost related to distance.

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A* uses the accumulated route cost together with a geographic heuristic. In the risk-aware version, additional costs are added when accident, weather, or traffic conditions increase the modeled risk.

A simplified representation of the implemented cost concept is:

Cost(edge) = BaseDistanceCost + AccidentPenalty + WeatherPenalty + TrafficPenalty

The A* evaluation function can then be expressed as:

The A* evaluation function is written as $f(n) = g(n) + h(n)$, where $g(n)$ represents the accumulated risk-aware cost and $h(n)$ is the distance-based heuristic. Geographic distance is calculated using the Haversine formula. Accident locations receive a strong additional penalty, while weather and traffic conditions add further cost when applicable.

Because the route cost includes risk information, the safest route does not always have to be the shortest route by distance. For example, an alternative route with a slightly greater distance can become preferable if it avoids a graph node with a high accident penalty or a route affected by unfavorable conditions.

6. SYSTEM IMPLEMENTATION

The navigation interface is divided into a control panel and a map area. The control panel allows the user to select the starting point and destination and provides Emergency Mode, Shortest Path, Safest Path, reset, route details, and voice functions. The map area displays routes, accident markers, traffic information, emergency facilities, and other route-related details.

The map is centered on the Visakhapatnam region and provides street-level zoom, perspective view, navigation controls, full-screen support, and browser geolocation. A 3D building layer and atmospheric map effects are also included to make the map easier to interpret.

Emergency Mode uses the browser's geolocation feature to identify the user's current position and searches for nearby hospitals and police facilities through the TomTom search service. The project uses a search radius of 10 km and provides a route action with speech synthesis so that the user can receive voice-assisted guidance.

7. FUNCTIONAL EVALUATION

Testing was carried out at the functional level using unit, integration, and end-to-end checks. The documented tests cover the A* route generator, accident penalties, disconnected routes, rain penalties, Haversine distance calculation, weather penalties, accident-data loading, and the combined risk score. These tests were used to check whether the main routing and risk functions behaved as expected.

Tes are:	Expected behavior	Evaluation purpose
A* rout generation	Valid path returne for connected nodes	Verify searc implementati on
Accident penalty	Accident-marked route receives highe cost	Verify safet influence
Weather penalty	Weather conditio changes modele cost	Verify environmenta l influence
Haversine distance	Geographic distance is calculated consistently	Verify heuristic/base distance
Accident loading	JSON records are loaded and mapped	Verify risl data availability
Composite risk	Risk level reflect configured signals	Verify UI risl indicator
Disconnect ed graph	No invalid path i produced	Verify failur handling

The project documentation does not contain a statistically controlled benchmark dataset with repeated measurements of route time, accuracy, or safety outcomes. For this reason, the evaluation in this manuscript is reported as functional testing rather than as a numerical percentage improvement in safety or routing performance. This avoids making quantitative claims that cannot be supported by the available project data.

8. DISCUSSION

One of the main strengths of RASNS is that it keeps the two route objectives separate. The user can see the shortest route and the risk-aware route and compare the trade-off between travel efficiency and the modeled safety factors. This is more transparent than presenting only one route without showing how safety information affects the choice.

The use of explicit penalties also makes the route calculation easier to understand. When a route passes through an accident-prone location or is affected by unfavorable weather or traffic, its calculated cost can increase and another route may become preferable.

Another useful feature is the combination of historical and current information. The accident dataset provides regional historical information, while weather and traffic are obtained from external services. This gives the navigation interface more context than distance-only routing. The application is also lightweight because the main pathfinding logic runs on the client side without requiring a separate backend. The design can be extended by adding more accident records, road nodes, or other risk factors.

9. LIMITATIONS

There are several limitations to the current prototype. First, the accident dataset is curated and historical, so it is not a continuously updated incident feed. Second, the custom road graph contains a limited set of 44 regional locations and does not cover every road in Visakhapatnam. Third, weather and traffic information depend on external APIs, so service availability and usage limits can affect the application.

The penalty values are also rule-based design choices. They were not learned or calibrated using a large dataset of collision outcomes. Similarly, the displayed risk score is an interpretable index and should not be considered an actual probability of an accident. The safest route is therefore safest only with respect to the factors and weights included in the implemented model. Continuous updates to the accident data and better real-world validation would be needed for a larger deployment.

10. FUTURE ENHANCEMENTS

There are several possible directions for future development. A larger and regularly updated accident dataset could improve the coverage of the system. Historical traffic patterns could also be added so that the system is not limited to the current traffic condition. A more advanced risk model could learn suitable penalty weights from accident records together with weather, traffic, road, and time-related information. Live incident feeds could also support faster rerouting when a new accident or road blockage is reported.

The current road graph could be expanded or replaced with a larger automatically generated road network so that the approach can be used beyond the present regional prototype. Other factors, such as road lighting, road surface, visibility, intersection density, and time of day, could also be considered when reliable data is available. Future benchmarking against conventional navigation systems would help measure route-length differences, processing cost, and changes in modeled risk under controlled test cases.

11. CONCLUSION

This paper presented a Risk-Aware Smart Navigation System for shortest and safest path detection. The prototype combines a regional road graph, A* search, documented accident locations, live weather information, traffic context, interactive mapping, and emergency support within a browser-based application. The central idea is to treat route safety as an explicit optimization objective rather than an external consideration.

This paper presented the Risk-Aware Smart Navigation System for shortest and safest path detection. The prototype brings together a regional road graph, A* search, documented accident locations, current weather information, traffic context, interactive mapping, and emergency support in a browser-based application. The main idea is to include route safety as an explicit part of route selection instead of leaving it entirely to the driver.

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