

Risk Mapping of Explosion Zones in Oil and Gas Refineries: A Safety Perspective

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Abstract— Emergency withdrawal plans are important in reality mapping of industrial threat areas and reducing the effects of disasters in high -risk areas. The project focuses on oil and gas refinery facilities across India, which suffers from incidents such as chemical leaks, fire and explosion. The proposed web application, ignition watch, integrates geophagical devices such as Leaflet.JS to imagine the risk areas through an interactive map. Live meteorological data - including air speed and UV radiation - is obtained through public API to assess environmental conditions affecting the spread of danger. The system calculates three concentrated danger areas (high, medium, low risk) with dynamic ready, which provides real -time estimates of potential danger areas. The smallest path for clearance is determined using the Dijkstra's algorithm, which guides the populated population in the nearest predetermined safe areas. The system identifies and displays the nearest fire station or emergency response unit for each refinery. A search feature allows users to detect specific refineries and look at live danger updates and customized escape routes. Unlike traditional systems relying on static predictions, this device optimized for real-time environmental changes, providing accurate, location-specific statusable awareness. It aims to support public to improve preparations for emergency planners, first respondents and public, reduce response time and reduce the loss of life and infrastructure.

Keywords- Disaster Management, Threat Zone Mapping, Dijkstra's Algorithm, Leaflet.JS, Oil and Gas Refineries, Real-Time GIS, Public Safety.

Introduction

India boasts an extensive system of oil refineries and gas processing plants, which serve as the foundation of its energy industry. These industrial facilities play a vital role in meeting the country's increasing energy needs and driving economic growth in various sectors. As India continues to urbanize and industrialize, the size and intricacy of these facilities are growing, making them crucial components of national infrastructure and strategic planning.

Although these refineries and gas terminals are crucial for the economy, they also pose significant safety and environmental risks. Industrial mishaps like toxic gas leaks, fires, and explosions are not uncommon and can have devastating consequences. These occurrences frequently lead to substantial loss of life, severe damage to essential infrastructure, and lasting harm to the environment. In numerous instances, the dangers are heightened due to the close proximity of residential areas to industrial zones, posing a direct threat to a significant number of people during emergency situations.

Environmental factors introduce an additional level of complexity to the management of industrial hazards. Elements like wind speed, wind direction, and atmospheric radiation are crucial in determining how hazardous gases disperse and how fires spread. These circumstances can fluctuate rapidly and unexpectedly, making immediate analysis crucial. Unfortunately, most current emergency preparedness systems are based on outdated risk models and rely on paper-based evacuation plans, which are not suitable for responding to rapidly changing threats in densely populated areas.

Given these difficulties, there is an immediate requirement for intelligent systems that can constantly monitor environmental data, evaluate threat levels in real-time, and facilitate prompt decision-making. Geospatial technologies and real-time data integration provide powerful tools for enhancing situational awareness, improving emergency response coordination, and reducing the impact of disasters. By combining geographic information systems (GIS), environmental sensing, and routing algorithms, a new generation of decision-support platforms can be developed to enhance industrial safety.

This paper presents ignition watch, a real-time web application that tracks potential danger areas and aids in the development of emergency evacuation plans for oil and gas facilities in India. The system combines real-time environmental data from public APIs, including wind speed and uv radiation, with open-source geospatial libraries like Leaflet.Js to create visual representations of hazard zones around industrial facilities. The application dynamically calculates and presents three concentric risk zones (high, medium, and low) based on the environmental conditions, providing a realistic evaluation of the spatial extent of threats.

In addition to threat visualization, the platform employs dijkstra's algorithm to simulate and display the most efficient evacuation routes from affected zones to designated safe areas. It also specifies the closest emergency response units, such as fire stations, enabling quicker coordination during emergencies. Users can easily find specific refinery locations, monitor real-time threat levels, and receive personalized route suggestions through a user-friendly and efficient interface. By integrating real-time environmental data, geospatial analysis, and intelligent route planning into a single application, ignition watch aspires to revolutionize industrial emergency management by enhancing preparedness, expediting response, and ultimately safeguarding lives and infrastructure.

Problem Statement

Industrial accidents at oil refineries and gas processing plants in India pose serious risks to human life, infrastructure, and the environment. Current safety systems rely on static data and lack the ability to adapt to real-time environmental changes such as wind speed and radiation. As a result, threat zones are not accurately defined, and evacuation plans are often unoptimized and inaccessible during emergencies. There is a critical need for a real-time, dynamic system that can assess hazards, visualize risks, and support safe and efficient evacuation.

Objectives

This project aims to develop a real-time web-based application to improve emergency response around industrial hazard zones. The key objectives are:

- To map dynamic threat zones around oil and gas facilities using real-time environmental data.
- To visualize high, medium, and low-risk areas using geospatial tools.
- To implement Dijkstra's algorithm for computing shortest evacuation routes.
- To identify and display the nearest emergency response centers.
- To provide an intuitive user interface for real-time threat monitoring and decision-making.

Related work

The oil and gas industry is prone to severe accidents like gas leaks, fires, and explosions. These events require quick and effective response strategies that depend on real-time data and spatial awareness. Traditional approaches relying on static risk models and paper-based evacuation plans are gradually being replaced by intelligent systems that combine environmental data, geospatial analysis, and algorithmic planning.

The utilization of geographic information systems (GIS) has greatly improved the process of mapping industrial hazards. Research has demonstrated that the use of geographic information systems (GIS) is crucial in depicting risk areas and facilitating effective emergency response strategies, particularly in highly populated industrial regions [1]. These systems facilitate the identification of regions at risk, thereby aiding in the prompt evacuation of vulnerable areas.

Factors like wind speed, wind direction, and radiation levels are crucial in determining how hazardous materials disperse and their level of intensity during industrial accidents. By incorporating real-time weather information into the process of determining hazard zones, the accuracy of risk modeling is enhanced. Studies have demonstrated that employing weather APIs to simulate the spread of harmful gases leads to more accurate and flexible risk zones compared to conventional static models [2].

Through blast simulation studies, researchers have gained valuable insights into the impact of explosions in refinery areas. By using simulated blast impacts, concentric risk zones can be created to categorize disaster severity into high, medium, and low zones, providing a scalable and standardized approach. These models are similar to the threat zone architecture used in systems like the proposed ignition watch [3].

Leaflet.js, a popular open-source mapping library, has been widely used in lightweight, browser-based platforms to provide interactive geospatial analysis. Studies have shown that these tools provide quick and easy-to-use interfaces for real-time disaster visualization, making them ideal for emergency response situations where speed and accessibility are crucial.

Simultaneously, the incorporation of graph theory into evacuation route optimization has significantly improved public safety outcomes during emergencies. Algorithms such as Dijkstra's shortest path algorithm have been effectively utilized in evacuation simulations to determine the most efficient escape routes, taking into account time-sensitive limitations [5]. Their reliable and speedy computation makes them perfect for real-time web applications.

Recent advancements in gas leak detection through the use of IoT have shown potential in providing early warnings. These systems employ sensor networks to identify gas concentrations and initiate alerts for evacuation and mitigation measures. Although the existing system relies on simulated UV data, these IoT frameworks provide a solid foundation for future enhancements that incorporate real-time sensor input.

Researchers have examined the use of artificial intelligence and machine learning models to predict potential hazards in petrochemical environments. These models utilize historical and environmental data to anticipate potential dangers, enabling proactive safety measures. Although not yet incorporated into ignition watch, predictive modeling has immense potential for enhancing proactive hazard response [7].

Additionally, the integration of proximity detection for emergency resources like fire stations has become a crucial component of contemporary disaster management systems. By utilizing GIS-based algorithms, emergency service centers can efficiently dispatch response teams from the closest available locations, resulting in faster response times and better allocation of resources during critical situations.

In summary, the reviewed literature supports a comprehensive approach that integrates geographic information systems, real-time data acquisition, graph-based algorithms, and intelligent visualization. These foundations serve as the basis for the design of ignition watches, offering a strong structure for risk zone mapping and evacuation planning in the realm of oil and gas refinery safety.

Methodology

The creation of the ignition watch platform followed a systematic and modular approach to guarantee clarity, scalability, and seamless integration of functionality at each stage. The system design was meticulously divided into separate but interconnected modules, with each module handling a specific and vital component of the entire application. This flexible approach to development enabled concurrent progress, streamlined debugging, and facilitated thorough testing of each component. Consequently, the implementation process became more streamlined, traceable, and flexible, allowing for future improvements. By repeatedly coding,

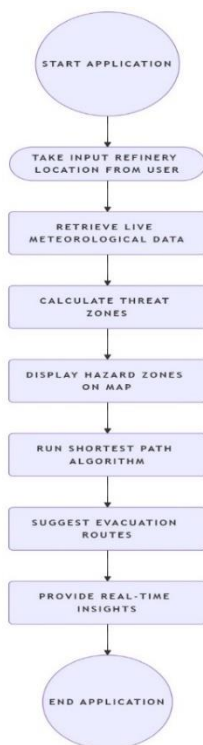


Fig.1. Workflow Diagram

testing, and validating the core modules, the development team successfully finished and confirmed the essential components necessary for the system to function. The subsequent sections provide an overview of each completed module and explain their specific functionalities in detail.

Location-based search module.

This module offers an interface for users to search for a particular oil refinery or gas terminal. Validation of client-side input to guarantee non-empty values. After gaining access, the system leverages the browser's localstorage API to save the input and redirect the user to the result page for additional processing.

Threat zone calculation module

This module is in charge of assessing the level of risk around a chosen industrial location. It connects with the openweathermap API to obtain real-time wind speed information. Furthermore, the simulated uv index values are designed to replicate different environmental conditions. Taking into account the given inputs, the system dynamically calculates the radii for high, medium, and low-risk zones, employing a predefined formula. The output is utilized for live spatial threat depiction.

Map visualization module.

The leaflet.js library is utilized to create an interactive geographic display. The map focuses on the designated hazardous area and overlays three concentric circles, each representing a different level of threat. Markers are placed to mark the position of refineries and nearby emergency response facilities, including fire stations. The module enables users to zoom in and out and pan around for a more comprehensive understanding of the situation.

Route evacuation module.

This module utilizes dijkstra's algorithm in JavaScript to determine the most efficient evacuation route from the hazardous site to

the closest designated safe zone. Graph nodes symbolize different places, and weighted edges signify the distances between them. The calculated route is depicted as a blue line on the map, showcasing waypoints and the flow of directions.

Module for Presenting Our Outcome

Following the completion of calculations, the system provides the user with crucial information about the environment and potential risks. This encompasses real-time wind speed, simulated ultraviolet index, and calculated threat zone radii. The data is presented in real-time by updating the document object model (dom) using JavaScript, allowing for responsiveness and interactivity without the need for a page reload.

User interface and design module.

The user interface (ui/ux) is built using HTML and CSS to guarantee a tidy, adaptable layout that functions uniformly across various screen sizes and devices. The module consists of visually appealing buttons, input fields, and containers that can dynamically display content. It prioritizes usability and accessibility to cater to the needs of both emergency responders and regular users.

To guarantee the reliability and correctness of the ignition watch platform, a series of functional tests were performed on its core modules. These were the tasks that needed to be completed, such as validating user input, ensuring accurate threat zone calculations, rendering map elements correctly, generating evacuation paths using dijkstra's algorithm, integrating API data successfully, and ensuring a responsive user interface. A concise overview of these tests is presented in table I.

Table I. Testing and Validation

Test Type	Description
Input Testing	Validated user inputs for refinery/gas terminal names and handled empty inputs.
Threat Zone Accuracy	Verified correctness of zone radius calculations based on wind speed and UV index.
Map Rendering	Checked placement and visibility of markers, circles, and routes on the map.
Evacuation Route Logic	Ensured Dijkstra's algorithm correctly generated the shortest path to safe zones.
API Integration Test	Confirmed successful API data retrieval and handled failure cases gracefully.
UI Testing	Validated layout responsiveness, button actions, and overall usability.

Result and Discussion

The system executes real-time threat zone simulation by continuously calculating hazard areas based on live wind speed data and simulated uv index, visually depicted as colored concentric circles. Utilizing dijkstra's algorithm, it accurately computes and renders the shortest evacuation paths with clear waypoints on an interactive leaflet.js map, which facilitates smooth cross-device visualization of hazard zones, refineries, and fire stations. The openweathermap api seamlessly integrates real-time wind speed data, with robust fallback mechanisms in place to guarantee stable system performance. Furthermore, the user interface is adaptable, ensuring accurate input validation, and dynamically updating results to offer a seamless and user-centric experience.

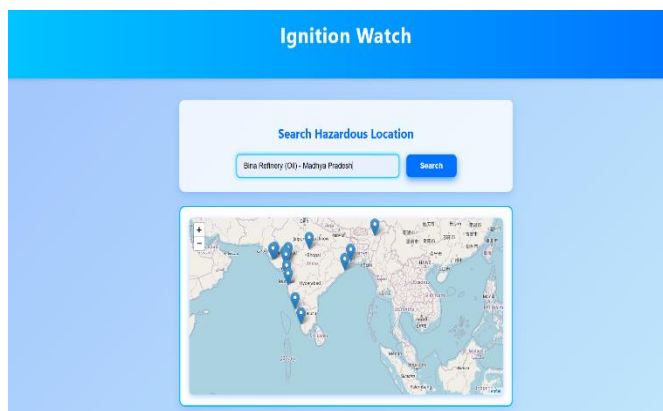


Fig.2. Front Page



Fig.3. User inputs for refinery

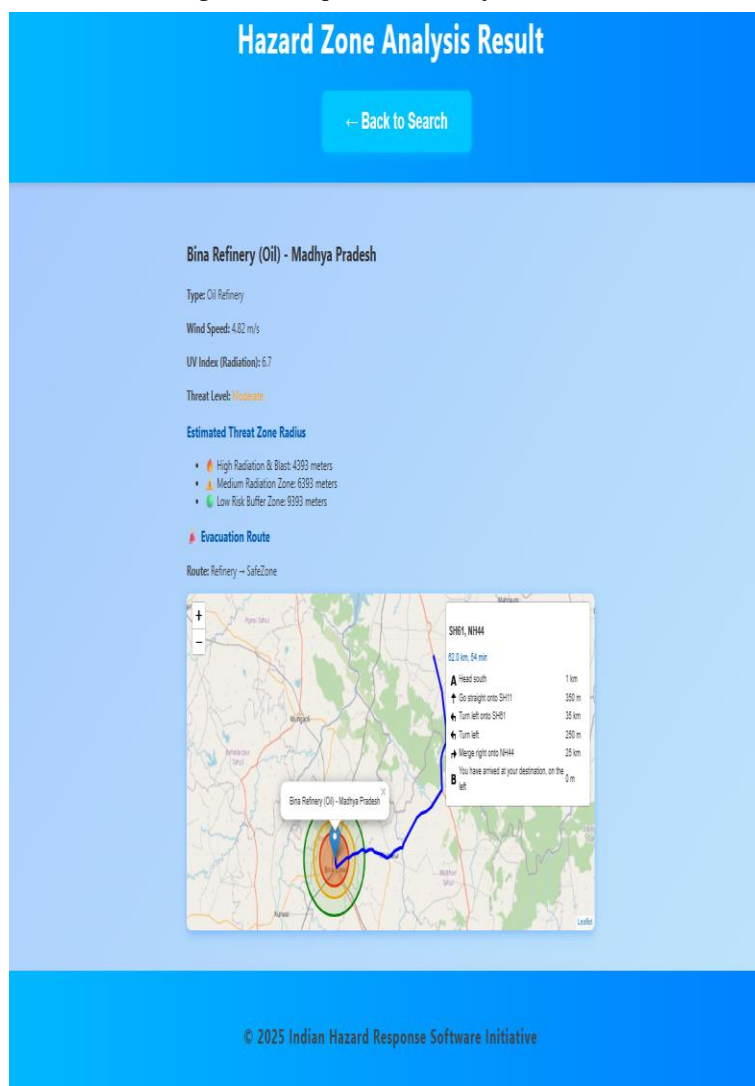


Fig.3. Complete Result

Conclusion

This project offers a live, online solution for analyzing potential hazards and planning evacuations specifically for oil and gas refineries in India. By integrating live environmental data with geospatial visualization and graph-based routing algorithms, the system significantly enhances situational awareness, emergency preparedness, and response capabilities during industrial disasters. The interactive platform enables stakeholders including emergency planners and the general public to assess hazard severity, visualize threat extents, and execute safe evacuations through optimized routes. The flexible and modular design of the architecture guarantees scalability and adaptability across various regions and hazard scenarios.

Although the current implementation shows promise in detecting threats and planning evacuations, there are still areas that can be improved upon. Future endeavors will concentrate on integrating real-time satellite imagery for more accurate hazard assessment, establishing mobile alert systems for immediate public communication, and incorporating live traffic data to enhance route optimization. By broadening the scope to encompass

other industrial hazards, such as chemical or nuclear facilities, and incorporating multi-language support, the system will become more inclusive and user-friendly. Collaborating with government disaster management authorities and integrating the platform into national emergency response systems are also part of the plan to make it a permanent part of public safety. Additionally, the application of machine learning techniques for predictive hazard modeling and risk forecasting presents a promising direction for proactive disaster mitigation.

To further enhance the system's utility in real-world deployment scenarios, efforts will be directed towards building a robust backend infrastructure capable of storing historical incident data, user interaction logs, and real-time alerts. This would enable the platform to support data-driven decision-making and facilitate the analysis of past disaster events. Incorporating database support and user authentication mechanisms would also enable personalized experiences for different user roles such as industrial operators, emergency coordinators, and public users, each with access to tailored data and response tools.

Furthermore, the platform's compatibility with mobile applications and iot-based sensors placed at industrial sites could generate a continuous flow of detailed environmental data, enabling more accurate and localized risk assessments. Real-time collaboration features, such as alert broadcasting and map sharing among emergency responders, could also be implemented to enhance coordination during critical incidents. These upcoming improvements intend to revolutionize the system, shifting it from a standalone tool to a comprehensive decision-support ecosystem that aids in industrial disaster risk reduction and public safety management.

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