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Terra Trace: A Smart Tourist Safety, Geofenced Alert, and Emergency Assistance Platform

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Abstract - *Tourists visiting unfamiliar destinations frequently encounter safety challenges, including losing direction, entering unsafe or restricted areas, theft, harassment, sudden illness, and medical emergencies. In many situations, visitors do not know local emergency numbers, nearby hospitals, police stations, or trusted assistance points. Conventional travel applications primarily support hotel booking, sightseeing information, and route navigation, but do not provide an integrated mechanism for continuous safety awareness, rapid emergency communication, and secure identity verification. Terra Trace is proposed as a smart tourist safety and emergency assistance system that brings essential safety services together in a single digital platform. The system is designed to support location aware safety notifications, a user initiated emergency distress facility, trusted emergency contact communication, nearby assistance discovery, and secure digital identity management. The proposed platform also provides a verified digital identity profile that helps a tourist share selected identification details during an emergency, subject to strong authentication and explicit consent controls. Nearby assistance discovery connects travellers to hospitals, police stations, pharmacies, and support services using mapping and location interfaces. Built around a modular four layer architecture spanning presentation interfaces, backend application services, relational database storage, and external geolocation and notification providers, the system balances rapid incident response with strict data minimization and user privacy.*

Key Words: Tourist Safety Platform, Geofencing Alerts, Emergency Assistance System, Digital Identity Management, Role-Based Access Control, Location-Based Services.

1. INTRODUCTION

Travel exposes individuals to unfamiliar surroundings, languages, transport systems, and local administrative procedures. While a tourist may feel confident when planning an itinerary, unexpected incidents such as losing direction in an unfamiliar locality, entering an isolated or restricted area, losing a mobile phone or wallet, facing harassment, or experiencing a medical emergency require immediate access to location context and trusted assistance. Terra Trace is a smart tourist safety platform developed at the Hyderabad Institute of Technology and Management (HITAM) to support travellers before and during such incidents by combining location-aware alerts, emergency communication, nearby assistance discovery, and secure digital identity features within a unified workflow.

1.1 Background of the Study

Modern smartphones provide hardware and software capabilities including Global Positioning System (GPS) positioning, cellular and Wi-Fi internet connectivity, interactive maps, push notifications, camera access, and biometric or token-based device authentication. Location services estimate a traveller's real-time coordinates, geofencing algorithms detect entry into configured geographic boundaries, and notification channels dispatch warnings or incident updates. However, continuous location tracking introduces significant privacy risks if coordinates are collected without clear consent, retained longer than necessary, or exposed to unauthorized parties. Consequently, a tourist safety application must balance operational usefulness with transparency, encryption, user consent, and failure resilience.

1.2 Problem Statement and Objectives

Existing travel applications primarily focus on reservations and turn-by-turn navigation without offering an integrated solution for real-time risk-zone monitoring, rapid emergency distress signaling, and consent-based identity verification. Tourists in distress often struggle to identify nearby trusted facilities or manually communicate their coordinates across separate messaging apps. Developed as a Project-Based Learning (PBL) initiative, the primary objectives of Terra Trace are:

- To develop a centralized platform that integrates proactive safety monitoring and emergency response features for tourists.
- To enable location-aware notifications when a user approaches or enters a configured risk or restricted zone where reliable zone data is available.
- To provide an Emergency Distress Signal (SOS) facility that enables users to alert selected emergency contacts and configured assistance channels with a single confirmed action.
- To display nearby support facilities including hospitals, police stations, and pharmacies using mapping and location services.
- To provide a secure digital identity profile with controlled, time-limited sharing of selected identification attributes.
- To maintain auditable incident records and alert statuses for authorized users and administrators while protecting personal data through Role-Based Access Control (RBAC), Multi-Factor Authentication (MFA), and Hypertext Transfer Protocol Secure (HTTPS) encryption.

1.3 Scope of the Project

The project scope encompasses the design and prototype realization of a tourist-facing web and mobile application alongside its supporting backend services. Core functions include account registration, authentication, emergency profile setup, explicit location-permission handling, safety-zone notifications, SOS initiation, trusted contact management, nearby assistance discovery, digital identity access, and an administrator interface for managing verified safety-zone polygons and reviewing system-level incidents. The prototype demonstrates the complete operational workflow using test accounts, sample geofences, and simulated emergency events while clearly distinguishing prototype alerts from official government dispatch systems.

2. LITERATURE REVIEW AND PROBLEM IDENTIFICATION

A review of contemporary literature and existing software categories highlights the functional capabilities and integration gaps in tourist safety technology. Warrier et al. [1] investigated tourist safety and incident response platforms, emphasizing that rapid incident reporting and simplified user interfaces are vital when travellers face unfamiliar emergencies. At the national policy and smart-tourism level, the Ministry of Development of North Eastern Region [2] outlined the architectural need for smart tourist safety monitoring and incident response systems combining Artificial Intelligence (AI), geofencing, and tamper-evident digital identifiers.

In the domain of spatial boundary detection, Sasaki et al. [3] demonstrated data-driven geofencing designs for point-of-interest notifiers, showing how coordinate boundary tolerances prevent alert fatigue caused by GPS jitter. Xiao et al. [4] analyzed the spatiotemporal behavior of adventure tourists using GPS trajectory data to optimize emergency rescue station placement and response times. Similarly, Perusomula et al. [5] implemented geofencing and automated Short Message Service (SMS) alert workflows for boundary-breach detection. Regarding identity management and trust in smart tourism, Kontogianni and Alepis [6] examined distributed ledger and digital trust frameworks for tourist services, while Sporny et al. [7] established the World Wide Web Consortium (W3C) core architecture for Decentralized Identifiers (DIDs) and controlled attribute disclosure.

2.1 Limitations of Existing Approaches and Research Gap

Across existing commercial tools, critical safety functions remain fragmented across four separate application categories: (1) navigation applications provide routes and directions but lack integrated emergency workflows and identity sharing; (2) travel booking applications manage reservations and itineraries without addressing personal safety incidents; (3) mobile operating system emergency calling and location sharing require multiple manual configuration steps and vary across devices and networks; and (4) digital identity tools authenticate users but are disconnected from tourist emergency workflows. Furthermore, network failure, disabled location permissions, low battery, or indoor GPS inaccuracy can degrade standalone safety tools. Table -1 summarizes the comparison between existing approaches and the proposed Terra Trace platform.

Table -1: Comparison of Existing Approaches and Proposed Terra Trace System

Existing Approach	Main Strength	Gap Addressed by Terra Trace
Navigation Applications	Route planning, directions, and travel time estimation.	Integrates safety-oriented geofence alerts and emergency response workflows.
Travel Booking Platforms	Hotel reservations, transport booking, and trip itineraries.	Connects active trip context directly with real-time safety assistance.
Messaging and Location Sharing	Ad-hoc coordinate sharing and contact messaging.	Provides a structured one-tap SOS flow with auditable incident metadata.
Digital Identity Tools	User authentication and identity attribute claims.	Enables consent-based, time-limited identity disclosure during emergencies.

2.2 Proposed Solution and Feasibility Study

Terra Trace addresses the identified integration gap by unifying tourist registration, trusted contact configuration, explicit location-permission management, geofenced risk-zone evaluation, SOS incident creation, nearby hospital and police discovery, and consent-based digital identity sharing within one platform. Feasibility analysis confirms four dimensions: (1) Technical Feasibility, leveraging standard web frameworks, Application Programming Interfaces (APIs), relational Database Management Systems (DBMS), and mapping services; (2) Operational Feasibility, utilizing high-contrast User Interfaces (UI) and User Experiences (UX) with prominent SOS confirmation controls; (3) Economic Feasibility, beginning with open-source and educational development tiers; and (4) Legal and Ethical Feasibility, enforcing informed consent, data minimization, retention controls, and transparent status reporting.

3. SYSTEM METHODOLOGY AND ARCHITECTURE

The project adopts a six-stage modular and iterative engineering methodology: (1) Requirement Analysis to identify tourist, emergency-contact, and administrator needs; (2) System Design to define module boundaries, data flows, and relational entities; (3) Prototype Development to implement authentication, profile, geofencing, SOS, nearby assistance, and identity modules incrementally; (4) System Integration connecting the frontend to backend APIs and MySQL storage; (5) Comprehensive Testing across functional, usability, security, and network-failure conditions; and (6) Evaluation to document test outcomes and operational boundaries.

3.1 Functional and Non-Functional System Requirements

Table -2 defines the nine core functional requirements (FR-01 through FR-09) governing the Terra Trace prototype. In addition, seven non-functional requirements are enforced: Usability (simple navigation and prominent emergency actions), Performance (low-latency screen and alert rendering), Security (encrypted HTTPS communication, password hashing, and RBAC), Privacy (strict data minimization and explicit permission prompts), Reliability (graceful handling of unavailable GPS, network loss, and duplicate requests), Scalability (modular service and database design), and Maintainability (documented REST APIs and testable components).

Table -2: Functional Requirements Specification for Terra Trace

Req. ID	Requirement Name	Functional Description
FR-01	Registration and Login	Allow a tourist to create an account and authenticate securely.
FR-02	Emergency Profile	Store selected emergency details and verified trusted contacts.
FR-03	Location Permission	Request location access with a clear explanation and user control.
FR-04	Safety-Zone Alerts	Notify users when coordinates match a configured risk-zone rule.
FR-05	SOS Assistance	Allow a user to initiate an emergency alert and share incident details.

Req. ID	Requirement Name	Functional Description
FR-06	Nearby Help Discovery	Display nearby hospitals, police stations, and pharmacies on map.
FR-07	Digital Identity	Provide authenticated, consent-based viewing or sharing of identity details.
FR-08	Incident History	Display a chronological record of alerts and SOS events to the user.
FR-09	Admin Management	Allow authorized administrators to manage verified safety-zone data.

3.2 Four-Layer System Architecture and Emergency Workflow

The system architecture is structured into four logical layers: (1) Presentation Layer, comprising the tourist web/mobile application and administrator dashboard to capture user actions and render maps, alerts, and delivery statuses; (2) Application Services Layer, coordinating authentication, coordinate evaluation, geofence matching, SOS incident creation, and identity token issuance; (3) Data Storage Layer, persisting user accounts, trusted contacts, safety zones, incidents, notifications, and audit logs with strict access restrictions; and (4) External Services Layer, interfacing with mapping providers, device GPS, push notification gateways, and messaging channels. Fig -1 illustrates the end-to-end architectural and emergency response workflow.

3.3 Core System Modules, Data Flow, and Security Considerations

Seven cohesive modules execute the platform workflow: (1) User Registration and Authentication validates inputs, hashes passwords, manages session expiry, and requires re-authentication or One-Time Password (OTP) verification for sensitive identity actions; (2) Tourist Profile and Emergency Contacts stores minimal safety metadata and designated SOS recipients; (3) Location Tracking and Safety-Zone Alerts evaluates permitted coordinates against circular (center and radius) or polygonal geofences while accounting for GPS uncertainty; (4) SOS and Emergency Response provides a confirmation-protected distress trigger that logs an incident, captures the latest coordinates and timestamp, dispatches alerts, and reports truthful delivery states (created, queued, sent, or failed); (5) Nearby Assistance queries local hospitals, police stations, and pharmacies with distance estimates and provider freshness disclosures; (6) Secure Digital Identity issues short-lived, consent-bound sharing tokens or Quick Response (QR) references without exposing raw identity documents publicly; and (7) Administrator Module enables authorized personnel to publish safety zones and audit system events.

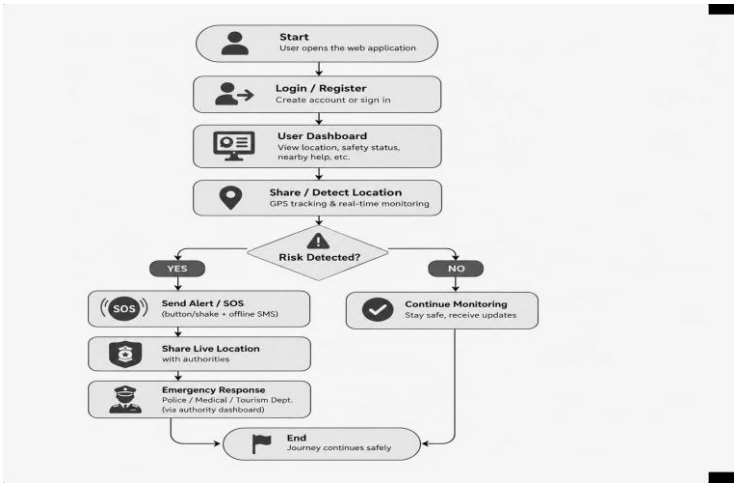


Fig -1: Proposed System Architecture and End-to-End Emergency Response Workflow

4. SYSTEM IMPLEMENTATION AND DATABASE DESIGN

To convert the architectural design into a working academic prototype, a decoupled client-server implementation stack was established. The frontend utilizes HTML5, CSS3, and JavaScript (or an Android application framework) to deliver an accessible, high-contrast tourist interface. The backend exposes authenticated Representational State

Transfer (REST) API endpoints using Java with Spring Boot (or a comparable REST framework), backed by a relational MySQL database, Device GPS and mapping APIs, Firebase Cloud Messaging for notifications, and JUnit alongside API testing tools for verification. Table -3 details the technology stack and core REST API routes.

Table -3: Proposed Technology Stack and Core Backend REST API Endpoints

Layer / Endpoint	Technology / HTTP Method	System Purpose and Operational Responsibility
Frontend Layer	HTML5, CSS3, JavaScript / Android	Build responsive tourist and administrator interfaces with prominent SOS controls.
Backend & Security	Java Spring Boot REST API, HTTPS, RBAC	Implement business logic, password hashing, token sessions, and role enforcement.
Database & Maps	MySQL DBMS, Device GPS, Places API	Persist relational safety records and retrieve real-time coordinates and nearby help.
/api/auth/register & login	POST	Register new tourist accounts and authenticate returning users securely.
/api/profile & /api/contacts	GET / POST / PUT / DELETE	Read or update authenticated tourist profiles and manage trusted emergency contacts.
/api/zones/nearby	GET	Retrieve active, verified geographic risk or restricted zones near supplied coordinates.
/api/incidents/sos & /incidents	POST / GET	Create a new SOS emergency incident and retrieve the user's incident history.
/api/identity/share	POST	Generate an authenticated, time-limited, consent-bound identity sharing token.

4.1 Relational Database Schema

The MySQL relational database organizes project data across seven normalized entities linked by primary and foreign keys: one user can maintain multiple emergency contacts and incident records, each notification log entry references a parent incident, safety zones are versioned by administrators, and encrypted identity profile references and audit logs enforce accountability. Table -4 summarizes the core database entities.

Table -4: Core Relational Database Entities and Key Attributes

Entity Name	Primary and Foreign Key Attributes	Storage Purpose
User	user_id, name, email, phone, password_hash, created_at	Core tourist and admin account authentication reference.
EmergencyContact	contact_id, user_id, name, phone, relationship, consent_status	Trusted emergency contacts linked to a specific tourist.
SafetyZone	zone_id, name, geometry, severity, source, verified_at, active_status	Configured geographic risk or restricted geofence zones.
Incident	incident_id, user_id, type, latitude, longitude, created_at, status	SOS distress events and safety incident records.
NotificationLog	notification_id, incident_id, recipient_ref, channel, delivery_status, sent_at	Message delivery tracking and audit metadata.
IdentityProfile	identity_id, user_id, encrypted_attributes_ref, updated_at	Protected reference to encrypted tourist identity attributes.
AuditLog	audit_id, actor_id, action, target_type, target_id, timestamp	Immutable log of administrative and identity-sharing actions.

4.2 Frontend Structure and User Interface Realization

The implemented frontend structure guides tourists through a calm, intuitive safety workflow across six primary views: (1) Main Dashboard ('Go further. Feel grounded.'), introducing trip readiness and route context; (2) Sign-In and Onboarding Page ('Let's get your bearings'), capturing essential traveller details (e.g., Ankita, mobile number, and destination Hyderabad) with explicit background-tracking disclosures; (3) User Overview ('Your trip, at a glance'), presenting quick-access cards for Explore, Safety, and Monitor modules; (4) User Explore Dashboard ('Get to know the place'), listing curated local landmarks and safe points of interest; (5) User Safety Dashboard ('Your safety plan'), configuring trusted contacts, default distress messages, local emergency numbers, and a prominent red SOS trigger; and (6) Trusted Monitor View ('A clear view of your trip'), ensuring location sharing remains active strictly while the monitor session is open. Fig -2 and Fig -3 showcase these interfaces.

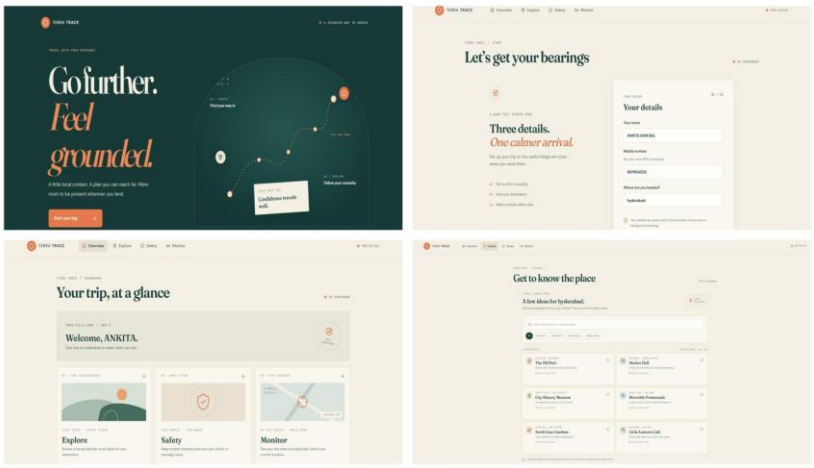


Fig -2: Terra Trace Core Interfaces (Main Dashboard, Sign-In Page, User Overview, and Explore Dashboard)

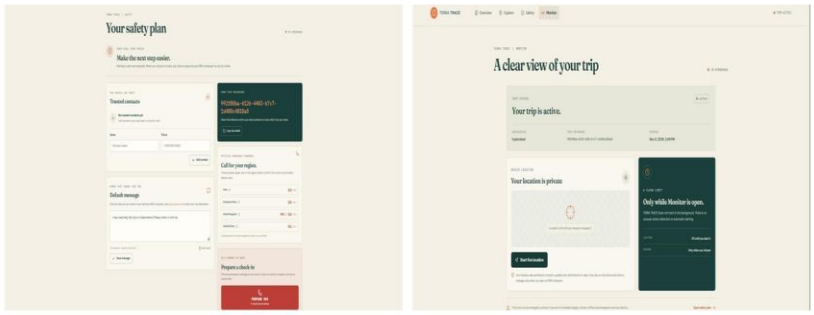


Fig -3: Terra Trace User Safety Plan Dashboard and Privacy-Preserving Trusted Monitor Interface

5. RESULT ANALYSIS AND DISCUSSION

The Terra Trace prototype was evaluated across six core dimensions: Usability (completing registration, locating help, and activating a test SOS), Alert Correctness (simulating coordinates against configured geofences without duplicate triggers), SOS Workflow (verifying incident creation and truthful delivery status under both online and offline conditions), Privacy (confirming consent-gated access paths), Security (testing authentication, RBAC authorization, and rate-limiting), and Reliability (verifying graceful fallback guidance during GPS denial or network interruption). Table -5 presents the ten verification test scenarios (TC-01 through TC-10), all of which aligned with the user stories and sample incident verification schema (e.g., Incident ID TT-TEST-0001, Type: SOS – medical assistance, Created: 2026-10-30 10:30, Status: Created – notification queued).

Table -5: Functional, Security, and Failure-Condition Verification Test Suite

Test ID	Test Scenario	Expected and Verified Prototype Result
TC-01	Register with valid tourist details	Account is created securely and confirmation screen is displayed.
TC-02	Register with duplicate email or phone	Backend rejects duplicate identifiers with a clear validation message.
TC-03	Authenticate with incorrect password	Access is denied with a safe, non-leaking error message.
TC-04	Deny device location permission	Application continues with limited functionality and explains the limitation.
TC-05	Enter a configured test safety zone	Relevant geofence alert is displayed once with severity and source metadata.
TC-06	Activate SOS with network available	Incident record is created and notification delivery status updates accurately.
TC-07	Activate SOS without network access	Application reports sending failed/pending and provides offline local guidance.
TC-08	Attempt to open another user's incident	Backend RBAC middleware denies unauthorized cross-account record access.
TC-09	Attempt identity sharing without consent	System blocks the disclosure operation until explicit consent is confirmed.
TC-10	Search nearby emergency assistance	Available hospitals, police stations, and pharmacies display with distance estimates.

Table -6: Sample Incident Verification Record (Illustrative Prototype Output)

Incident Field	Sample Recorded Value
Incident ID	TT-TEST-0001
Incident Type	SOS – Medical Assistance
Location Coordinates	Test Coordinates Only (Permitted Session)
Created Timestamp	2026-10-30 10:30 (Sample)
Delivery Status	Created – Notification Not Yet Confirmed
Designated Recipient	Configured Trusted Emergency Contact
Verification Note	Illustrative Prototype Record; Not a Live Emergency Event

The prototype demonstrates key operational advantages by unifying geofenced alerts, one-tap SOS signaling, nearby help discovery, and consent-bound digital identity sharing into a single modular platform. At the same time, transparent operational boundaries are maintained: indoor or dense-urban GPS multipath inaccuracies, mobile network outages, operating-system background execution limits, and the need for formal government dispatch partnerships are explicitly accounted for so users never receive false assurances during an emergency.

6. CONCLUSIONS

Terra Trace provides a cohesive, privacy-conscious smart tourist safety and emergency assistance platform that bridges the gap between standalone navigation apps, manual location sharing, and digital identity tools. By integrating user registration, emergency contact management, geofenced risk-zone notifications, truthful SOS incident reporting, nearby assistance discovery, and consent-based identity sharing across a four-layer architecture, the system significantly reduces the cognitive load required for a traveller to recognize a risk and request help. Future work will extend the platform through integration with verified public-safety hazard feeds, multilingual and accessibility support for international travellers, offline emergency instructions with locally cached contact directories, time-limited trip-sharing links, moderated crowd-sourced risk reporting, multi-source positioning fusion, and field trials with tourism authorities.

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