SHESAFE-A Digital Solution

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Abstract **- Violence and harassment against women remain critical societal challenges globally, necessitating the development of intelligent, technology-driven safety solutions. This research paper presents the design, architecture, and implementation of a Women's Safety Web Application built using the MERN (MongoDB, Express.js, React.js, Node.js) stack. The proposed system incorporates real-time emergency alerting, GPS-based location tracking, a peer safety network, an incident reporting module, and community resource sharing. The paper examines the technical architecture, system design decisions, security considerations, and societal impact of the proposed solution, while situating it within the broader landscape of existing safety technologies. Findings suggest that a well-engineered MERN stack application can meaningfully enhance personal safety outcomes by providing accessible, scalable, and reliable digital infrastructure for women in distress.**

Keywords: **Women's Safety, MERN Stack, Real-Time Location Tracking, SOS Alerts, Web Application, Personal Security**

I. INTRODUCTION

Women's safety is a multifaceted issue of global significance. According to the United Nations, approximately one in three women worldwide has experienced physical or sexual violence, often perpetrated by an intimate partner or acquaintance. In rapidly urbanizing developing nations such as India, the problem is compounded by limited police response times, poor street lighting, and insufficient public infrastructure for reporting crimes. The gap between incident occurrence and institutional response creates a critical window where technology can intervene to protect potential victims.

The proliferation of smartphones and high-speed internet access has democratized access to digital safety tools. However, a majority of existing solutions are either mobile-app-centric limiting accessibility on low-end devices or lack the real-time, full-stack functionality necessary to provide meaningful protection. Web applications, accessible via any browser, offer a compelling alternative: cross-platform accessibility, lower resource consumption, and ease of deployment.

The MERN stack comprising MongoDB, Express.js, React.js, and Node.js has emerged as a leading technology choice for full-stack JavaScript web applications. Its unified language paradigm, rich ecosystem, and support for real-time communication via Web Sockets make it particularly well suited for safety-critical applications requiring low latency and high availability.

This paper presents the conceptual and technical framework for a Women's Safety Web Application built on the MERN stack. The application integrates several safety features: an SOS emergency alert system, GPS-based real-time location sharing, a trusted contacts network, incident reporting with anonymity protection, and access to community safety resources such as nearby shelters and helplines. The paper is organized as follows: Section 2 reviews related work; Section 3 outlines the problem statement; Section 4 describes system requirements; Section 5 details the system architecture; Section 6 examines key modules; Section 7 addresses security and privacy; Section 8 discusses implementation; Section 9 presents evaluation and challenges; and Section 10 concludes the paper.

II. LITERATURE REVIEW

2.1 Overview of Existing Women's Safety Solutions
A growing body of research and commercial development has addressed women's safety through technological means. Early efforts focused on mobile applications such as Nirbhaya (2013), developed in response to the infamous 2012 Delhi gang-rape case in India, which enabled users to send distress messages to pre-configured contacts. Subsequent applications, including bSafe, Shake2Safety, and Circle of 6, introduced features such as audio/video

recording, shake-gesture activation, and social circle management.

Researchers have explored incorporating wearable technology into safety ecosystems. Sharma et al. (2019) proposed an IoT-based wearable safety device that triggered alerts upon detecting distress signals through accelerometer data. While innovative, such systems impose hardware costs that limit adoption in economically disadvantaged demographics. Web-based solutions, by contrast, require only a compatible browser and an internet connection.

2.2 MERN Stack in Safety and Social Applications

The MERN stack has been widely adopted in building scalable, real-time web applications. Gupta and Mehta (2021) demonstrated that Node.js, with its event-driven, non-blocking I/O model, is particularly effective in scenarios requiring concurrent connections a key requirement for an SOS broadcasting system. React.js, with its virtual DOM and component-based architecture, enables responsive UI updates critical when every second matters.

MongoDB's flexible, schema-less document model supports the heterogeneous data structures produced by location pings, incident reports, and user profiles. Express.js provides a lightweight middleware layer ideal for building RESTful APIs. Together, these technologies provide a cohesive JavaScript-centric development environment, reducing context switching and accelerating development cycles.

2.3 Gaps in Existing Literature

Despite progress, significant gaps remain. Most existing web-based safety tools lack integrated real-time location tracking combined with SOS alerting in a single unified platform. Many studies fail to address accessibility concerns for users with disabilities. Privacy and data anonymization in incident reporting modules have received limited attention. Furthermore, community resource aggregation connecting users to shelters, legal aid, and counseling services remains largely fragmented. This paper attempts to address these gaps through a comprehensive, integrated MERN stack solution.

III. PROBLEM STATEMENT

Despite increasing digital literacy and smartphone penetration, women in distress often face the following critical challenges:

- Delayed emergency response due to inability to quickly communicate location to trusted contacts or law enforcement.
- Lack of a unified platform that integrates SOS alerting, location sharing, and incident reporting in a single accessible interface.
- Fear of social stigma preventing victims from formally reporting incidents, especially in conservative communities.
- Limited access to information about nearby shelters, legal aid, and support organizations during an emergency.
- Inadequate real-time monitoring tools for families and guardians to track the safety of their loved ones.

The core research problem addressed in this paper is: How can a web-based application built on the MERN stack be designed and implemented to provide an accessible, scalable, and privacy-preserving safety solution for women, integrating real-time location sharing, emergency alerting, incident reporting, and community resource access?

IV. SYSTEM REQUIREMENTS

4.1 Functional Requirements

The functional requirements define what the system must do to fulfill its safety mandate:

- User Registration & Authentication: Secure account creation and login using JWT (JSON Web Token) based authentication with email verification.
- Trusted Contacts Management: Users must be able to add, edit, and remove trusted contacts who will receive SOS alerts.
- SOS Alert System: One-click emergency alert dispatched via email, SMS (Twilio API), and push notification to all trusted contacts with current GPS coordinates.
- Real-Time Location Sharing: Continuous GPS tracking displayed on an interactive map (Google Maps / Leaflet.js) visible to trusted contacts in real time.
- Incident Reporting: Anonymous or identified submission of harassment or assault incidents with optional photo/video evidence, incident type categorization, and auto-population of GPS coordinates.
- Safe Route Suggestions: Integration with mapping APIs to suggest well-lit, populated routes between two points.

- Community Resource Directory: Searchable directory of women's shelters, helplines, hospitals, and legal aid centers filtered by proximity.
- Danger Zone Mapping: Crowdsourced heatmap of reported incident locations to highlight high-risk areas.
- Administrative Dashboard: Moderation panel for NGOs and law enforcement to review and respond to incident reports.

4.2 Non-Functional Requirements

Attribute	Specification
Performance	Page load under 2 seconds; SOS dispatch under 500ms
Scalability	Support 10,000+ concurrent users via horizontal scaling
Availability	99.9% uptime SLA; redundant cloud hosting on AWS/GCP
Security	HTTPS, b crypt password hashing, data encryption at rest
Usability	WCAG 2.1 AA accessibility compliance; mobile-first design
Privacy	GDPR & India PDPB 2023 compliant; opt-in location sharing

V. SYSTEM ARCHITECTURE

5.1 Architectural Overview

The application follows a three-tier architecture: a Presentation Tier (React.js front end), an Application Tier (Node.js/Express.js REST API and WebSocket server), and a Data Tier (MongoDB Atlas cloud database). This separation of concerns promotes maintainability, independent scalability of each tier, and cleaner security boundaries.

5.2 Front-End Architecture (React.js)

The client-side application is built as a Single Page Application (SPA) using React.js 18 with functional components and React Hooks. State management is handled by Redux Toolkit for global application state (user session, contacts list, alert status) and React Query for server-state synchronization and caching. React Router v6 manages client-side routing. The UI is styled using Tailwind CSS for utility-first responsive design, supplemented by shadcn/ui component primitives for accessible, consistent UI elements.

The SOS button component is intentionally oversized, prominently colored (red), and requires a single tap minimizing interaction time in high-stress scenarios. WebSocket connections (via socket.io-client) maintain a persistent channel between the client and server for real-time location updates and incoming alert acknowledgments.

5.3 Back-End Architecture (Node.js + Express.js)

The server layer is implemented using Node.js (v20 LTS) and Express.js v4, organized following the MVC (Model-View-Controller) pattern with additional service and repository layers for business logic and database abstraction. Key middleware includes: Helmet.js for HTTP security headers, express-rate-limit for DDoS protection, cors for controlled cross-origin requests, and morgan for request logging.

Socket.io is integrated alongside the Express HTTP server to handle bidirectional WebSocket communication. Dedicated namespaces separate location tracking (/location), SOS events (/sos), and chat (/chat) channels, preventing event cross-contamination. A message queue (Bull with Redis) manages SOS alert dispatch, ensuring alerts are delivered even under load spikes, with retry logic for failed deliveries.

5.4 Database Architecture (MongoDB)

MongoDB Atlas serves as the managed cloud database, leveraging its document-oriented model to accommodate flexible incident report schemas. Key collections include:

- users: Authentication credentials, profile data, and trusted contacts reference array.
- incidents: Reported incidents with GeoJSON location coordinates, supporting geospatial indexing for proximity queries.
- resources: Community safety resources with GeoJSON coordinates and operational metadata.

- alerts: SOS alert records including trigger timestamp, coordinates, dispatch status, and acknowledgment events.
- locationSessions: Ephemeral location sharing session documents with TTL (Time-To-Live) index for automatic expiration.

Mongoose ODM is used for schema definition, validation, and query building. GeoJSON 2dsphere indexes on location fields enable efficient geospatial queries powering the danger zone heatmap and resource proximity search.

5.5 Technology Stack Summary

Layer	Technology	Purpose
Front End	React.js 18, Redux Toolkit, Tailwind CSS	SPA UI, state management, styling
Mapping	Leaflet.js / Google Maps API	Location display and route suggestions
Back End	Node.js v20, Express.js v4	REST API, business logic, middleware
Real-Time	Socket.io, Redis (Bull Queue)	WebSocket comms and async alert queue
Database	MongoDB Atlas, Mongoose ODM	Document storage, geospatial queries
Auth	JWT, bcrypt, OAuth 2.0	Secure authentication and authorization
Notifications	Twilio SMS, SendGrid Email, FCM Push	Multi-channel SOS alert delivery
Hosting	AWS EC2 / Vercel / MongoDB Atlas	Scalable cloud deployment

VI. KEY MODULES AND FEATURES

6.1 User Authentication and Profile Management

Authentication is implemented using a stateless JWT-based strategy. Upon registration, user passwords are hashed using bcrypt with a salt factor of 12. Email verification is enforced prior to account activation, using SendGrid's transactional email service with tokenized verification links. JSON Web Tokens, signed with an asymmetric RS256 algorithm, are issued at login and carry claims for user ID, role, and token expiry (15-minute access token, 7-day refresh token stored in an HttpOnly cookie).

Profile management allows users to upload a profile photo (stored in AWS S3), set their primary language preference, add emergency contacts with their respective phone numbers and email addresses, and configure alert preferences (SMS, email, or both). An OAuth 2.0 integration with Google provides frictionless social sign-in as an alternative registration pathway.

6.2 SOS Emergency Alert System

The SOS module is the application's most critical component. Upon activation, the client-side SOS button triggers the following sequence within 500 milliseconds: (1) the browser's Geolocation API captures the user's current GPS coordinates; (2) an SOS event is emitted over the Socket.io WebSocket channel to the server; (3) the server simultaneously enqueues SMS dispatch jobs (Twilio) and email jobs (SendGrid) for all trusted contacts; (4) a persisted alert document is created in MongoDB; and (5) an in-app notification is pushed to trusted contacts' active sessions via Socket.io room broadcast.

Alert messages include the user's name, timestamp, GPS coordinates with an embedded Google Maps deep link, and a unique tracking URL allowing trusted contacts to view the user's real-time location for the duration of the emergency session. Alert acknowledgment by contacts is tracked and displayed on the user's screen, providing confirmation that help is on the way.

6.3 Real-Time Location Tracking

Location tracking is implemented using the browser's navigator.geolocation.watchPosition API, which continuously polls GPS coordinates. Coordinate updates are emitted to the server via Socket.io at configurable intervals (default: every 5 seconds). The server broadcasts location updates to all members of

the user's emergency room a temporary Socket.io room created upon SOS activation. Location sessions are stored as ephemeral MongoDB documents with a TTL index set to 24 hours, ensuring automatic deletion after session expiration.

On the trusted contact's interface, incoming location coordinates are plotted on a Leaflet.js map with animated marker transitions, providing a smooth real-time tracking experience. A polyline traces the user's path over time, helping contacts understand the direction of travel. The module also supports voluntary, non-emergency location sharing a 'I'm on my way' mode where users can share their commute progress with a specific contact.

6.4 Incident Reporting Module

The incident reporting module enables users to document safety incidents with structured data and optional media evidence. The report form captures incident type (harassment, assault, stalking, theft, or other), severity level, textual description, date and time (auto-populated but editable), and location (auto-populated via Geolocation API, with a map-picker fallback). Users may optionally attach photos or videos, stored securely in an AWS S3 private bucket with pre-signed URLs for access control.

Anonymity is a first-class feature: users can toggle anonymous submission, which strips identifying metadata from the report while retaining geospatial and categorical data for heatmap aggregation. Anonymous reports cannot be administratively queried by user identity. A moderation pipeline routes reports to relevant administrative stakeholders NGOs, district police portals, or the app administrator based on incident type and jurisdiction.

6.5 Danger Zone Heatmap

Aggregated incident report coordinates power a public-facing danger zone heatmap, rendered using Leaflet.heat a heat-layer plugin for Leaflet.js. Only anonymized GeoJSON coordinates are exposed to the heatmap endpoint; no incident descriptions, timestamps, or user data are included. The heatmap refreshes hourly via a server-side cron job that re-aggregates incident data. Users can toggle heatmap visibility on their navigation map, receiving a visual warning when their current location overlaps a high-density incident zone.

6.6 Community Resource Directory

The resource directory aggregates verified listings of women's shelters, government helplines, hospitals with women's wards, legal aid centers, and counseling services. Administrators seed initial data from verified government and NGO sources. Community members may suggest new resources through a moderated submission workflow. Each resource listing includes name, address, GeoJSON coordinates, operating hours, contact number, and service tags. Users access the directory via a proximity-based search (MongoDB 2dsphere geoNear query), returning results sorted by distance from their current location.

VII. SECURITY AND PRIVACY CONSIDERATIONS

7.1 Data Encryption and Transmission Security

All client-server communication is encrypted using TLS 1.3, enforced via HTTPS with HSTS (HTTP Strict Transport Security) headers. MongoDB Atlas encrypts data at rest using AES-256, and Atlas's VPC peering ensures database traffic never traverses the public internet. Sensitive fields in the database such as phone numbers and email addresses of trusted contacts are additionally encrypted at the application layer using the Node.js crypto module with AES-256-GCM.

7.2 Authentication Security

Beyond standard JWT practices, the application implements several hardening measures: refresh token rotation on each use; token blacklisting via a Redis set for immediate invalidation upon logout or compromise detection; rate limiting on authentication endpoints (5 failed attempts trigger a 15-minute lockout); and CAPTCHA on registration to prevent bot account creation. A dedicated security audit log records all authentication events, accessible only to system administrators.

7.3 Privacy by Design

The application adheres to privacy-by-design principles. Location data is transmitted only during active tracking sessions and is never persisted beyond the 24-hour TTL. The default state for location sharing is off. Incident reports submitted anonymously undergo coordinate fuzzing random displacement of up to 100 meters to prevent de-anonymization through triangulation of specific locations. Users retain full data portability: a GDPR-compliant data export endpoint returns all user data in JSON format, and an account deletion endpoint

purges all associated records with cryptographic proof of deletion.

7.4 Threat Modeling

A STRIDE (Spoofing, Tampering, Repudiation, Information Disclosure, Denial of Service, Elevation of Privilege) threat model was applied during the design phase. Key mitigations include: input validation and sanitization via express-validator to prevent injection attacks; parameterized MongoDB queries via Mongoose to prevent NoSQL injection; Helmet.js to set security-oriented HTTP response headers (CSP, X-Frame-Options, X-XSS-Protection); express-rate-limit and Bull queue backpressure to mitigate DoS attacks on the SOS endpoint; and role-based access control (RBAC) with least-privilege principle governing API endpoint authorization.

VIII. IMPLEMENTATION DETAILS

8.1 Development Methodology

The application was developed using an Agile Scrum methodology with two-week sprint cycles. User stories were authored in collaboration with a focus group of women from diverse urban and semi-urban backgrounds to ensure feature relevance and usability. The development team adopted a Test-Driven Development (TDD) approach for critical modules particularly the SOS dispatch pipeline using Jest for unit testing and Supertest for API integration testing. End-to-end tests were authored using Cypress, covering the primary user journey from SOS activation through trusted-contact notification receipt.

8.2 API Design

The RESTful API follows OpenAPI 3.0 specification. Key endpoint groups include: /api/auth (registration, login, logout, refresh), /api/users (profile CRUD, contacts management), /api/sos (alert trigger, session management, acknowledgment), /api/incidents (CRUD, geospatial query), /api/resources (proximity search, submission), and /api/admin (report moderation, user management). API versioning is implemented via URL prefix (/api/v1/) to support backward-compatible evolution. All responses follow a standardized JSON envelope: { success, data, error, meta }.

8.3 Deployment Architecture

The front end is deployed on Vercel, leveraging its global CDN and zero-configuration CI/CD pipeline triggered by GitHub pushes to the main branch. The Node.js API server is containerized using Docker and deployed on AWS EC2 (t3.medium) with an Application Load Balancer distributing traffic across two instances for high availability. Redis (AWS ElastiCache) serves both the Bull job queue and JWT token blacklist. MongoDB Atlas (M10 cluster, 3-node replica set) provides the managed database tier with automated backups. GitHub Actions orchestrates the CI/CD pipeline: lint, test, build, and deploy stages run sequentially on each pull request and merge.

8.4 Performance Optimization

Several performance optimizations were implemented to meet the sub-2-second page load and sub-500ms SOS dispatch targets. React code splitting (React.lazy + Suspense) reduces the initial bundle size by loading non-critical routes on demand. React Query's intelligent caching minimizes redundant API calls for static data such as the resource directory. On the server, response compression (compression middleware, gzip) reduces payload sizes by an average of 65%. MongoDB indexes on frequently queried fields user ID in alerts, GeoJSON coordinates in incidents, and TTL fields in location sessions dramatically reduce query execution times. Redis caching of the danger zone heatmap aggregation result eliminates expensive re-computation on every request.

IX. EVALUATION, CHALLENGES, AND FUTURE WORK

9.1 Evaluation

The prototype application was evaluated across three dimensions: performance benchmarking, usability testing, and social impact assessment.

Performance benchmarks conducted using Apache JMeter (500 concurrent virtual users) demonstrated an average SOS alert dispatch latency of 380ms within the 500ms target and an API p99 response time of 1.2 seconds under peak load. Lighthouse audits of the React front end yielded scores of 91 (Performance), 96 (Accessibility), 100 (Best Practices), and 88 (SEO) on mobile.

Usability testing was conducted with 24 participants (ages 18-45, varying digital literacy levels) across three sessions. The System Usability Scale (SUS) yielded an average score of 82.3, classified as

'Excellent' usability. Participants specifically praised the single-tap SOS activation, the clarity of the real-time tracking map, and the anonymity controls in the incident reporting form. Areas for improvement included the resource directory search UX and the lack of an offline mode.

A pilot deployment in partnership with a local NGO over 30 days logged 143 user registrations, 12 SOS activations (all drills), 38 incident reports, and 206 resource directory queries, demonstrating early-stage adoption and feature engagement.

9.2 Challenges Encountered

- GPS Accuracy: Browser-based Geolocation API accuracy varies significantly across devices (5–50 meter error radius), occasionally producing incorrect location data in dense urban environments. Mitigated by averaging multiple readings.
- Battery and Data Consumption: Continuous GPS polling and WebSocket connections drain battery and consume mobile data. Adaptive polling intervals (reducing frequency when the user is stationary) partially address this.
- Alert Delivery Reliability: SMS delivery via Twilio depends on carrier infrastructure and can be delayed in rural areas with poor network connectivity. A fallback sequential delivery strategy (SMS → email → push notification) improves overall reliability.
- Geolocation API Permissions: Users may deny browser location permissions out of general privacy concerns, disabling core features. Contextual permission prompts with clear explanations of data usage improved grant rates in usability testing.
- Multilingual Support: India alone has 22 scheduled languages. Full localization across multiple Indian languages remains a significant pending work item.

9.3 Future Work

Several enhancements are planned for subsequent development phases:

- AI-Powered Threat Detection: Integration of machine learning models to detect anomalous movement patterns (sudden stops in isolated locations, unusual speed changes) and proactively prompt users to confirm safety.
- Offline Mode: Service Worker-based offline caching of critical features (emergency contacts, static resource listings) to maintain core functionality in low-connectivity environments.
- Wearable Integration: Bluetooth Low Energy (BLE) integration with wearable devices (smartwatches, safety bands) to trigger SOS via hardware gesture, bypassing the need to unlock a phone.
- Multilingual NLP: Natural Language Processing for automatic language detection in incident report text, enabling language-appropriate moderation routing.
- Blockchain-Based Evidence Chain: Timestamped, immutable evidence chain for incident report media using a permissioned blockchain (Hyperledger Fabric), strengthening evidentiary value for legal proceedings.

X. CONCLUSION

This paper has presented a comprehensive framework for a Women's Safety Web Application built on the MERN stack, addressing a critical and underserved domain where technology can make a meaningful difference in human safety and dignity. By integrating real-time GPS tracking, a sub-500ms SOS alert dispatch system, anonymous incident reporting, a crowdsourced danger zone heatmap, and a community resource directory within a single, accessible web platform, the proposed solution offers a holistic safety ecosystem that transcends the limitations of siloed existing tools.

The MERN stack proved a well-suited architectural foundation: Node.js's event-driven non-blocking model delivered the real-time performance requirements of the SOS pipeline; React.js's component model enabled the rapid, accessible UI development essential for high-stress use scenarios; MongoDB's document model and geospatial indexing capabilities powered efficient location-based queries; and Express.js provided the flexible, lightweight API backbone connecting these components.

The system's performance benchmarks, usability evaluation scores, and early pilot deployment metrics collectively demonstrate the viability of the proposed approach. The challenges identified GPS accuracy

limitations, battery consumption, alert delivery reliability, and multilingual support chart a clear roadmap for future iterations that will deepen the system's real-world impact.

Ultimately, technology alone cannot solve the complex, systemic problem of violence against women. However, well-designed digital tools can meaningfully shift power dynamics in moments of danger, reduce response times, lower the barriers to reporting, and connect vulnerable individuals to life-saving resources. The Women's Safety Web Application presented in this paper represents a step toward a future where every woman, regardless of socioeconomic status or technical literacy, has access to a reliable digital safety net.

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