

Intelligent Crowd Management, Navigation and Emergency Response For Large Religious Mass Gatherings: A Literature Survey Supporting The TRIVA System

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Abstract: This literature survey reviews research that can inform TRIVA, a proposed crowd-management, navigation and emergency-assistance system for Nashik Kumbh 2027. The review follows the planned functions of the project rather than discussing crowd analytics in general. These functions include map-based navigation, crowd-level information, facility locations, help requests, Family ID-based reunification, optional wristband identification, volunteer and authority coordination, and a central control-room dashboard. The selected studies cover crowd detection and simulation at Kumbh events, pedestrian accessibility, GIS-based planning, operational surveillance, mobile health information systems, family reunification and preparedness for Nashik Kumbh 2027. Taken together, the studies offer useful methods for individual functions, but they do not show all of these services working together in one lightweight platform for visitors. TRIVA will explore this integration through an academic prototype, using controlled or simulated data wherever official live feeds are unavailable.

Keywords: Kumbh Mela, TRIVA, crowd management, GIS, pedestrian navigation, emergency response, family reunification, mobile application, control dashboard, mass gathering.

I. INTRODUCTION

Large religious gatherings such as the Kumbh Mela create a temporary urban setting where transport, pedestrian movement, public facilities, healthcare, security and emergency services all have to operate at the same time. As described in the TRIVA synopsis, visitors may struggle to find suitable routes or essential facilities, avoid restricted areas, obtain timely help or reconnect with family members. These problems can be especially difficult for children and older visitors.

Research has examined many of these issues, although usually from separate perspectives. Kumbh-related studies look at crowd detection, pedestrian accessibility, surveillance, healthcare monitoring and event preparedness. GIS research helps planners understand crowd movement and emergency routes, while family-reunification systems show how digital records can help reconnect separated people. These findings offer a useful starting point for the different modules planned for TRIVA.

This survey looks at what the existing studies establish, where their approaches remain separate, and which ideas can realistically be brought into a diploma-level software project. The papers are therefore discussed according to their relevance to TRIVA's requirements, not simply in order of publication.



II. OBJECTIVES AND SCOPE OF THE LITERATURE SURVEY

- Identify research that directly supports crowd information, pedestrian navigation, emergency response and family safety at large gatherings.
- Compare the methods used in Kumbh and other religious mass-gathering studies with the proposed TRIVA modules.
- Identify limitations in existing approaches, especially the separation between visitor-facing services and authority-side coordination.
- Distinguish features supported by current evidence from features that should remain future extensions of the academic prototype.
- Formulate a research gap and a defensible contribution statement without claiming that TRIVA is the first system of its kind.
- The survey is scoped around software functions that can reasonably be demonstrated with controlled or simulated data. Large-scale government integration, city-wide IoT deployment, production emergency dispatch and full-scale CCTV analytics are treated as future extensions rather than assumed capabilities of the prototype.

III. LITERATURE SURVEY METHODOLOGY

The literature was organized by functional relevance rather than by publication year. The selected sources cover five major evidence groups: (i) Kumbh-specific crowd sensing and simulation, (ii) pedestrian accessibility and GIS-based spatial planning, (iii) command, surveillance and digital information systems, (iv) family-reunification technology, and (v) Nashik-specific preparedness and predictive crowd analytics. Bibliographic details were cross-checked against the supplied source material and publicly available publication records where necessary.

Each source was evaluated using four questions: What problem does the study address? What method or system does it use? Which TRIVA requirement does it support? What limitation prevents the study from directly serving as the complete TRIVA solution? This approach keeps the survey research-oriented and makes the transition from literature to project design explicit.

IV. REQUIREMENT-ORIENTED LITERATURE REVIEW MATRIX

TRIVA Requirement	Key Sources	Methods / Evidence	Relevance and Limitation
Crowd awareness	[1], [3], [10]	Image processing, crowd simulation, CCTV monitoring and command-centre practices	Supports representation and monitoring of crowd conditions; direct visitor integration remains limited.
GIS navigation	[2], [5]	Pedestrian accessibility analysis, GIS mapping, route and closure analysis	Strong basis for route display and alternative-route planning; studies are primarily analytical/planning-oriented.
Facilities and restricted zones	[3], [5], [6]	Spatial mapping, route planning, infrastructure and emergency analysis	Supports facility and zone mapping; not delivered as one multilingual visitor service.
Emergency assistance	[3], [5], [6]	ICCC coordination, GIS emergency routes and spatial preparedness	Supports location-aware reporting and response coordination, but not the complete TRIVA workflow.
Digital information management	[4]	Tablet/cloud data capture, remote dashboard and resource monitoring	Demonstrates low-cost digital information management at temporary mass gatherings.
Family reunification	[7]	Database-driven	Provides a conceptual basis for Family



		missing/found-person information and web/mobile channels	ID and reunification; context is disaster response rather than Kumbh.
Nashik preparedness	[8], [9]	Comparative preparedness and systems-oriented review	Provides local context and supports an extensible architecture.
Predictive analytics	[10]	CCTV-based forecasting of density, flow and entropy with risk alerts	Strong future direction; beyond the initial controlled-data prototype scope.

V. CROWD INFORMATION AND CROWD MANAGEMENT

Karthika, Verma and Pal [1] combine image processing with crowd simulation for the Kumbh Mela context. Pedestrian inflow obtained from image processing is fed into a crowd simulator using the Social Force Model, and a heat-map representation is generated for crowd-risk assessment. The study demonstrates that sensed crowd information can be transformed into a structured representation useful for decision support. For TRIVA, this supports the concept of displaying crowd conditions rather than treating the map as a static geographical layer.

Kanaujiya and Tiwari [3] provide an operational perspective from the Prayagraj Kumbh Mela 2019. Their discussion describes an Integrated Command and Control Centre supported by technologies including CCTV, RFID, drones, mapping and communication systems. The study also emphasizes stakeholder coordination and the role of centralized command in emergency response. This is directly relevant to TRIVA's authority/control-room interface.

However, these studies address different levels of the problem. [1] is primarily concerned with sensing and simulation, while [3] describes operational crowd management and surveillance. Neither represents the complete visitor-oriented TRIVA workflow. For the academic prototype, predefined Low/Medium/High crowd states or controlled sample data are therefore more defensible than claiming real-time city-scale crowd detection.

VI. GIS, MAP-BASED NAVIGATION AND ROUTE ACCESSIBILITY

Karthika, Kedar and Verma [2] study pedestrian accessibility during the Ujjain Kumbh Mela 2016 using pedestrian speed, spatial accessibility and route-choice analysis. The study uses space syntax and travel-time accessibility to investigate how pedestrians choose routes and how temporary road closures can redirect movement. Distance and direction are identified as important determinants of route choice. These findings provide direct conceptual support for TRIVA's map and route-recommendation functions.

Kasthala, Binoy and Lakra [5] examine spatial strategies for crowd management during the Ardh Kumbh Mela 2016 in Haridwar using remote sensing and GIS. The work considers crowd-flow routes, infrastructure and emergency routes. Kasthala, Binoy and Thambi [6] extend this spatial approach to Thrissur Pooram using 3D GIS, visibility and capacity analysis and emergency-response vehicle routes. Together, these studies demonstrate that spatial data can support both routine navigation and emergency preparedness.

For TRIVA, the important design implication is that maps should contain meaningful event information—destinations, medical centres, toilets, water points, police/help points, restricted zones and relevant routes—rather than merely showing geographic coordinates. Nevertheless, the cited studies do not validate a multilingual visitor application with integrated alerts, family safety and assistance tracking; those functions remain part of TRIVA's proposed integration.

VII. EMERGENCY ASSISTANCE AND CENTRALIZED COORDINATION

Emergency assistance in a digital system requires more than displaying an emergency location. A practical workflow must capture the incident, identify its location, transmit the request to an authorized person, record acknowledgement or assignment, and maintain the status of the case. The operational experience described by Kanaujiya and Tiwari [3] provides evidence for centralized coordination, while the GIS studies [5], [6] support the spatial component of emergency planning.



Kazi et al. [4] provide an additional digital-information precedent from the 2013 Kumbh Mela. Their tablet-based system captured field health information and synchronized it with a cloud database, enabling remote analysis of caseloads and resource utilization. The study also demonstrated the practical value of user-centred design and offline synchronization in a temporary, resource-constrained setting. These lessons are useful for TRIVA because the proposed system should remain simple for visitors and volunteers and should not assume continuous high-quality connectivity. TRIVA's emergency module should therefore be described as an assistance-request and coordination mechanism, not as a replacement for official emergency dispatch services. This distinction improves both technical realism and the academic validity of the project.

VIII. FAMILY IDENTIFICATION AND REUNIFICATION

Family safety is the feature that most clearly differentiates TRIVA from a conventional crowd-monitoring application. Thoma et al. [7] describe People Locator, a system that processes missing- and found-person information through a database to support family reunification after large-scale disasters. The system demonstrates the value of structured personal records and multiple digital access channels.

TRIVA adapts this general concept to a controlled Kumbh-event workflow. A Family ID can connect registered family members, while an optional secure identifier or wristband can be associated with selected vulnerable members. An authorized volunteer or help point can use the identifier to locate the relevant family record and initiate contact or reunification. This is intentionally simpler than biometric identification or disaster victim identification.

The literature therefore supports the underlying digital workflow but does not establish the exact event-specific combination proposed by TRIVA: proactive family registration, optional vulnerable-member identification, location-aware assistance and volunteer coordination within a religious mass gathering. This represents a useful integration opportunity, provided the project avoids overstating novelty.

IX. NASHIK KUMBH 2027 AND SYSTEM-LEVEL PREPAREDNESS

Sharma and Gupta [8] discuss preparedness for the Nashik Kumbh Mela 2027, emphasizing the scale and complexity of recurring religious mass gatherings and the evolution of infrastructure, sanitation, surveillance, crowd management and environmental planning. The study provides direct contextual justification for designing information systems around the specific characteristics of the Nashik event.

Wadghane [9] presents a systems-oriented view connecting public health, crowd risk, water systems, environmental protection and governance. For TRIVA, the important architectural lesson is that the software should be modular enough to accommodate additional information sources and services later. TRIVA should therefore be designed as an extensible information and coordination layer rather than as a single crowd-prediction algorithm.

X. PREDICTIVE CROWD ANALYTICS AS A FUTURE EXTENSION

Bhargavan and Verma [10] present a CCTV-based early-warning framework that forecasts crowd density, flow and entropy and converts the forecast outputs into graded risk alerts for control-room use. The study uses real CCTV data from the Ujjain Kumbh Mela and demonstrates the potential of forecasting to move crowd management from reactive monitoring toward earlier intervention.

This work is highly relevant to TRIVA but should be positioned carefully. The current academic project is not dependent on live CCTV feeds or city-wide IoT infrastructure. Predictive analytics can instead be treated as a future extension in which measured or simulated crowd values are replaced by forecast values. This keeps the core project implementable while retaining a clear research pathway toward AI/ML-based crowd prediction.

XI. COMPARATIVE SYNTHESIS

The reviewed literature can be understood as five complementary layers. First, crowd sensing and simulation provide methods for estimating and representing crowd conditions [1]. Second, GIS and accessibility studies provide spatial



intelligence for routes, facilities and emergency planning [2], [5], [6]. Third, operational Kumbh research demonstrates the importance of centralized coordination and multi-agency response [3]. Fourth, digital information systems show how temporary field data can be collected and accessed remotely [4], while family-reunification research demonstrates a database-oriented approach to separated-person cases [7]. Finally, Nashik-specific preparedness studies provide local context and a systems perspective [8], [9], and predictive CCTV research provides a future analytics path [10].

The central observation is fragmentation. A crowd model can indicate congestion without helping a visitor find a medical centre. A GIS emergency study can identify an emergency route without providing a family-reunification workflow. A family-reunification system can support identification without providing crowd-aware navigation. An authority-side command system can coordinate operations without necessarily delivering the same information directly to visitors. TRIVA is positioned at this integration boundary.

XII. LITERATURE-TO-TRIVA TRACEABILITY

TRIVA Module	Literature Basis	Proposed Academic Implementation
Crowd condition display	[1], [3], [10]	Controlled Low/Medium/High states in the initial prototype; predictive CCTV analytics reserved for future work.
Map and navigation	[2], [5]	Leaflet/OpenStreetMap-based destination and route display; alternative routes can be represented using controlled event data.
Facilities and restricted areas	[3], [5], [6]	Map medical, toilet, water, police/help points and restricted zones as event locations.
Emergency/help request	[3], [4], [5], [6]	Location-aware request, volunteer assignment/status and control-room visibility.
Family safety	[7]	Family ID, member records and optional secure identifier/wristband workflow.
Control dashboard	[3], [4]	Incidents, requests, facilities, crowd state and announcements shown to authorized users.
Future AI/ML extension	[1], [10]	Use live or simulated feeds for crowd forecasting, risk classification and route optimization in later versions.

XIII. RESEARCH GAP

The literature establishes strong foundations for most of the individual functions required by TRIVA. Crowd sensing and simulation support crowd-state representation [1]; accessibility research supports route selection [2]; GIS studies support spatial planning and emergency routes [5], [6]; operational Kumbh research supports centralized coordination [3]; mobile systems demonstrate digital field information management [4]; and People Locator provides a conceptual basis for family reunification [7]. Nashik-focused studies establish the relevance of integrated preparedness for the 2027 event [8], [9].

Despite this coverage, the reviewed studies are distributed across different objectives, datasets, events and operational settings. There is limited evidence in the reviewed set of a lightweight, event-oriented, visitor-facing platform that combines crowd-condition information, map-based navigation, facility discovery, emergency/help requests, proactive family registration and reunification, multilingual communication, and an authorized volunteer/control-room workflow in one coherent academic system.

Accordingly, the research gap for TRIVA should be stated as an integration gap, not as the absence of all previous work. The project does not claim to invent crowd management, GIS navigation, emergency coordination or family reunification individually. Its proposed contribution is to integrate these established ideas into a single, technically feasible software architecture tailored to a Kumbh-like mass gathering and to evaluate the resulting workflows using controlled or simulated data.



XIV. PROPOSED CONTRIBUTION OF TRIVA

- A unified visitor application for map-based navigation, crowd-condition display, facility discovery, alerts and assistance requests.
- A Family Safety Module based on a structured Family ID and optional secure identifier for selected vulnerable members.
- A volunteer/authority workflow for receiving, updating, assigning and resolving assistance or reunification cases.
- A centralized control dashboard connecting crowd information, facilities, incidents, announcements and request status.
- A multilingual interface supporting Marathi, Hindi and English to improve accessibility for a diverse visitor population.
- A modular architecture that can later accept live crowd feeds, CCTV analytics, AI/ML prediction, advanced route optimization and official-service integration.
- A controlled-data prototype whose major functions can be demonstrated and tested within the scope of a diploma-level major project.

XV. LIMITATIONS OF THE REVIEW AND PROPOSED SYSTEM

- Several studies are based on specific events such as Ujjain Kumbh 2016, Prayagraj Kumbh 2019, Haridwar Ardh Kumbh 2016 and Thrissur Pooram; their findings cannot automatically be generalized to Nashik Kumbh 2027.
- The People Locator study is based on disaster/family-reunification contexts and therefore provides conceptual rather than Kumbh-specific validation for TRIVA's Family Safety Module.
- GIS and accessibility studies support spatial reasoning but do not validate the complete TRIVA software workflow.
- Predictive CCTV analytics are promising but require suitable data, computing resources and operational integration; they should remain outside the core prototype unless appropriate data become available.
- The proposed system should not be presented as a substitute for government emergency services, police systems or production-grade command infrastructure.
- Controlled or simulated data can demonstrate system workflows, but such testing cannot establish real-world performance at the scale of the Nashik Kumbh Mela.

XVI. CONCLUSION

The reviewed literature supports the relevance of TRIVA and provides evidence for its major functional components. Kumbh-specific crowd research supports crowd-state representation; pedestrian-accessibility research supports route-aware navigation; GIS studies support facility and emergency-route planning; operational studies support centralized coordination; mobile information systems demonstrate the feasibility of digital field reporting; and family-reunification research supports structured identity and reunification workflows. Nashik-specific preparedness research further establishes the need for coordinated, forward-looking approaches to the 2027 gathering.

The review also shows that these capabilities are fragmented rather than absent. This leads to a precise and defensible project position: TRIVA is an integration-oriented academic prototype that connects visitor-facing information and navigation with structured emergency, family-safety and authority-coordination workflows. Predictive crowd analytics, live CCTV integration and large-scale IoT connectivity should be treated as future extensions. This framing keeps the literature survey aligned with the actual project scope, avoids exaggerated novelty claims, and provides a clear research basis for implementation and evaluation.



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