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Samudra Setu - A Mobile Application for Recreational Suitability Assessment of Beach Locations Across India

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Abstract

Coastal tourism plays a vital role in India's economy and cultural development. However, tourists often face safety risks due to unpredictable environmental conditions such as high waves, strong ocean currents, and sudden weather changes. Access to accurate and real-time beach condition information is limited, which can lead to unsafe recreational experiences.

This research presents Samudra Setu, a mobile application designed to provide recreational suitability information for beach locations across India. The proposed system integrates environmental data such as weather conditions, tidal information, water quality, and crowd density to calculate a suitability score for each beach location. The application employs machine learning techniques, computer vision, natural language processing, and graph algorithms to enhance user experience and provide intelligent recommendations.

The system also incorporates crowdsourced data verification, personalized itinerary planning, and sustainability awareness features to promote responsible coastal tourism. By providing real-time alerts and interactive visualizations, the application helps tourists make informed decisions regarding beach visits. The proposed solution contributes to safer recreational planning, improved tourism management, and sustainable coastal development.

Introduction

Coastal tourism is one of the most vibrant and rapidly expanding sectors of the travel and hospitality industry in India. With a coastline stretching over 7,500 kilometers, India offers a wide variety of beach destinations ranging from calm and scenic backwaters to lively recreational shores that attract domestic as well as international tourists. These coastal areas contribute significantly to the tourism economy by generating employment, supporting local communities, and promoting cultural exchange. Additionally, coastal tourism aligns with the concept of the Blue Economy, which emphasizes sustainable utilization of ocean resources while preserving marine ecosystems [39].

Despite its importance, coastal tourism development faces several challenges related to safety, environmental monitoring, and decision-making. Beaches are dynamic environments influenced by tidal variations, ocean currents, wave patterns, and weather conditions. Studies on maritime weather routing and oceanographic modeling highlight the complexity of such environmental factors and their impact on safety and navigation [6], [13], [41]. Similarly, research on ship routing optimization and weather-aware navigation demonstrates how environmental data can significantly influence decision-making in marine contexts [18], [24], [40].

A major issue in beach tourism is the lack of real-time, integrated information systems. Tourists often rely on fragmented and outdated data sources, which may lead to unsafe situations. Advances in machine learning and data analytics provide promising solutions to this problem. For instance, scalable machine learning models such as XGBoost [1] and deep learning approaches integrating meteorological variables [22], [33] have been successfully applied in predictive systems. These techniques have also been used in domains like ship fuel consumption prediction and environmental modeling, demonstrating their ability to process large-scale ocean and weather datasets [3], [32]. Furthermore, fuzzy forecasting models and uncertainty-aware prediction techniques have been explored in maritime and environmental domains, improving decision-making under uncertain weather conditions [42], [37].

Moreover, IoT-based environmental monitoring systems have been widely used for predicting air and water quality conditions [9], [19], enabling real-time data acquisition and analysis. Such systems, combined with geospatial datasets like those provided by global ocean reanalysis platforms [36] and geographic mapping resources [38], can support the development of intelligent coastal monitoring applications.

Security and accessibility are also crucial aspects of mobile applications handling environmental and user data. Encryption techniques for secure communication [2], access control models such as RBAC and identity-based systems [4], [17], and graphical authentication mechanisms [8] ensure safe and reliable user interactions. Additionally, structured digital management platforms, such as e-governance and e-court systems, demonstrate the effectiveness of centralized web-based systems in handling large-scale data and user interactions [16].

Furthermore, advancements in real-time object tracking and surveillance systems [5], [12] can be leveraged for monitoring crowd density and ensuring safety in public beach areas. In addition, machine learning and forecasting models have demonstrated effectiveness in predictive analytics across domains such as agriculture, economics, and environmental science [7], [11], [15], [25], [26], [27], [29]. Data preprocessing and augmentation techniques further enhance model performance and reliability [20], [14]. Emerging technologies such as IoT-enabled smart systems [21] and AI-driven intelligent frameworks [30], [31] provide opportunities to build scalable and adaptive applications.

Inspired by these advancements, this research proposes Samudra Setu, a mobile application designed to assess recreational suitability of beaches across India. The system integrates environmental data, weather forecasts, and user-generated feedback to provide real-time recommendations. By leveraging machine learning, oceanographic data, and crowdsourced inputs, the application aims to improve safety, enhance user experience, and promote sustainable tourism.

Furthermore, the system supports efficient route planning and accessibility through algorithms such as A* pathfinding [10], which can help users identify optimal travel routes to beach locations. The integration of environmental intelligence with user-centric design makes the proposed system a comprehensive solution for coastal tourism management.

In summary, Samudra Setu bridges the gap between environmental monitoring and tourism decision-making by combining real-time analytics, community participation, and intelligent recommendation systems. The proposed approach aims to make beach tourism safer, smarter, and more sustainable while supporting authorities in effective coastal management.

Literature Review

Several research studies have explored digital platforms, environmental monitoring systems, and intelligent decision-support mechanisms for coastal safety and tourism planning.

García-Alba et al. (2021) developed the SOSeas Web Application, which utilizes deep neural networks to predict drowning risks based on oceanographic parameters such as waves, wind speed, and currents. This aligns with advancements in machine learning models used for environmental prediction and optimization [22], [33]. However, the system lacks integration of user-generated data.

Peña-Abreu and Terroso-Saenz (2023) proposed a crowdsensing platform enabling users to report beach conditions such as crowd density and cleanliness. This approach is supported by IoT-based sensing systems and participatory data collection frameworks [21], [19]. However, such systems depend heavily on user engagement.

Zhang et al. (2024) introduced a tourism suitability assessment model using the Delphi method and Analytic Hierarchy Process (AHP). While effective for structured evaluation, similar predictive models in other domains suggest that machine learning-based approaches offer greater adaptability and real-time responsiveness [7], [11].

Lad et al. (2025) proposed the AquaVista application, which aggregates environmental data from multiple APIs. This approach is comparable to systems that integrate meteorological and oceanographic datasets for predictive analytics [3], [32]. However, reliance on external APIs limits system independence and validation.

Archana et al. (2025) developed a web-based system that evaluates beach suitability using environmental parameters such as wave height and currents. Similar approaches have been used in maritime routing and optimization systems [18], [24], but these systems often lack user-centric features and scalability.

In maritime research, several studies have focused on optimizing navigation using environmental data. Weather routing systems [13], hazard avoidance strategies [41], and energy-efficient routing frameworks [28], [34] demonstrate how environmental intelligence can enhance decision-making. Additionally, research on fuel-efficient ship operation under uncertain weather conditions highlights the importance of incorporating uncertainty modeling into predictive systems [37]. Evaluation criteria for such systems further emphasize the need for accuracy, efficiency, and adaptability [35], while parametric design tools for ship optimization provide insights into energy-efficient system design [43].

Recent advancements in machine learning and predictive modeling further support the development of intelligent systems. Techniques such as ensemble learning [1], LSTM-based forecasting [29], and fuzzy logic-based forecasting models [42] improve prediction accuracy in uncertain environments. Data preprocessing methods [20] also play a critical role in enhancing model performance. Applications in agriculture and economics [25], [26], [27] demonstrate the versatility of these approaches.

Security and system reliability have also been widely studied. Access control mechanisms [4], [17], encryption techniques [2], and secure authentication methods [8] ensure safe handling of user data. Additionally, centralized digital platforms such as e-governance and e-court systems demonstrate scalable architectures for handling large datasets and user interactions [16]. Similarly, real-time monitoring systems using computer vision [5], [12] enable surveillance and crowd management in public environments.

Furthermore, emerging IoT-enabled systems [21] and smart environmental monitoring platforms [9] provide real-time insights into environmental conditions. Applications such as amphibious waste collection systems [23] also highlight the importance of sustainability in coastal environments.

Despite these advancements, existing systems primarily focus on environmental data or isolated features. Few platforms integrate environmental intelligence, user feedback, security, and sustainability into a unified framework.

The proposed Samudra Setu system addresses these limitations by combining:

- Real-time environmental data analysis
- Machine learning-based prediction models
- Crowdsourced user feedback
- Secure and scalable mobile architecture

This integrated approach provides a comprehensive solution for beach suitability assessment and sustainable coastal tourism management.

System Architecture

The proposed architecture [1] is designed for a Beach Recreational Suitability Mobile Application that analyzes beach conditions and provides intelligent recommendations for recreational activities. The system integrates machine learning, computer vision, natural language processing, and graph algorithms to support decision-making for beach visitors. It is developed using open-source technologies such as React Native, Django, MongoDB, and Python libraries.

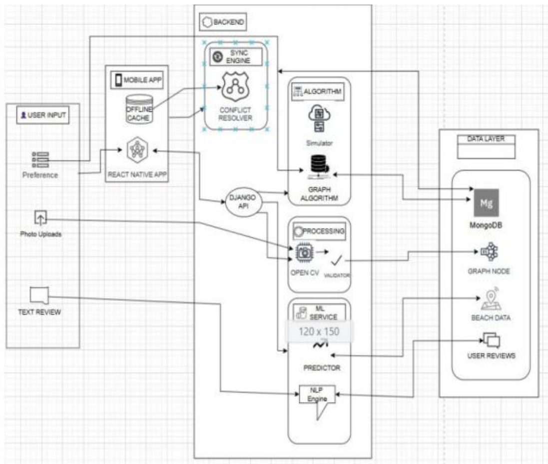

Fig 1: System Architecture of Samudra Setu Mobile Application [1]

1. Mobile Application (Input):
The mobile application serves as the main interface where users search for beaches, upload images of beach conditions, and submit reviews. It also displays suitability scores, travel itineraries, and eco-impact information. All user inputs are sent to the backend server for processing.

2. Recreational Suitability Prediction Model: A machine learning model predicts how suitable a beach is for recreational activities such as swimming or relaxation. The model analyzes environmental factors like weather, tide conditions, pollution levels, and seasonal patterns to generate a suitability score.

3. Crowdsourced Beach Condition Verification: Users can upload images of beach conditions such as cleanliness or crowd levels. These images are analyzed using OpenCV-based computer vision techniques to verify the information before updating the system database.

4. Personalized Itinerary Builder: This module generates optimized beach travel plans based on user preferences and suitability scores. Beaches are represented as nodes in a graph, and Dijkstra's algorithm is used to compute the most efficient travel route.

5. Sentiment Analysis for Beach Reviews: User reviews are processed using NLP techniques to determine the overall mood or vibe of a beach. The system analyzes text data to identify sentiments and important keywords related to user experiences.

6. Offline Data Synchronization: The system supports offline functionality by storing data locally on the device when internet connectivity is unavailable. Once the connection is restored, the data is synchronized with the backend server.

7. Eco-Impact Simulation Module: This module estimates the environmental impact of visiting a beach by calculating carbon emissions and potential waste generation. The system also provides eco-friendly suggestions to encourage sustainable tourism.

8. Backend Server and Database: All modules are connected through a Django backend server, which handles system processing and API communication. The system uses MongoDB to store beach data, user reviews, images, and suitability information.

Methodology

1. Data Collection: The application integrates real-time marine and meteorological data using the Open-Meteo API. Critical parameters include wave height and direction, wind wave height and direction, swell wave height and direction, and ocean current velocity and direction. Historical data is also incorporated for model training and validation, ensuring robustness and accuracy.

2. Data Processing And Normalization: Collected parameters are normalized to allow cross-comparison. Thresholds for safe recreational activities are defined based on scientific guidelines. Each parameter is assigned a weight, prioritizing high-impact factors like wave height and ocean current velocity.

3. Suitability algorithm: A multi-criteria decision-making model calculates a Suitability Index (SI) for each beach using the formula: Suitability Index (SI) = Σ (Weight * Parameter Score) / Σ Weights Based on the SI score, beaches are categorized as: Suitable (S1 > 0.8) Moderately Suitable (0.5 ≤ S2 ≤ 0.8) Not Suitable (S3 < 0.5)

4. Geospatial Visualization Using Gis Technology: the application displays suitability on interactive maps with color- coded markers (green, yellow, red) for each beach. Users can access detailed insights by clicking on markers.

5. User Notifications: Location-based alerts inform users of sudden risks like high waves or strong currents. Notifications are triggered dynamically based on real-time data changes.

Flowchart

1. **User Data Collection:** The process begins when the user accesses the system and provides basic information such as UserID, Username, and Email. The user can then upload beach images and submit beach reviews describing their experiences. All the uploaded images, reviews, and user details are stored in the system database. After storing the information, the collected data is forwarded to the next stage for further processing.

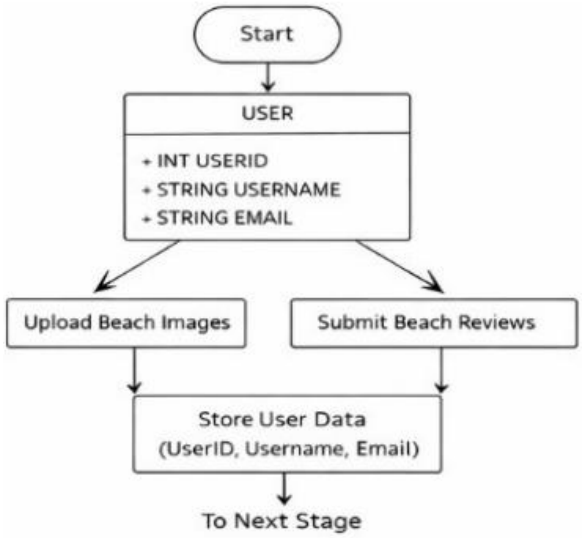

Fig 2: User Data Collection

2. Beach Condition Verification: In this stage, the system receives the uploaded beach images and performs image processing. A machine learning model then loads the required training data and analyzes the processed images to predict the beach suitability score. A consensus mechanism is applied to verify the prediction results and ensure reliability. Finally, the verified beach condition is updated in the beach database and passed to the next stage.

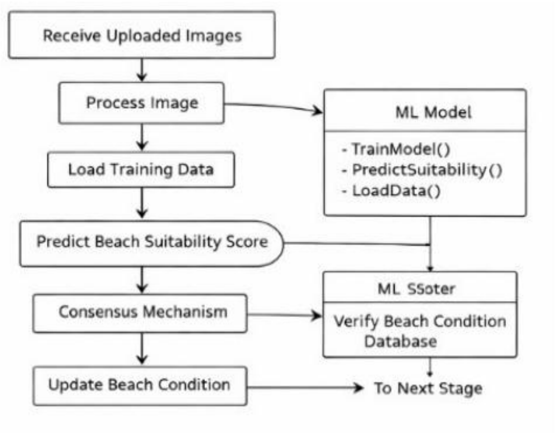

Fig 3: Beach Condition Verification

3. Review Sentiment Analysis: This stage focuses on analyzing the reviews submitted by users. The system first receives beach reviews and processes the text using sentiment analysis techniques. It analyzes the reviews, extracts important keywords, and generates a sentiment score indicating whether the feedback is positive, negative, or neutral. The sentiment results are then used to update the beach suitability information in the database.

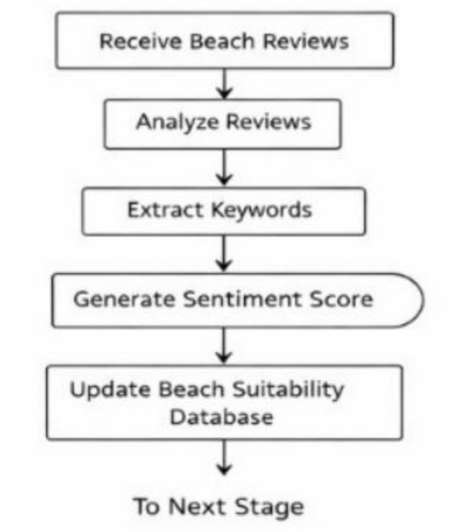

Fig 4: Beach Condition Verification

4. Beach Itinerary Planning: In the final stage, the system receives the verified beach data from the previous processes. It calculates the overall suitability score by considering factors such as beach conditions, sentiment scores, user preferences, and time constraints. The itinerary builder module then generates an optimized travel plan using a graph structure where beaches are represented as nodes and routes as edges. A shortest path algorithm is applied to determine the most efficient route, and the final itinerary is produced for the user.

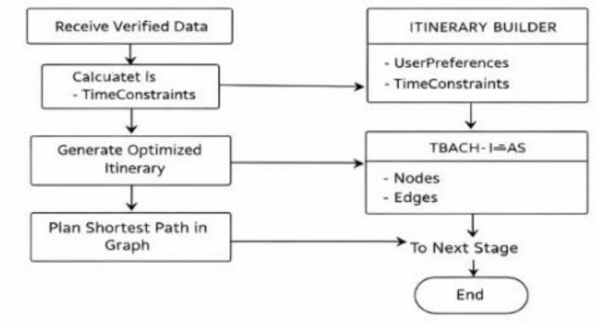

Fig 5: Beach Itinerary Planning

Expected Outcomes

The development and implementation of the proposed mobile application for coastal tourism suitability assessment is expected to deliver the following outcomes:

1. Enhanced Tourist Safety: The application will provide tourists with real-time safety assessments of beaches based on dynamic oceanic and meteorological conditions. By categorizing beaches as Suitable, Moderately Suitable, or Not Suitable, it ensures that users can make informed decisions about their recreational plans, reducing the risk of accidents and injuries.

2. Improved Planning for Tourism Activities: Tourists and travel planners will have access to detailed suitability insights for beaches across India. This data-driven approach will allow for better scheduling of recreational activities, ensuring an optimal balance between enjoyment and safety.

3. Increased Stakeholder Awareness: Local governments, tourism authorities, and stakeholders will gain valuable insights into the conditions of beaches under their jurisdiction. This can drive investment in improving infrastructure, ensuring compliance with safety standards, and fostering sustainable tourism practices.

4 Dynamic Monitoring of Beach Conditions: The system provides continuous updates on environmental parameters such as wind speed, wave height, and tidal conditions. These updates allow the application to classify beaches dynamically into safe, moderate, or unsafe categories.

5 Interactive Map Visualization: The application includes an interactive map that displays Indian beaches along with markers showing safety status, suitability levels, and the availability of facilities. This visualization helps users easily identify suitable destinations.
6. Effective Risk Mitigation: The application's alert system notifies users about sudden changes in ocean conditions, including strong waves, dangerous currents, or extreme weather events. These alerts help reduce exposure to hazardous situations.
7. Support for Sustainable Tourism: By integrating oceanographic and environmental data, the system promotes responsible tourism practices and aligns with India's Blue Economy initiatives. It encourages visitors to choose environmentally safe beaches and supports balanced tourism development.
8. Positive User Experience: The intuitive and user-friendly interface, coupled with actionable insights, will enhance user satisfaction. Tourists will feel empowered with real-time, reliable data for decision-making, improving their overall travel experience. Visitors have the option to upload pictures, rate the cleanliness, and file safety reports, hence fostering a community led platform.
9 Administrative Data Dashboard: A dedicated dashboard provides administrators and policymakers with visualized data on beach conditions, crowd distribution, and safety trends. This information supports better decision-making and coastal management.

Result
The proposed Samudra Setu mobile application is expected to significantly enhance coastal tourism in India by providing real-time, data-driven insights into beach safety and recreational suitability. By integrating environmental parameters such as wave conditions, tides, weather, and water quality with machine learning models and crowdsourced user feedback, the system enables accurate classification of beaches into safe, moderate, or unsafe categories. This improves tourist safety, supports better travel planning, and reduces the risk of accidents. Additionally, features like personalized itinerary generation, sentiment analysis of reviews, and interactive GIS-based visualization enhance user experience and decision-making. The platform also benefits authorities by offering an administrative dashboard for monitoring beach conditions and crowd patterns, while promoting sustainable tourism through eco-impact awareness. Overall, the system delivers a comprehensive, intelligent, and user-centric solution that supports safer recreation, efficient tourism management, and environmentally responsible coastal development.

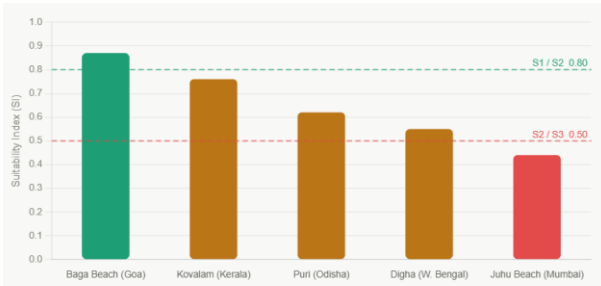

Fig 6: Recreational Suitability Index (SI) scores for five evaluated Indian beach locations

Table 1: *Recreational Suitability Assessment Results for Selected Indian Beach Locations*

Beach Location	State	Wave Height (m)	Current Velocity (m/s)	Wind Speed (m/s)	SI Score	Category	Suitability Status
Baga Beach, Goa	Goa	0.4	0.3	0.5	0.87	S1	Suitable
Kovalam Beach	Kerala	0.6	0.5	0.6	0.76	S2	Moderately Suitable
Puri Beach	Odisha	0.7	0.6	0.7	0.62	S2	Moderately Suitable
Digha Beach	West Bengal	0.8	0.7	0.8	0.55	S2	Moderately Suitable

Dashed lines indicate the S1/S2 threshold (0.80) and S2/S3 threshold (0.50).[2]

Conclusion
This research presents Samudra Setu, a mobile application designed to evaluate and provide recreational suitability information for beaches across India. By integrating environmental data, machine learning models, crowdsourced verification, and advanced analytical techniques, the system provides tourists with accurate and reliable information regarding beach safety and conditions. The proposed solution not only enhances tourist safety but also supports sustainable tourism development and coastal

resource management. Future work may include expanding the system to support additional coastal regions, integrating IoT sensors for real-time monitoring, and improving prediction accuracy through advanced machine learning models. Overall, the deployment of this system is expected to improve environmental awareness,reduce accident risks, and promote responsible tourism. It will also help distribute tourism activity across multiple beaches, benefiting local economies and supporting sustainable coastal development.

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