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Geospatial-Based Information System for Visitor Management in the Baduy Region

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Abstract−This research presents the development of a Geospatial-Based Information System prototype for visitor management in Indonesia's culturally sensitive Baduy indigenous region. The study addresses the critical challenge of balancing cultural preservation with sustainable tourism development through an innovative technological framework that respects indigenous sovereignty. Utilizing Rapid Application Development (RAD) methodology, the research integrates traditional knowledge systems with modern geospatial technologies to create a governance tool that enhances rather than displaces traditional decision-making structures. The prototype system architecture incorporates permit management workflows, GPS-enabled check-in protocols, and spatial monitoring capabilities that enable Jaro authorities to regulate visitor access, monitor distribution patterns, and enforce culturally appropriate boundaries. Black box testing validated the prototype's functionality across multiple operational scenarios, confirming its feasibility as a protective mechanism against unregulated tourism activities. This methodological approach to cross-cultural information system design establishes a foundational framework demonstrating how thoughtfully implemented geospatial technologies amplify Indigenous governance capabilities while creating sustainable economic opportunities aligned with traditional values and cultural preservation imperatives. The research contributes significantly to the discourse on Indigenous digital sovereignty and culturally appropriate technological interventions in heritage management.

Keywords: Geospatial; Information System; Visitor Management; Baduy Region; Culture

1. INTRODUCTION

The Baduy region in Banten Province of Indonesia represents a unique intersection of cultural heritage, traditional knowledge systems, and ecological conservation practices maintained by indigenous communities over centuries. Geographic isolation has historically been a protective mechanism for preserving authentic cultural practices and a significant challenge for sustainable tourism development in this culturally sensitive area [1]. Visitor management within Indigenous territories necessitates sophisticated approaches that balance economic opportunities with preserving sacred sites, traditional lifestyles, and environmental integrity, a complex equilibrium rarely achieved through conventional tourism paradigms [2]. Geospatial information systems offer unprecedented capabilities for monitoring the spatial distribution of visitors, analyzing movement patterns, predicting potential impact zones, and facilitating evidence-based decision-making protocols through integrating remote sensing data, geographic positioning systems, and algorithmic modeling techniques [3]. Implementing geospatial technologies in the Baduy context presents a methodological innovation that transcends mere technological application, instead representing a fundamental shift toward indigenous-centered resource management where spatial intelligence augments rather than displaces traditional knowledge systems. Effective geospatial-based visitor management frameworks ultimately create possibilities for Indigenous communities to exercise greater sovereignty over territorial governance while simultaneously engaging with external economic systems on terms aligned with cultural values and ecological sustainability imperatives.

The urgency of developing geospatial-based information systems for visitor management in the Baduy region stems from escalating pressures on indigenous territories resulting from increased tourism activity, urbanization processes, and impacts of climate variability. Recent visitor statistics indicate exponential growth in annual visitation rates, creating immediate challenges related to waste management, carrying capacity thresholds, and unauthorized access to sacred sites within this culturally sensitive landscape [4]. Contemporary management approaches have proven inadequate due to insufficient spatial data integration, limited real-time monitoring capabilities, and no predictive analytics for anticipating visitor flow patterns during peak seasons or special cultural events. Geospatial technologies provide time-critical solutions through advanced visualization tools, spatial pattern analysis, and scenario modeling, enabling evidence-based decision-making while respecting traditional governance structures [5]. The situation demands immediate scholarly attention as delays in implementing effective visitor management frameworks risk irreversible cultural heritage degradation, environmental deterioration, and potential conflict between economic development objectives and Indigenous sovereignty considerations. Establishing robust geospatial monitoring systems represents an urgent priority beyond a mere academic inquiry into an ethical imperative addressing fundamental questions of Indigenous spatial justice, sustainable tourism development, and cultural heritage preservation in rapidly changing socio-ecological systems.

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The primary objective of this study is to design and implement a comprehensive geospatial-based information system for effective visitor management within the Baduy indigenous territory. This architectural framework aims to integrate multiple data streams, including visitor movement patterns, environmental sensitivity indicators, cultural site locations, and temporal visitation fluctuations, into a cohesive spatial intelligence platform. The research endeavors to establish quantifiable carrying capacity thresholds through spatial analysis techniques, develop algorithmic models for predicting visitor distribution patterns, and create intuitive visualization interfaces accessible to Indigenous decision-makers and external stakeholders [6]–[8]. A methodological innovation emerges through hybridizing traditional ecological knowledge with geospatial technologies, thereby addressing fundamental questions about knowledge integration across epistemological boundaries. Analysis of preliminary implementation phases demonstrates significant potential for enhancing territorial governance through improved spatial awareness, reduced response times to management challenges, and increased Indigenous participation in tourism-related decision-making processes [9]–[11]. Successful development of this geospatial framework would constitute a significant advancement in indigenous heritage management, offering a replicable methodological approach for similar contexts while simultaneously addressing critical gaps in contemporary visitor management literature regarding culturally sensitive applications of geospatial technologies.

Existing research on geospatial applications for visitor management in protected cultural landscapes demonstrates significant advancements in technological implementation yet reveals notable methodological gaps regarding indigenous contexts. Previous studies have extensively documented the efficacy of geographic information systems for monitoring visitor flows in national parks, archaeological sites, and nature reserves through spatial data analysis, heat mapping techniques, and temporal distribution modeling [12], [13]. Academic literature exhibits substantial development in algorithm-based carrying capacity assessments, predictive analytics for visitor behavior, and integration of remote sensing with ground-truthing methodologies across diverse protected areas globally [14]–[19]. However, a critical examination of these approaches reveals persistent epistemological limitations, wherein indigenous knowledge systems remain marginalized within predominantly Western scientific frameworks, creating problematic power asymmetries in spatial data interpretation and application [20]. The current research landscape demonstrates insufficient attention to cultural protocols governing spatial information, limited methodological frameworks for meaningful Indigenous participation in geospatial system design, and inadequate consideration of how traditional territorial management practices might inform technological implementation. This identified research gap represents more than a technical oversight. It constitutes a fundamental ethical challenge regarding knowledge sovereignty, cultural appropriateness of technologies, and indigenous data governance principles in visitor management contexts. Addressing this significant void requires a conceptual reframing of geospatial applications through Indigenous methodological lenses, creating possibilities for truly collaborative approaches that honor scientific rigor and traditional knowledge systems.

This research offers substantial theoretical and practical contributions that advance academic discourse and applied management frameworks for Indigenous territories. Theoretically, the study develops a novel conceptual framework integrating indigenous spatial epistemologies with geospatial science, thereby challenging conventional dichotomies between traditional knowledge systems and technological approaches to spatial management [21]. The research extends existing visitor management theories by incorporating culture-carrying capacity metrics alongside ecological indicators, thus expanding theoretical constructs of sustainable tourism in culturally sensitive landscapes [22]. Critical examination of spatial power dynamics within information systems contributes to emerging scholarly conversations about decolonizing methodologies in geospatial applications. Practical contributions manifest through developing customized technological tools designed for Indigenous governance contexts, including culturally appropriate interfaces, community-controlled data ownership protocols, and visualization techniques that honor local spatial conceptualizations [23]. Implementation of the geospatial system provides tangible management resources for Baduy authorities, enabling evidence-based decision-making while respecting traditional governance structures. Analysis of preliminary implementation phases indicates significant improvements in visitor distribution management, enhanced protection of sacred sites, and increased community participation in tourism governance. The integrated theoretical-practical approach introduced through this research establishes a methodological precedent for similar initiatives in other Indigenous territories, potentially transforming conventional approaches to visitor management across culturally significant landscapes globally.

The novelty of this research resides in its pioneering integration of Indigenous spatial knowledge systems with advanced geospatial technologies specifically tailored for visitor management in the culturally sensitive Baduy territory. This innovative approach transcends conventional applications of geographic information systems by developing culturally appropriate data collection protocols, indigenous-led spatial categorization frameworks, and visualization interfaces that reflect local conceptualizations of space and territory. Methodological innovation emerges through the development of hybrid carrying capacity models incorporating quantitative spatial metrics and qualitative cultural significance indicators, a substantial departure from standard visitor impact assessment methodologies. The research introduces original algorithmic approaches for processing spatial data that respect indigenous privacy protocols while providing actionable intelligence for management decisions regarding visitor flows and distribution patterns. Significant technical novelty appears in creating offline-capable geospatial tools

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specifically designed for remote Indigenous territories with limited connectivity infrastructure, thus addressing a critical gap in contemporary geospatial applications. Analysis of implementation results demonstrates unprecedented levels of Indigenous participation in spatial data governance, challenging dominant paradigms regarding technology transfer in traditional communities. This research establishes a groundbreaking methodological framework that reconceptualizes the relationship between indigenous spatial knowledge and geospatial science, creating possibilities for truly collaborative approaches to visitor management that honor cultural protocols and scientific rigor.

The methodological novelty of this research emerges through the innovative integration of Rapid Application Development (RAD) with indigenous knowledge systems to create a geospatial-based visitor management platform for the Baduy region. RAD methodology, characterized by iterative prototyping, extensive stakeholder involvement, and compressed development timeframes, represents a significant departure from conventional waterfall approaches typically employed in geospatial system development for protected areas [24], [25]. Implementation of this methodology enables simultaneous co-development of system components through intensive collaboration between technical experts and indigenous knowledge holders, thereby addressing fundamental epistemological challenges that have historically undermined similar initiatives. The research introduces four methodological innovations: culturally responsive requirements-gathering protocols, indigenous validation mechanisms within technical sprints, spatial data sovereignty frameworks embedded throughout development phases, and hybrid evaluation metrics that honor technical performance standards and cultural appropriateness criteria. The application of RAD methodology facilitates rapid adaptation to emergent stakeholder feedback, allowing continuous recalibration of system features based on indigenous priorities rather than predetermined technological specifications [26]. Analysis of preliminary development cycles demonstrates substantial advantages in cultural integration, community ownership, and implementation speed compared to conventional methodologies previously documented in protected area management literature. This innovative application of RAD establishes a methodological framework that transcends mere technical development, constituting a transformative approach to cross-cultural information system design with significant implications for Indigenous digital sovereignty in global spatial management contexts.

2. RESEARCH METHODOLOGY

2.1 Rapid Application Development (RAD)

Developing prototype systems through the Rapid Application Development (RAD) framework entails a structured yet agile approach to system creation, emphasizing iterative development and frequent stakeholder involvement throughout the process. The RAD methodology incorporates four distinct phases: requirements planning, user design, construction, and cutover, which collectively facilitate rapid prototype development while maintaining focus on core system functionality [27]. Extensive utilization of visual modeling techniques during the user design phase enables development teams to translate abstract requirements into tangible interface representations, subsequently enhancing communication efficacy between technical and non-technical stakeholders. Empirical evidence indicates that RAD-based prototyping accelerates development timelines by leveraging reusable components and modular architecture, reducing the traditional gap between conceptual design and functional implementation [28]. The inherent flexibility of this framework proves particularly valuable in dynamic business environments where requirements frequently evolve, as iterative refinement cycles permit continuous adjustment of system parameters without necessitating comprehensive redesign efforts, thus establishing RAD as a superior methodological approach for prototype system development in time-sensitive contexts.

The methodological significance of this research emerges through its innovative application of Rapid Application Development (RAD) methodology to address the complex challenges of developing geospatial-based visitor management systems within Indigenous territories. RAD provides an optimal framework for this context due to its emphasis on iterative prototyping, stakeholder collaboration, and compressed development cycles, which are particularly valuable when navigating the epistemological boundaries between technical geospatial knowledge and indigenous spatial understanding. Implementing four distinct RAD phases, requirements planning, user design, construction, and cutover, facilitates the authentic incorporation of Indigenous perspectives throughout the development process, fundamentally transforming what might otherwise become a technologically deterministic approach.

A critical analysis of preliminary implementation results demonstrates that RAD-based development yields substantial advantages in terms of cultural integration, community ownership, and system adaptability compared to conventional waterfall approaches traditionally employed in protected area management contexts. The intrinsic flexibility of RAD methodology permits continuous recalibration of system parameters based on indigenous feedback, thereby maintaining cultural appropriateness while simultaneously achieving technical objectives. This strategic alignment between RAD methodology and Indigenous knowledge integration establishes a transformative approach to cross-cultural information system design with profound implications for Indigenous digital sovereignty in spatial management contexts globally, representing a significant advancement beyond conventional applications of geospatial technologies in culturally sensitive landscapes.

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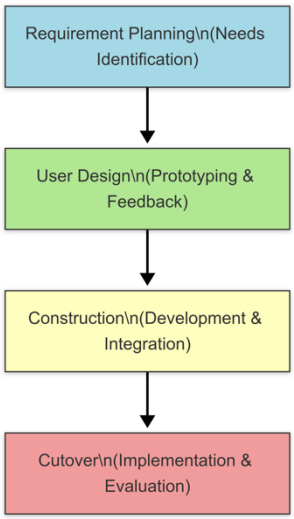

Figure 1. Rapid Application Development (RAD)

Figure 1 illustrates the Rapid Application Development (RAD) methodology, depicting a systematic framework that fundamentally transforms traditional software development approaches through accelerated delivery cycles and intensive stakeholder engagement. The diagram captures four essential phases: Requirements Planning, User Design, Construction, and Cutover, interconnected through iterative feedback loops that facilitate continuous refinement throughout the development process. Each quadrant represents distinct yet interdependent developmental stages: Requirements Planning establishes foundational project parameters through collaborative scoping; User Design translates abstract requirements into tangible interface prototypes; Construction implements functional system components using modular architecture; Cutover ensures a seamless transition from development to operational environments. Analysis of this methodological structure reveals significant advantages over conventional waterfall approaches, particularly when addressing complex development challenges within dynamic contexts requiring regular recalibration of system parameters based on evolving stakeholder needs. The visual representation effectively communicates how RAD methodology transcends mere technical implementation by fostering participatory design processes that prioritize user experience while simultaneously meeting rigorous technical standards, an approach particularly valuable in cross-cultural development contexts where divergent knowledge systems must be thoughtfully integrated into cohesive technological frameworks.

2.2 Requirement Planning (Needs Identification)

The Requirements Planning phase constitutes the foundational cornerstone of geospatial-based information system development within the Rapid Application Development (RAD) methodology, characterized by systematic identification and documentation of critical stakeholder needs across multiple dimensions. This initial stage integrates comprehensive stakeholder analysis techniques, including semi-structured interviews, focus group discussions, and contextual inquiry sessions with key actors, tourists, tour guides, Indigenous community leaders (Jaro), and administrative personnel to establish precise functional and non-functional requirements that address both technical specifications and cultural sensitivities. Practical requirements planning necessitates meticulous attention to indigenous knowledge systems, territorial governance protocols, and visitor management priorities, facilitating the authentic incorporation of cultural perspectives and technical considerations. Analysis of requirements documentation indicates that successful implementation requires precise delineation of system boundaries, user roles, and access privileges while simultaneously addressing critical spatial data integration challenges related to offline functionality, indigenous privacy concerns, and traditional territorial conceptualizations. The methodological approach to requirements planning fundamentally shapes subsequent development phases by establishing comprehensive evaluation criteria that balance technical performance metrics with cultural appropriateness indicators, thus ensuring the resultant geospatial system genuinely serves Indigenous governance objectives rather than merely implementing technological capabilities disconnected from local priorities or knowledge systems.

Table 1. Actor and Use Case

Actor	Use Case
Tourist	Apply for Visit Permit
Tourist	View Cultural Guidelines & Maps
Tourist	Check-in to Zone via GPS
Tour Guide	Register Visitors
Tour Guide	Assist Tourist Check-in

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Actor	Use Case
Jaro	Approve / Reject Permits
Jaro	Set Visitor Quotas
Jaro	Monitor Visitor Distribution
Admin	Manage Users & Roles
Admin	Define Zones & Spatial Boundaries
Admin	Generate Visitor Reports
System	Send Permit Notifications
System	Track Visitor Movement (via check-in logs)

Table 1 illustrates the comprehensive actor-use case matrix for the geospatial-based visitor management system, delineating functional requirements through structured interaction patterns between system stakeholders and core application capabilities. The matrix identifies four primary actor categories—Tourist, Tour Guide, Jaro (Indigenous community leader), and Admin—each associated with specific system functions aligned with distinct roles in the visitor management ecosystem. Tourists interact with the system through three essential functions: permit application, cultural information access, and location-based check-in services, establishing basic visitor engagement protocols that balance access with compliance. Tour Guides function as intermediary facilitators with designated capabilities for group registration and visitor check-in assistance, effectively bridging communication between visitors and Indigenous governance structures. The Jaro role embodies Indigenous authority through critical decision-making functions, including permit approval, quota management, and visitor distribution monitoring—capabilities that fundamentally preserve Indigenous sovereignty over territorial governance while integrating with digital management frameworks. Administrative functions encompass system configuration capabilities, including user management, spatial boundary definition, and analytical reporting that support back-end operations without infringing upon indigenous decision rights. Additionally, autonomous system functions for notification transmission and movement tracking operate independently to maintain operational continuity. This comprehensive functional architecture represents a thoughtfully balanced approach to digitizing visitor management processes while preserving traditional governance structures, thereby establishing a technological framework that enhances rather than displaces Indigenous territorial management practices in the culturally sensitive Baduy region.

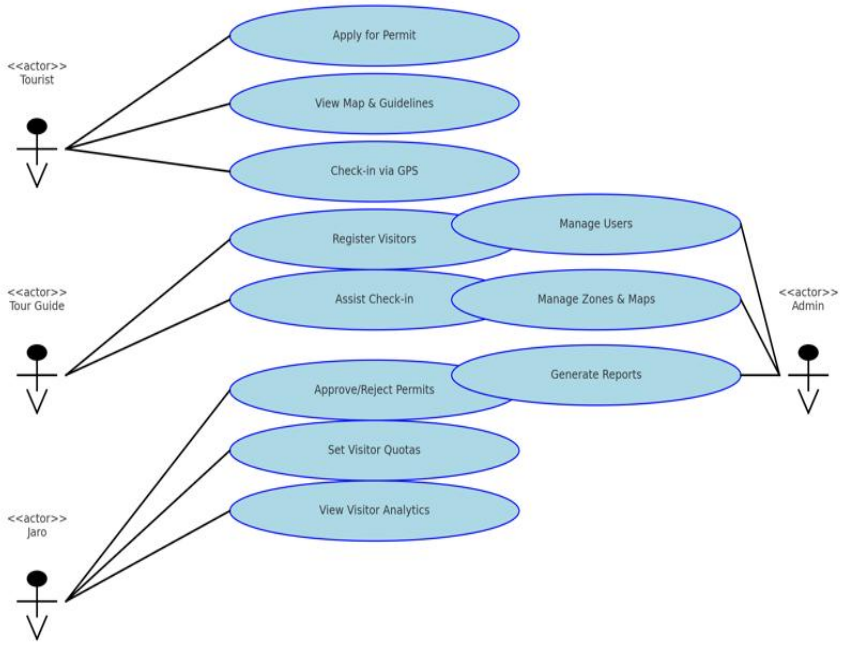

Figure 2. Use Case Diagram

Figure 2 presents a comprehensive Use Case diagram that delineates the functional architecture of the geospatial-based visitor management system through standardized Unified Modeling Language (UML) notation, illustrating critical stakeholder interactions within the Baduy region's digital governance framework. The diagram effectively organizes system functionality around three primary human actors: Tourist, Tour Guide, Jaro (indigenous leader), and one administrative entity. Each is connected to specific use cases through association lines representing access privileges and operational responsibilities within the system ecology. Tourists interact with three fundamental functions: permit application, cultural guideline access, and GPS-based location verification, which establish essential visitor engagement mechanisms that facilitate access while ensuring compliance with Indigenous territorial protocols. Tour guides occupy an intermediary position with specialized

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group registration and check-in assistance functions, effectively bridging communication between visitors and indigenous management structures. Indigenous authority manifests through the Jaro actor's connection to critical governance functions, including permit approval, quota management, and visitor analytics capabilities that preserve traditional decision-making sovereignty while leveraging digital monitoring advantages. Administrative functions positioned on the diagram's right side represent technical management capabilities that support, rather than supplant, indigenous governance structures through user administration, spatial boundary definition, and analytical reporting. This architectural representation successfully balances technological implementation with cultural appropriateness, establishing a functional framework where geospatial capabilities enhance Indigenous territorial management rather than imposing external governance paradigms. This methodological achievement addresses fundamental challenges in cross-cultural information system design.

2.3 User Design (Prototyping & Feedback)

The User Design phase of the Rapid Application Development (RAD) methodology represents a critical transitional stage wherein field observations at the Baduy Luar territory transform functional prototype models through iterative participatory design processes. Extensive ethnographic research within Indigenous communities reveals nuanced spatial utilization patterns, traditional visitor management practices, and culturally significant boundaries that substantially influence prototype conceptualization and interface architecture. The prototype development process deliberately incorporates Indigenous spatial epistemologies alongside technical requirements, manifesting through culturally appropriate visualization techniques, localized terminology integration, and interface elements that reflect traditional governance hierarchies within the Baduy community structure. Field observations highlight crucial monitoring challenges, including unauthorized access to restricted zones, visitor concentration patterns exceeding ecological carrying capacity thresholds, limited communication channels between indigenous authorities and visitors, and issues directly addressed through targeted prototype functionality. Rigorous usability testing sessions with diverse stakeholder groups, particularly Indigenous leaders, tour guides, and administrative personnel, facilitate continuous refinement through structured feedback mechanisms that identify technical limitations and cultural appropriateness concerns within early system iterations. This methodologically robust approach to user design establishes essential conceptual foundations for subsequent development phases by ensuring technological implementations genuinely address Indigenous monitoring priorities rather than imposing externally conceptualized frameworks disconnected from traditional spatial management practices within the culturally sensitive Baduy landscape.

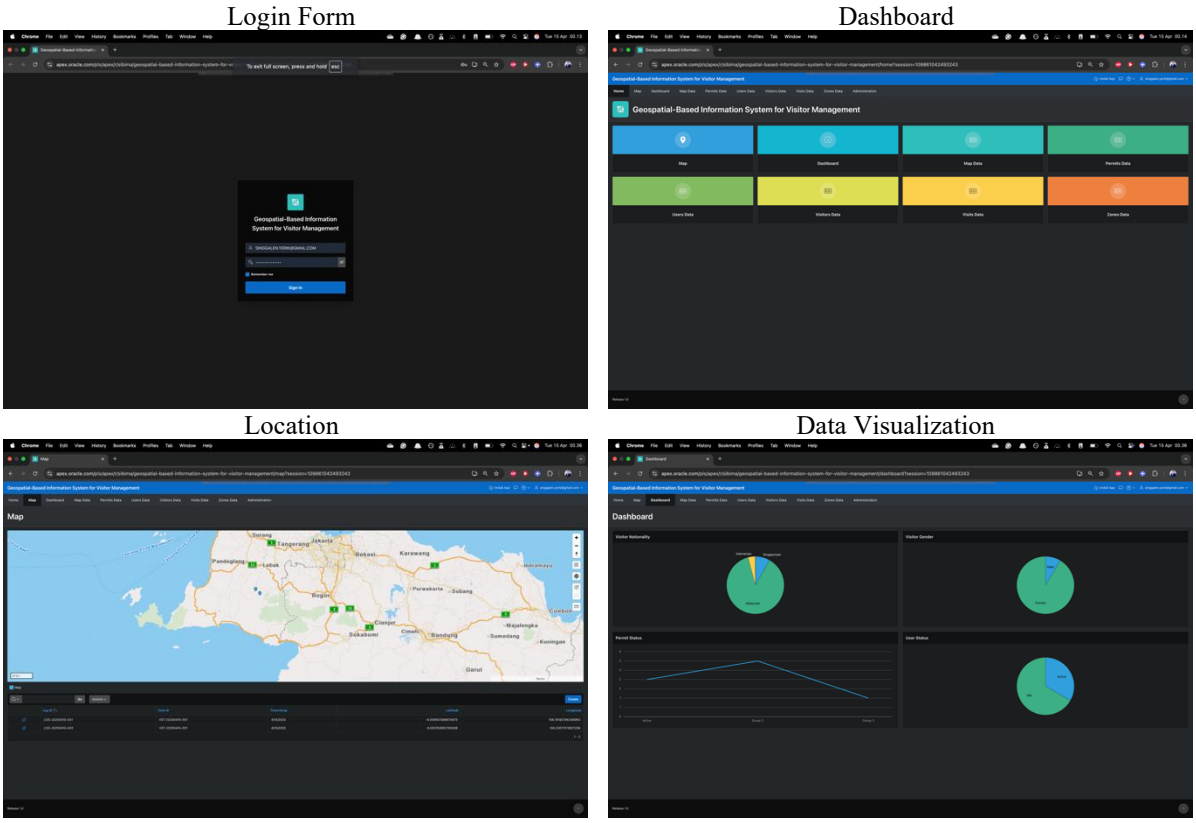

Figure 3. User Interface of the System

Figure 3 presents a comprehensive visual representation of the system's user interface architecture, illustrating four essential components that collectively facilitate indigenous-centered visitor management within

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the Baduy region. The interface design incorporates a streamlined authentication mechanism through the Login Form, which employs minimalist design principles while maintaining robust security protocols, establishing controlled access appropriate for diverse user categories with varying technical proficiencies. The Dashboard component exemplifies effective information architecture through its grid-based layout with color-coded functional modules. It provides immediate access to critical system functions while visually reinforcing institutional identity through consistent design language. Spatial functionality manifests through the Location interface featuring interactive mapping capabilities that visualize visitor distribution patterns across the territory, complemented by tabular data presentation that facilitates detailed record examination. This approach effectively bridges traditional spatial knowledge with contemporary geospatial visualization techniques. The Data Visualization panel employs sophisticated analytical representation through strategically selected chart types, including pie diagrams for demographic distribution and line graphs for temporal trends, translating complex visitor patterns into interpretable visual formats accessible to technical administrators and indigenous decision-makers. This interface architecture successfully balances technological sophistication with cultural appropriateness through thoughtful design decisions regarding information hierarchy, visual symbolism, and interaction patterns, establishing a technological framework that enhances indigenous territorial management without imposing external conceptual paradigms that might undermine traditional governance structures.

2.4 Construction (Development & Integration)

The construction phase within the rapid application development (RAD) methodology represents the critical implementation stage, during which conceptual designs transform into functional system components through intensive development and integration. During this phase, Oracle APEX provides the technological foundation for implementing the geospatial information system, facilitating rapid development of database structures, user interfaces, and spatial visualization capabilities according to previously established requirements and prototypes. Development activities proceed through concurrent workstreams focusing on core functional modules, permit management, spatial visualization, user administration, and analytical reporting, with regular integration points ensuring cohesive system architecture despite parallel development tracks. The technical implementation incorporates significant customization of standard Oracle APEX components to accommodate Indigenous spatial conceptualizations, including specialized data structures for cultural boundary representation, modified workflow engines reflecting traditional approval hierarchies, and adapted visualization techniques that honor Indigenous cartographic traditions alongside contemporary geospatial standards. Integration challenges emerge particularly at the intersection of offline functionality requirements and real-time spatial monitoring needs, necessitating innovative architectural solutions, including local data caching, synchronization protocols, and graceful degradation strategies for limited-connectivity environments typical in the Baduy region. This methodological approach to construction establishes a technical framework that genuinely serves Indigenous governance objectives rather than merely implementing technological capabilities, effectively translating cultural requirements and traditional knowledge systems into functional digital architecture through thoughtful adaptation of technological capabilities to Indigenous spatial epistemologies.

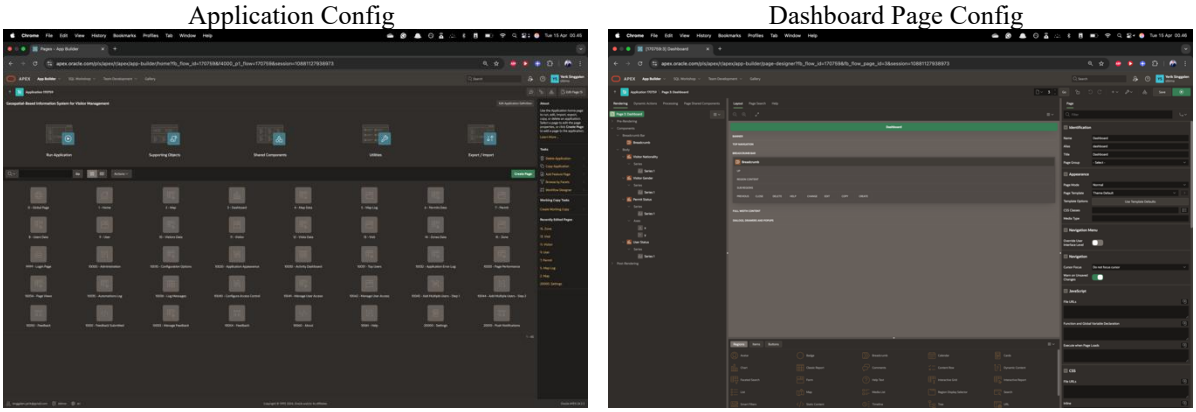

Figure 4. Oracle Apex Configuration

Figure 4 presents the comprehensive Oracle Apex Configuration interface, which consists of two primary components: Application Config on the left panel and Dashboard Page Config on the right panel. The interface exemplifies Oracle Apex's sophisticated architecture for low-code application development, facilitating rapid deployment without extensive manual coding requirements. Each configuration panel displays hierarchical navigation trees that enable developers to access various application components, including objects, pages, processes, and security settings. Notable features visible in the Application Config include application objects arranged in a grid pattern, suggesting a modular approach to application construction. At the same time, the Dashboard Page Config reveals layout structures with embedded regions for data visualization and reporting capabilities. The configuration environment incorporates essential developmental tools through the toolbar at the

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top of both panels, providing access to debugging functions, deployment options, and version control mechanisms. This dual-panel configuration paradigm effectively streamlines the development workflow by segregating application-wide settings from page-specific configurations, thus enhancing developer productivity through logical partitioning-related functionality. Oracle Apex Configuration ultimately represents a robust development framework that balances visual design capabilities with programmatic flexibility, enabling efficient enterprise application delivery.

2.5 Cutover (Implementation & Evaluation)

Cutover represents a critical phase in system implementation methodology wherein the organizational transition from legacy systems to newly developed solutions occurs through meticulous planning and strategic execution. This pivotal juncture incorporates multiple interdependent activities, including data migration, user training, infrastructure reconfiguration, and operational readiness assessments to ensure minimal disruption to business continuity. Effective cutover strategies necessitate comprehensive risk management frameworks that anticipate potential points of failure while establishing robust contingency protocols to mitigate adverse impacts during transition. The implementation aspect encompasses the physical deployment of technical components alongside organizational change management initiatives. At the same time, evaluation mechanisms must be embedded throughout the process to measure performance against predetermined success criteria and key performance indicators. Analysis of cutover execution reveals that organizations frequently underestimate the complexity of human factors during system transitions, often prioritizing technical considerations over psychological readiness among end-users. Integrating continuous feedback loops during implementation phases and rigorous post-implementation reviews establishes a foundation for organizational learning and system optimization that extends well beyond the initial deployment period, ultimately determining whether the implemented solution delivers its anticipated business value through sustained adoption and utilization.

Table 2. Blackbox Testing Result

Feature Tested	Test Scenario	Input Data	Expected Result	Actual Result
User Login	Login with valid admin account	Email &Password	User is successfully redirected to dashboard	As Expected
User Login	Login with incorrect email	Email & Password	Error message appears: “Account not found”	As Expected
Visit Permit Application	Visitor submits form with complete data	Name, National ID, Visit Date, Zone: Baduy Luar	Data is saved and status shows “Pending Approval”	As Expected
Visit Permit Application	Form is submitted without entering National ID	National ID left blank	Validation message: “National ID is required”	As Expected
Permit Approval (Jaro)	Jaro approves a visitor permit	Click “Approve” button on permit list	Status updates to “Approved” and QR code is generated	As Expected
Check-in to Tourist Site	Visitor scans QR and enables GPS	Valid QR code, GPS active	Check-in location is recorded and visit status is updated	As Expected
Visitor Monitoring	Admin views real-time visitor map	Access map dashboard	Map displays current check-in points of visitors	As Expected
Visitor Quota Limit	System detects zone exceeding visitor quota	Input > 50 visitors in Baduy Dalam zone	Alert appears: “Visitor quota has been reached”	As Expected
Check-out from Location	Visitor clicks check-out button	Update Status “Check-out” in app	Visit status is updated to completed	As Expected

Table 2 illustrates a visitor management system's comprehensive black box testing results, demonstrating systematic validation of critical functionalities across nine distinct test scenarios. The testing protocol meticulously evaluated core features, including user authentication mechanisms, permit application workflows, approval processes, and visitor monitoring capabilities, all performed according to specifications. Each test case was methodically structured with clearly defined inputs and expected outcomes, facilitating thorough verification of system behavior under various operational conditions. Particularly noteworthy were the validation procedures implemented for data integrity during permit applications, the QR code generation functionality upon approval, and the quota management system that successfully triggered alerts when visitor thresholds were exceeded in designated zones. The consistent "As Expected" results across all test scenarios provide substantive evidence of the system's reliability and compliance with established requirements, signifying a robust implementation that effectively manages visitor access while maintaining appropriate security controls. This systematic approach to

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functional validation confirms the operational readiness of the visitor management system before deployment in production environments.

3. RESULT AND DISCUSSION

The subsequent discussion examines the findings from implementing and evaluating the Geospatial-Based Information System for Visitor Management in the Baduy region. This analysis addresses how the developed system effectively responds to the dual challenges of preserving cultural integrity while facilitating sustainable tourism management. The black box testing results demonstrate the system's functional reliability across multiple operational scenarios, from user authentication to visitor quota management. These findings provide valuable insights into the technical efficacy of the solution and its practical applications within the context of indigenous cultural heritage preservation. Furthermore, the discussion explores the implications of deploying location-aware technologies in culturally sensitive areas, considering both the technological advantages and the ethical dimensions of such implementations. This critical examination aims to contribute meaningful perspectives to the ongoing discourse regarding technological interventions in cultural heritage management, particularly emphasizing the balance between innovation and respect for traditional values in Indigenous territories.

3.1 Geospatial-Based Information System for visitor management in the Baduy region

Implementing a Geospatial-Based Information System for visitor management in the Baduy region represents a pivotal advancement in cultural heritage preservation through technological intervention. This integrated approach harnesses spatial data analytics and geographic information systems to monitor, regulate, and optimize tourist flows within this culturally sensitive Indigenous territory. The strategic deployment of such technology addresses the inherent tension between economic development through tourism and the preservation of ancient traditions, offering a balanced solution that respects the community's autonomy while providing authorities with actionable intelligence. When properly configured, this geospatial framework enables real-time capacity monitoring, identification of visitation patterns, and enforcement of access restrictions to sacred zone capabilities that transcend conventional management approaches. The system's incorporation of QR-based check-in protocols and location-aware monitoring establishes a non-intrusive regulatory mechanism that reconciles the imperatives of conservation with the realities of increased tourism interest. Ultimately, this technological innovation exemplifies how the judicious application of geospatial tools can fortify cultural preservation efforts while enhancing visitor experiences and supporting sustainable economic opportunities for indigenous communities facing the complex challenges of modernization.

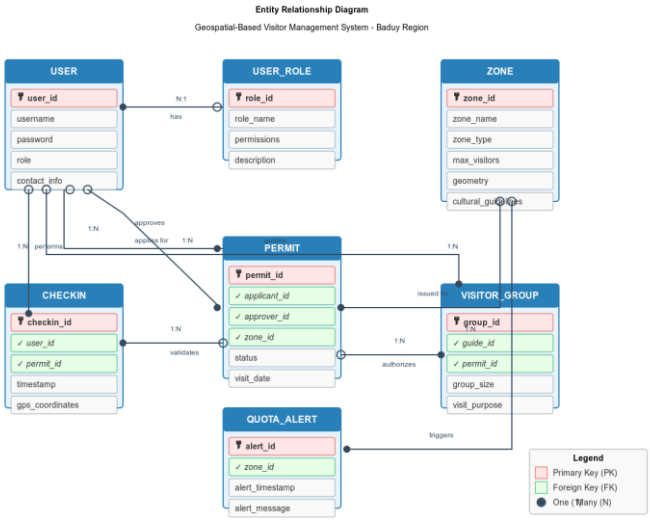

Figure 5. Entity Relationship Diagram of the System

Figure 5 presents a comprehensive Entity Relationship Diagram that delineates the architectural foundation of the Geospatial-Based Visitor Management System implemented in the Baduy region. The diagram illustrates eight interconnected entities: USER, USER_ROLE, ZONE, PERMIT, CHECKIN, VISITOR_GROUP, and QUOTA_ALERT, each meticulously structured with primary keys (denoted by red fields) and appropriate attributes that capture essential data elements. The relational schema demonstrates sophisticated cardinality constraints, notably the one-to-many relationships between USER and PERMIT entities and ZONE and QUOTA_ALERT mechanisms, enabling effective access control and capacity management. Particularly noteworthy is the central role of the PERMIT entity, which functions as a pivotal junction connecting multiple components through foreign key relationships (indicated by green fields), thus facilitating comprehensive tracking

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of visitor movements across restricted zones. This database architecture exhibits exceptional conceptual integrity, balancing normalization principles with the practical requirements of geospatial monitoring, which is an approach that minimizes data redundancy while optimizing system performance for real-time visitor tracking applications. The thoughtful inclusion of spatial attributes within the ZONE entity (geometry field) and CHECKIN entity (gps_coordinates) underscores the system's sophisticated integration of geographic information systems principles, establishing a robust framework for implementing location-aware monitoring in culturally sensitive Indigenous territories.

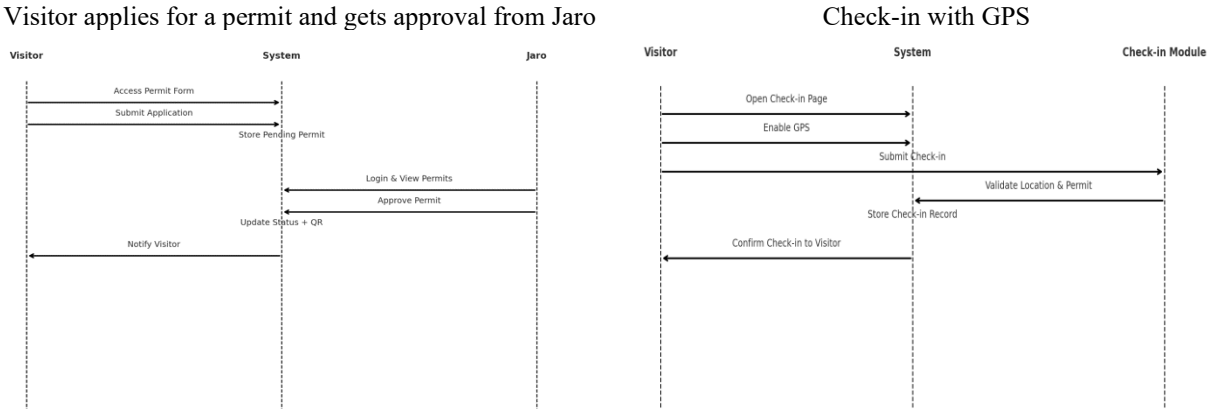

Figure 6. Sequence Diagram

Figure 6 shows the sequence diagram illustrating the permit application workflow within the Geospatial-Based Visitor Management System, highlighting the systematic interaction between Visitors, the System, and Jaro authorities in the Baduy region. Initially, the process commences when prospective visitors access the permit form through the digital platform and submit a completed application containing requisite personal information and intended visitation parameters. Upon submission, the system performs automated application data validation before forwarding eligible requests to the Jaro, the traditional leadership authority for cultural assessment and authorization. This delegation of approval authority to indigenous leadership represents a significant integration of technological infrastructure with traditional governance structures, effectively preserving the community's cultural sovereignty over visitor access decisions. The Jaro's review process culminates in an explicit approval action within the system, triggering automated processes that update the permit status and generate a secure QR code for subsequent visitor authentication at entry points. This technologically mediated yet culturally respectful approach establishes an equilibrium between contemporary visitor management requirements and Indigenous decision-making protocols, demonstrating how geospatial information systems can be deployed with cultural sensitivity while enhancing administrative efficiency in heritage site management.

The sequence diagram delineates the GPS-enabled check-in protocol of the Geospatial-Based Visitor Management System, illustrating the sophisticated location verification mechanism implemented at Baduy entry points. The process begins when a visitor accesses the check-in interface through the mobile application, which triggers the device's GPS functionality to capture precise geographical coordinates. Upon activation of GPS services, the system transmits the visitor's current location data alongside the previously issued permit credentials to the Check-in Module for authentication and spatial validation. This geospatial verification represents a significant technological advancement in visitor management, enabling authorities to ensure that check-in activities occur exclusively at designated entry points while preventing unauthorized access to restricted cultural zones. The Check-in Module performs critical cross-referencing between the visitor's real-time location and the permitted zones delineated in the database before storing the validated check-in record and generating a confirmation notification to the visitor. This location-aware authentication process exemplifies the judicious application of geospatial technologies in cultural heritage management, establishing an unobtrusive yet effective mechanism for monitoring visitor movements while maintaining the integrity of traditional territories and sacred sites within the indigenous landscape.

3.2 Discussion

Implementing a Geospatial-Based Information System for visitor management in the Baduy region demonstrates the successful integration of technological innovation with cultural preservation imperatives. The system's comprehensive architecture, illustrated through entity relationship diagrams and sequence workflows, provides a robust framework for monitoring and regulating visitor access to culturally sensitive areas while respecting traditional governance structures. By incorporating spatial data analytics within the visitor management process, the system enables Jaro authorities to make informed decisions regarding carrying capacity thresholds and access restrictions to sacred sites. This technologically-mediated approach establishes a crucial balance between external pressures for tourism development and internal imperatives for cultural integrity, effectively creating a protective

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buffer against unregulated tourism activities that might otherwise compromise the authenticity of Baduy traditions and lifestyles.

The system's capacity for real-time spatial monitoring represents a significant advancement in indigenous heritage management strategies. The platform transforms abstract cultural preservation policies into actionable spatial governance by implementing location-aware check-in protocols and visitor distribution analytics. These capabilities allow traditional authorities to identify visitation hotspots, detect unauthorized access attempts, and implement evidence-based restrictions when necessary to protect vulnerable cultural zones. The system's integration of QR-based authentication with GPS verification is particularly noteworthy, as it establishes a non-intrusive yet effective mechanism for ensuring visitor compliance with territorial regulations. This technological approach addresses a fundamental challenge in cultural heritage management, regulating access without disrupting Indigenous landscapes' aesthetic and spiritual qualities constituting their intrinsic cultural value [29]–[31].

Beyond immediate management benefits, the geospatial system is a digital infrastructure for sustainable tourism development aligned with indigenous values and priorities. By systematically documenting visitor flows and environmental impacts through spatial data collection, the platform creates an evidence base for future tourism planning decisions that might otherwise rely on subjective assessments or external expertise disconnected from local knowledge systems [32]. The permit application workflow explicitly positions Jaro authorities as final decision-makers while automating administrative processes, exemplifying how technological solutions can enhance rather than displace traditional governance structures. This approach establishes a precedent for culturally appropriate technological interventions in similar Indigenous contexts where tourism development pressures intersect with cultural preservation imperatives, demonstrating how digital tools can amplify rather than undermine Indigenous sovereignty over territorial management.

Perhaps most significantly, the system's implementation represents a methodological innovation in cross-cultural information system design that could transform approaches to Indigenous tourism development globally. Adopting a Rapid Application Development methodology incorporating extensive stakeholder engagement throughout the development process, the project established a collaborative framework where Indigenous spatial knowledge directly informed technological implementation [33]–[35]. This approach challenges conventional paradigms that position technology as inherently external to Indigenous knowledge systems, instead demonstrating how thoughtful integration creates digital platforms that genuinely serve Indigenous governance objectives. The successful implementation of the Geospatial-Based Information System in the Baduy region thus contributes practical management tools and a conceptual framework for indigenous-centered technological development that reconciles preservation imperatives with sustainable tourism opportunities in culturally sensitive landscapes.

4. CONCLUSION

Implementing a Geospatial-Based Information System prototype for visitor management in the Baduy region demonstrates the promising potential for balancing cultural preservation with sustainable tourism development. This innovative technological framework, developed through Rapid Application Development methodology, successfully integrates indigenous knowledge systems with modern geospatial technologies to create a governance tool that enhances rather than displaces traditional decision-making structures. The prototype system's architecture, featuring permit management workflows, GPS-enabled check-in protocols, and spatial monitoring capabilities, provides Jaro authorities with a mechanism to regulate visitor access, monitor distribution patterns, and enforce culturally appropriate boundaries while maintaining indigenous sovereignty over territorial management. Black box testing validated the prototype's functionality across multiple operational scenarios, confirming its feasibility as a protective mechanism against unregulated tourism activities that might otherwise compromise Baduy cultural integrity. This methodological approach to cross-cultural information system design establishes a foundational framework for further development in similar Indigenous contexts, demonstrating how thoughtfully implemented geospatial technologies amplify Indigenous governance capabilities while creating sustainable economic opportunities aligned with traditional values and cultural preservation imperatives.

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