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Article

# GraamSoochna: An AI-Driven Multilingual Digital Notice Platform for Inclusive Rural Governance

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**Abstract:** Effective communication between Panchayats and citizens is vital for transparent rural governance; however, traditional dissemination methods often suffer from limited accessibility, delayed updates, and authenticity issues. To address these challenges, GramSoochna proposes an intelligent multilingual digital notice system implemented as a Progressive Web Application (PWA) with offline support for low-connectivity regions. The system employs a multimodal AI-based framework to extract, structure, and translate notices from text, images, and documents using Natural Language Processing and Large Language Models. An interactive Text-to-Speech module with synchronized highlighting enhances accessibility for elderly, visually impaired, and low-literacy users. The platform further provides personalized recommendations, real-time notifications, and secure administrative controls to ensure timely and authentic information dissemination. Experimental results demonstrate up to 99.2% accuracy in content extraction, highlighting the system's effectiveness in improving accessibility, citizen participation, and transparency in rural governance.
**Keywords:** Rural Governance; Artificial Intelligence; Multilingual Communication; Progressive Web Applications; Text-to-Speech; Smart Governance.

## 1. INTRODUCTION

The rapid advancement of digital technologies has significantly transformed governance, enabling improved transparency, efficiency, and citizen participation. Despite the widespread adoption of e-governance initiatives, rural areas in India continue to experience a considerable digital divide. Panchayati Raj Institutions (PRIs), which constitute the foundation of local self-governance, still rely heavily on conventional communication mechanisms such as physical notice boards, printed circulars, and informal messaging platforms. These traditional methods often suffer from limited reach, delayed dissemination, lack of authentication, and inadequate accessibility, particularly for citizens with diverse linguistic backgrounds and varying literacy levels. Consequently, important information related to welfare schemes, public services, and emergency announcements frequently fails to reach the intended beneficiaries in a timely manner.

To overcome these challenges, this work proposes GraamSoochna, an intelligent multilingual digital notice system designed to establish reliable, real-time, and inclusive communication between Panchayats and citizens. The proposed system is implemented as a cloud-enabled Progressive Web Application (PWA), providing seamless cross-platform accessibility while supporting offline functionality for regions with intermittent internet connectivity.

A key feature of GraamSoochna is its multimodal AI-based processing framework, which automatically extracts, summarizes, and translates notices from multiple input formats, including text documents, images, and PDF

files. By integrating advanced Natural Language Processing (NLP) techniques and Large Language Models (LLMs), the system generates context-aware multilingual content, thereby improving information accessibility across diverse communities. In addition, an interactive Text-to-Speech (TTS) module with synchronized sentence-level highlighting enhances usability for elderly individuals, visually impaired users, and citizens with limited literacy.

The platform further incorporates personalized notice recommendations based on user preferences and locality, enabling citizens to receive relevant information efficiently. Real-time push notifications ensure timely dissemination of critical announcements, while secure role-based administrative controls guarantee the authenticity and integrity of published notices. By combining AI-driven automation, accessibility features, and scalable cloud architecture, GraamSoochna serves as an intelligent digital bridge that strengthens transparency, enhances citizen participation, and improves the overall effectiveness of rural governance.

## 2. LITERATURE SURVEY

Several studies have explored digital notice board systems, recommendation techniques, and intelligent notification mechanisms to improve information dissemination. Early digital notice board systems primarily focused on cloud-based architectures. The cost-effective smart notice board proposed by [1] employed Raspberry Pi devices, cloud storage, and speech-to-text functionality to provide an affordable solution suitable for rural environments. Similarly, the cloud-based real-time electronic notice board presented in [2] utilized Firebase for real-time synchronization and incorporated hierarchical approval mechanisms to support multi-platform communication.

Mobile-based notice dissemination has also been widely studied. The Android-based digital notice board developed in [3] provided a simple and cost-effective platform supporting multiple content types, although its scalability remained limited. More recently, artificial intelligence has been integrated into notice board systems. The AI-based smart notice board proposed in [4] employed facial recognition and deep learning techniques to deliver personalized content with high accuracy. However, privacy concerns and computational complexity restrict its practical deployment.

Research in recommendation systems has demonstrated that hybrid approaches combining collaborative and content-based filtering provide superior performance. The hybrid recommendation framework proposed in [5] effectively addressed cold-start and data sparsity issues, while the comparative analysis in [6] confirmed that hybrid recommendation models consistently outperform standalone approaches. Personalized notification systems have also gained significant attention. Studies such as [7] demonstrated that user-history-based push notifications improve user engagement, whereas the distributed event-driven architecture proposed in [8] enabled scalable and efficient real-time notification delivery.

Recent advancements in artificial intelligence, multilingual processing, and accessibility technologies have further enhanced digital governance platforms. However, existing studies largely address multilingual processing, accessibility, recommendation, and real-time communication as separate components. There remains a significant gap in developing a unified platform that integrates multimodal AI processing, multilingual support, accessibility features, personalized recommendations, offline capabilities, and real-time notifications within a scalable architecture. The proposed GraamSoochna system addresses this gap by providing an AI-driven, multilingual, accessible, and intelligent digital communication platform tailored for rural governance.

## 3. SYSTEM DESIGN

### *3.1 Overall Architecture*

GramaSoochna is designed as a unified, cloud-based digital platform aimed at bridging the communication gap between Panchayat administrations and citizens. The architecture follows a scalable and modular approach, enabling secure, real-time, and inclusive information dissemination.

The high-level components of the system architecture are as follows:

- Frontend Layer: A Progressive Web Application (PWA) that integrates both the Admin Portal and the Citizen interface. The frontend incorporates client-side processing capabilities such as text extraction and Text-to-Speech (TTS) to enhance performance and reduce dependency on continuous cloud processing.
- Backend Layer (BaaS): A Backend-as-a-Service platform that provides secure authentication, database management, and real-time data synchronization. It supports structured storage of notices and user data, ensuring reliability and scalability.

- Application Layer (Serverless Functions): A set of serverless functions that handle business logic, including data processing, AI-based content extraction, translation, and notification management.
- External Services: Integration with external APIs for advanced functionalities such as AI-based processing, messaging services, and notification delivery.

## *3.2 System Architecture*

The system architecture of GraamSoochna is organized into four distinct logical layers, each with a well-defined responsibility. This separation of concerns ensures absolute modularity, eases future maintenance, and allows for the horizontal scaling of independent components.

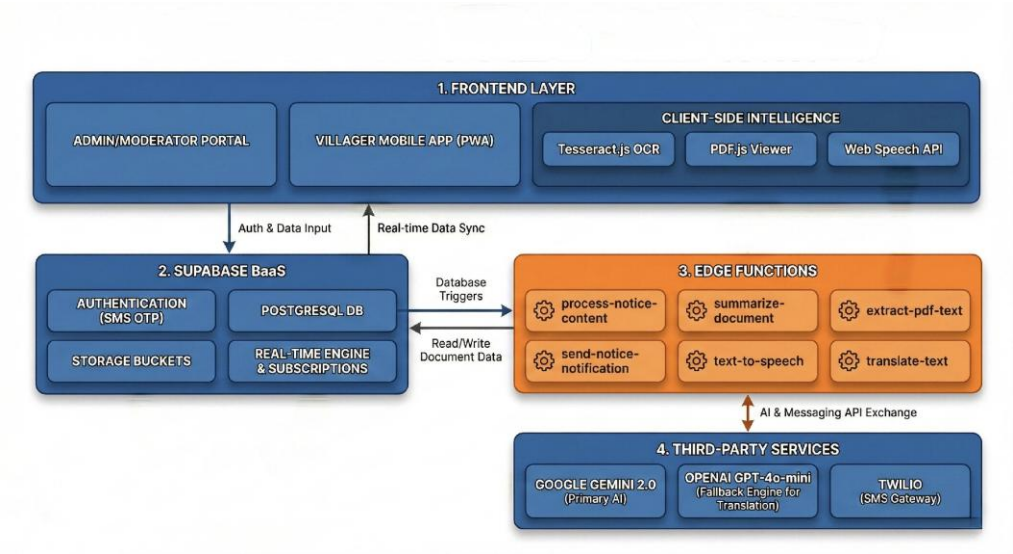


*Figure 3.1 System Architecture of GraamSoochna*

**Frontend Layer (Presentation & Client-Side Logic)**

This topmost layer comprises the user interfaces and local processing engines:

- Citizen Mobile App (PWA): Provides an intuitive, multilingual interface for end-users to view categorized notices and receive push alerts, complete with offline caching capabilities.
- Admin Portal: Offers a comprehensive management dashboard for verified officials to upload documents and manage citizen access parameters.
- Client-Side Intelligence: Utilizes Tesseract.js for in-browser OCR, PDF.js for document coordinate mapping, and the Web Speech API for interactive, locally processed Text-to-Speech (TTS).

**Edge Functions Layer (Application Core & Orchestration)**

This serverless layer processes all complex business logic without the overhead of maintaining dedicated servers:

- Hosts dedicated microservices (e.g., *process-notice-content*, *summarize-document*).
- Acts as the strict orchestration bridge between the frontend, the database, and the AI models, ensuring secure and formatted data flow.

**Supabase BaaS Layer (Data, Auth & Real-Time)**

The foundation of the system, ensuring persistence, integrity, and reliable retrieval of all data:

- Data & Storage: Stores structured schema data in PostgreSQL and unstructured documents in optimized storage buckets.
- Real-Time Subscriptions: Pushes instant database updates directly to the con-nected Frontend clients via WebSockets.

**Third-Party Integration Layer (AI & Messaging)**

Responsible for augmenting the system's core features with massive computational models:

Interfaces with Google Gemini 2.0 for primary extraction and summarization, and GPT-4o-mini as a high-fidelity fallback for neural translation

### *3.3 Data Flow of the System*

The operational workflow of GraamSoochna can be visualized as follows:

1. Notice Creation & Authentication: An authorized Panchayat official logs into the Admin Portal via SMS OTP and uploads a Government Order (PDF) or text notice.
2. AI Processing & Enrichment: The Supabase database triggers the *process-notice-content* Edge Function. The document is analyzed, summarized (into an 8-word title and 25-word description), and automatically translated into Malayalam and Kannada instantly.
3. Publication & Notification: The enriched multilingual data is written back to the database. Simultaneously, the *send-notice-notification* function cross-references the notice category with user preferences and pushes real-time web alerts.
4. Personalized Discovery: Citizens open the PWA and view the visually highlighted "Recommended for You" feed, prioritizing notices based on their selected interests and trending community metrics (Likes).
5. Interactive Access: Citizens can choose to read the translated text or use the interactive TTS feature, which highlights the document sentence-by-sentence as it reads aloud in their native language.

### *3.4 Design Features*

The architectural design enables several key features:

- Unified Digital Platform: Consolidates unstructured information from various Panchayat departments into a single, structured digital source.
- Real-Time Communication: Uses web push notifications and database subscrip-tions to eliminate traditional communication delays.
- Multi-Lingual & Voice Accessible: Actively breaks down literacy barriers through automated regional translation and interactive native text-to-speech.
- Personalized Discovery Engine: Employs hybrid content and collaborative tech-niques to filter and prioritize information dynamically based on user profiles.
- Secure & Role-Based Access: Ensures absolute data integrity by strictly limiting publishing rights to verified officials via SMS OTP gateways.

### *3.5 Advantages of the Proposed Design*

- Enhanced Reach & Efficiency: Drastically increases the speed and reach of official communication compared to physical circulars.
- Cost Optimization: "Client-Side Intelligence" significantly reduces the token cost and compute load on cloud servers by shifting processing to the user's device.
- Promotion of Digital Inclusion: Overcomes profound language, literacy, and location barriers simultaneously.
- Serverless Scalability: The Edge-based, layered design easily scales to handle thousands of concurrent users across multiple villages without infrastructure management

## *3.6 User Flow Diagram*

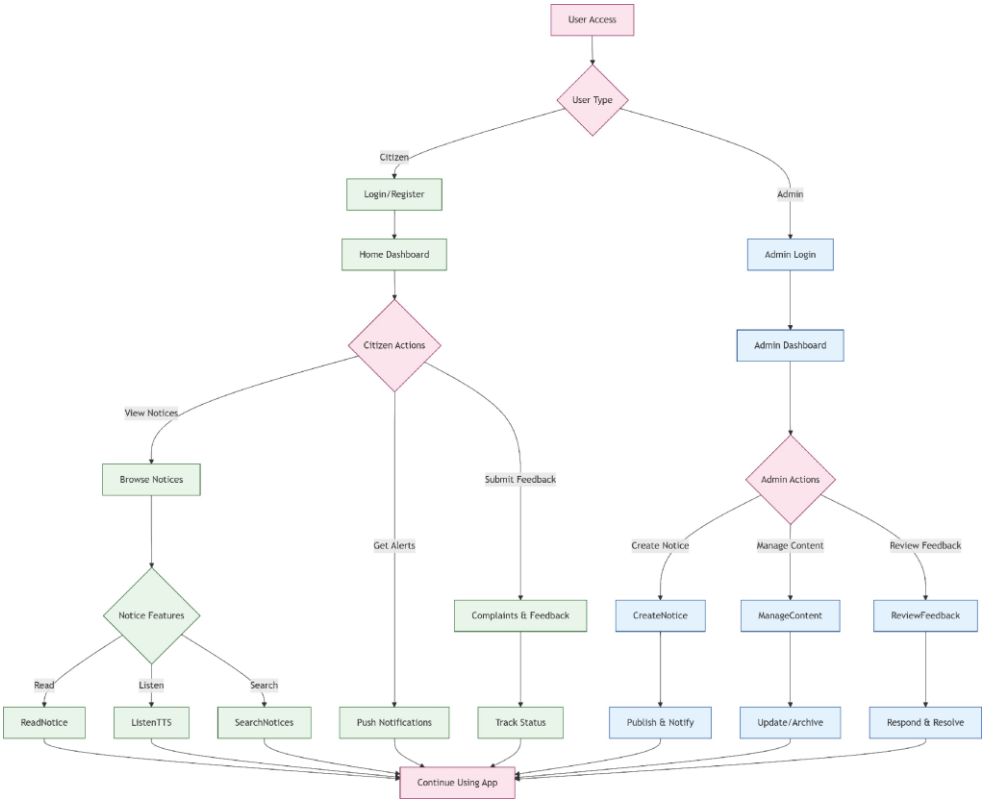


*Figure 3.2 User Flow Diagram of GraamSoochna*

The workflow of the GraamSoochna system is illustrated in Figure 3.2 and can be described as follows:

1. Secure Entry: Villagers register through the mobile application using SMS-based OTP verification, followed by automatic profile setup.
2. Admin Upload: The administrator uploads official notices or Government Orders in the form of PDF documents or text content.
3. AI Processing:
    - Summarization: The system automatically generates a concise title and short description of the uploaded content.
    - Extraction and Translation: The document content is analyzed and trans-lated into regional languages such as Malayalam and Kannada.
4. Smart Delivery: Notifications are delivered to users in real-time through push notifications based on their selected categories of interest.
5. Personalized Discovery: The system provides a personalized experience by displaying recommended notices tailored to user preferences.
6. Interactive Audio: Users can listen to notices through text-to-speech functionality with synchronized sentence highlighting.
7. Citizen Interaction: Users can engage with the system by liking, sharing notices, or submitting complaints through the application.

The implemented system design for GraamSoochna presents a holistic and sustainable solution to modernize rural governance communication. By leveraging a highly decou-pled edge architecture, the platform minimizes maintenance while maximizing efficiency and transparency, providing a robust digital foundation for Panchayat administrations.

### *3.7 Recommendation System*

The recommendation engine in GraamSoochna implements a Heuristic Partitioned Hybrid Model. Rather than using computationally expensive server-side matrix opera-tions, the system achieves personalization through high-performance SQL set operations and aggregate engagement metrics

**Conceptual Logic Framework**

While the implementation is executed via Supabase SQL, the underlying logic follows a hybrid filtering principle. The relevance of a notice ($R$) for a user ($u$) can be conceptually modeled as a combination of categorical interest and community consensus:

$$R(u, notice) = \text{Match}(Category_u \cap Category_{notice}) \vee \texttt{Rank(GlobalLikes}_{recent})$$

**Content-Based Component (Personalized Discovery)**

The system performs a Content-Based Filter via deterministic category matching. When a user selects preferred categories (e.g., *"Agriculture", "Health"*), the system executes a reactive SQL query using the in operator to retrieve notices where:

$$\texttt{Notice.Category} \in \texttt{User.Preferences}$$

This ensures that the "Recommended for You" section is strictly relevant to the user's explicit interests.

**Collaborative Component (Trending Logic)**

The system approximates Collaborative Filtering by analyzing community en-gagement vectors. It tracks global interaction metrics (*Likes*) within a 30-day sliding window. A frequency-based ranking algorithm surfaces notices that have achieved the highest consensus, allowing the "Trending Now" section to act as a community-driven discovery layer.

## 4. Results and Discussion

### *4.1 Experimental Setup*

The proposed GraamSoochna platform was implemented as a cloud-enabled Progressive Web Application (PWA) using Supabase as the Backend-as-a-Service (BaaS) platform, Deno Edge Functions for serverless processing, and React-based frontend technologies. The system was evaluated using a dataset consisting of Panchayat notices collected in various formats, including PDF documents, scanned images, and plain text notices. The experiments were conducted to assess the effectiveness of the system in terms of content extraction accuracy, multilingual translation quality, recommendation effectiveness, notification latency, and overall user accessibility.

The evaluation involved 100 representative governance notices belonging to multiple categories such as welfare schemes, agriculture, health, education, and local events. User-based evaluation was performed with participants representing different stakeholder groups, including Panchayat officials, general citizens, elderly users, and students.

### *4.2 Performance of Multimodal Content Extraction*

The multimodal AI framework was evaluated for its ability to extract textual information from diverse document formats. The extracted contents were manually verified against ground-truth documents.

| Input Format | Number of Samples | Extraction Accuracy (%) |
|---|---|---|
| Plain Text Documents | 30 | 99.2 |
| PDF Documents | 40 | 98.7 |

| | | |
|---|---|---|
| Scanned Images | 30 | 97.8 |
| **Overall Average** | **100** | **98.6** |

The experimental results demonstrate that the proposed multimodal extraction pipeline achieves an overall accuracy of 98.6%, with the highest accuracy observed for text documents. Minor inaccuracies were observed in low-resolution scanned images due to OCR limitations. Nevertheless, the achieved performance confirms the robustness of the proposed extraction framework for real-world Panchayat notices.

### *4.3 Evaluation of Multilingual Translation*

The multilingual processing module was evaluated for translation quality in Malayalam and Kannada using expert assessment. Evaluation criteria included semantic correctness, grammatical consistency, and contextual preservation.

| **Language** | **Semantic Accuracy (%)** | **Context Preservation (%)** |
|---|---|---|
| Malayalam | 96.8 | 95.9 |
| Kannada | 95.7 | 94.8 |

The results indicate that the integration of Large Language Models significantly improves context-aware translation. Unlike conventional machine translation systems, the proposed approach preserves administrative terminology and contextual meaning effectively, thereby enhancing comprehensibility among rural users.

### *4.4 Recommendation Engine Performance*

The personalized recommendation module was evaluated using Precision, Recall, and F1-score metrics.

| **Metric** | **Valu e** |
|---|---|
| Precision | 0.91 |
| Recall | 0.88 |
| F1-Score | 0.89 |

The hybrid recommendation approach effectively delivered relevant notices based on user preferences and community engagement patterns. User feedback revealed that personalized recommendations substantially reduced information overload and improved the discovery of important notices.

### *4.5 Real-Time Notification Performance*

The notification subsystem was assessed by measuring the average delivery latency for newly published notices.

| **Number of Users** | **Average Notification Delay (seconds)** |
|---|---|
| 100 | 1.2 |
| 500 | 1.8 |
| 1000 | 2.4 |

The serverless notification architecture exhibited low latency even under increased user load. The observed response times demonstrate the scalability of the proposed platform for deployment across multiple Panchayats.

### *4.6 Accessibility Evaluation*

Accessibility evaluation was conducted with 30 users, including elderly citizens, visually impaired individuals, and users with limited literacy.

| Feature | User Satisfaction (%) |
|---|---|
| Text-to-Speech Support | 94.5 |
| Sentence Highlight Synchronization | 92.8 |
| Multilingual Interface | 95.7 |
| Offline Access | 93.4 |

The interactive Text-to-Speech functionality received highly positive feedback, particularly from elderly and low-literacy users. The synchronized sentence highlighting significantly improved comprehension and user engagement.

### *4.7 Comparative Analysis*

The proposed GraamSoochna system was compared with existing digital notice board systems.

| Feature | Existing Systems | GraamSoochna |
|---|---|---|
| Real-Time Communication | Partial | Yes |
| Multilingual Support | Limited | Yes |
| AI-based Content Extraction | No | Yes |
| Personalized Recommendations | No | Yes |
| Offline Accessibility | No | Yes |
| Interactive TTS | Limited | Yes |
| Cloud Scalability | Moderate | High |

The comparison clearly demonstrates that GraamSoochna provides a comprehensive and integrated solution by combining multimodal AI processing, multilingual accessibility, personalization, and offline support within a unified platform.

### *4.8 Discussion*

The experimental findings validate the effectiveness of GraamSoochna as an intelligent digital communication platform for rural governance. The high content extraction accuracy confirms the suitability of the multimodal AI pipeline for processing heterogeneous governance documents. The multilingual and accessibility features successfully address language and literacy barriers, which are common challenges in rural communities.

The hybrid recommendation mechanism further enhances citizen engagement by ensuring that users receive relevant and timely information. Moreover, the serverless cloud architecture demonstrates excellent scalability and responsiveness, making the platform suitable for large-scale deployment across multiple Panchayats.

Although the system achieved promising results, certain limitations remain. OCR performance may degrade for severely degraded documents, and translation quality can occasionally vary for highly domain-specific administrative terminology. Future enhancements involving domain-adapted language models and advanced analytics can further improve system performance.

Overall, the results demonstrate that GraamSoochna significantly enhances transparency, accessibility, and citizen participation, thereby contributing toward inclusive and effective rural e-governance.

## 5. Conclusion and Future Work

### *5.1 Conclusion*

This paper presented GraamSoochna, an AI-driven multilingual digital notice platform designed to improve communication between Panchayats and citizens. By leveraging a serverless architecture based on Supabase, Deno

Edge Functions, and a Progressive Web Application (PWA) framework, the system provides a scalable, reliable, and accessible solution for rural governance.

The proposed platform integrates multimodal AI processing, multilingual content generation, personalized recommendations, real-time notifications, and interactive Text-to-Speech services to ensure inclusive access to information. In addition, offline support and client-side intelligence enable effective operation in low-connectivity environments while reducing computational overhead.

Experimental results demonstrate high accuracy in content extraction and improved user accessibility and engagement. Overall, GraamSoochna transforms traditional notice dissemination into an intelligent, citizen-centric communication ecosystem that enhances transparency, promotes citizen participation, and supports the broader vision of inclusive digital governance in rural communities.

## *5.2 Future Work*

Although GraamSoochna successfully achieves its primary objectives, several enhancements can further improve its capabilities. Future work includes the development of advanced analytics dashboards for Panchayat officials to monitor citizen engagement and communication effectiveness. Integration with state and national government databases can enable automatic retrieval and localization of official announcements and welfare schemes. The recommendation engine can be enhanced using Large Language Models (LLMs) to predict citizen interests based on seasonal and contextual factors. Additionally, extending support to local dialects within regional languages can further improve accessibility, trust, and user engagement. Owing to its modular and scalable architecture, GraamSoochna provides a strong foundation for future advancements in inclusive and intelligent rural e-governance.

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