IJIRSET
International Journal of Innovative Research in Science | Engineering | Technology

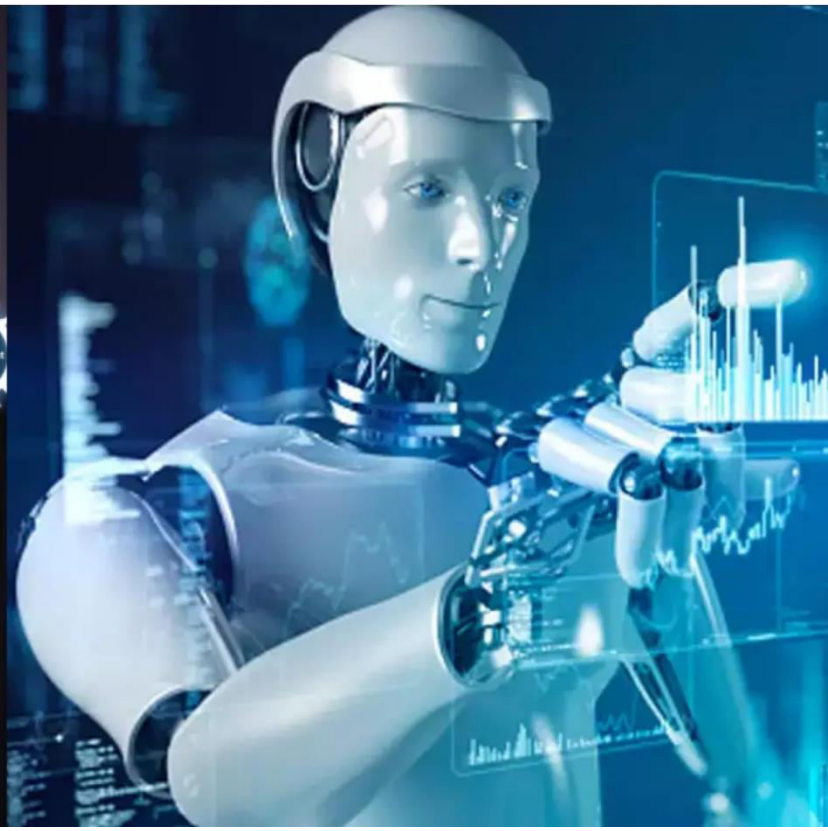
ISSN(O): 2319-8753
ISSN(P): 2347-6710



International Journal of Innovative Research in Science Engineering and Technology (IJIRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)





Impact Factor: 9.935

Volume 15, Issue 11, November 2026

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|www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

Volume 15, Issue 11, November 2026

|DOI: 10.15680/IJIRSET.2026.1511023|

GramAI: Smart Digital Bridge Between Citizens and Grampanchayat(Gram-Connect)

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ABSTRACT: Village administration plays a vital role in delivering public services, maintaining citizen records, and implementing government welfare schemes. However, traditional Gram Panchayat operations often rely on manual paperwork, physical registers, and time-consuming administrative procedures, resulting in delays in service delivery, limited transparency, and difficulties in grievance resolution. To address these challenges, this paper proposes E-Grampanchayat: An AI-Powered Smart Village Administration System, an integrated digital platform designed to improve the efficiency, accessibility, and transparency of rural governance.

The proposed system integrates Artificial Intelligence (AI), cloud computing, database management, and web technologies to digitize and streamline essential Gram Panchayat services. It provides centralized management of citizen records, property details, tax information, government schemes, applications, and public grievances. AI-based techniques are incorporated to support automated complaint classification, grievance prioritization, chatbot-based citizen assistance, and document verification. The system enables citizens to submit service requests, apply for certificates, access relevant government scheme information, and track the status of applications and complaints through a digital interface. Administrative dashboards provide officials with organized records, service updates, and analytical reports to support informed decision-making.

The proposed system aims to reduce paperwork, improve administrative efficiency, strengthen communication between citizens and local authorities, and enhance accountability in village-level governance. Its performance can be evaluated through functional testing, response time, complaint classification accuracy, document-processing performance, security assessment, and usability testing. The framework is designed to be modular and scalable, allowing future integration with mobile applications, multilingual voice assistants, geographic information systems, and external government service portals. Overall, E-Grampanchayat presents an AI-enabled approach to digital village administration that supports improved public service delivery and the broader vision of Digital India and smart villages.

KEYWORDS E-Grampanchayat, Artificial Intelligence, E-Governance, Smart Village Administration, Grievance Management, Natural Language Processing, Digital Governance, Rural Development..

I. INTRODUCTION

Village administration plays a significant role in rural development by providing essential public services, maintaining administrative records, and implementing government welfare schemes. The Gram Panchayat is responsible for managing various activities, including citizen services, property and tax records, certificate applications, public grievances, and village development initiatives. Efficient management of these activities is necessary to ensure transparency, accountability, and timely service delivery. However, many administrative processes continue to depend on manual documentation, physical registers, and conventional communication methods, which can make information management and service delivery time-consuming.

With the advancement of digital technologies, e-governance has emerged as an effective approach to modernizing public administration. The integration of web applications, cloud computing, centralized databases, and Artificial

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Intelligence (AI) creates opportunities to simplify administrative operations and improve access to government services. Digital platforms can help maintain organized records, reduce repetitive paperwork, and enable citizens to access services without depending entirely on in-person visits to Gram Panchayat offices. Despite these developments, challenges such as fragmented records, delayed grievance resolution, limited application tracking, and difficulties in accessing relevant government scheme information continue to affect village-level administration.

To address these challenges, this project proposes **E-Grampanchayat: An AI-Powered Smart Village Administration System**, a centralized digital platform designed to improve the efficiency and accessibility of Gram Panchayat services. The proposed system integrates citizen record management, property and tax management, government scheme information, online applications, and public grievance handling into a unified platform. Artificial Intelligence techniques, including Natural Language Processing (NLP) and machine-learning methods, can be used to classify citizen complaints, prioritize grievances, provide chatbot-based assistance, and support document verification. These features aim to simplify administrative tasks and help officials manage citizen requests more systematically.

II. LITERATURE SURVEY

Sr. No.	Author(s)	Year	Research / Technology Area	Key Findings / Relevance
1	S. Chougule, H. S. Hulyalkar, D. Nayak, P. Mulik, S. Khade	2026	AI-Powered Digital Governance for Rural Panchayats	Proposed DigiGram, integrating complaint management, certificate services, property and water tax management, government schemes, and an AI chatbot. The study also explored machine-learning-based complaint classification and prioritization.
2	Rahul Deka, Reetesh Kumar	2025	AI-Based Public Grievance Analysis	Investigated NLP and topic-modelling approaches for analyzing unstructured government grievances, supporting automated complaint categorization, identification of recurring issues, and analysis of citizen feedback.
3	Sheedhal K. Reji, B. Moulya, P. S. Rajeswari	2025	Evolution of e-Governance in India	Examined India's transition from basic computerization to cloud-based and citizen-centric digital governance. The study identified rural infrastructure, digital literacy, privacy, and cybersecurity as key implementation challenges.
4	He Li, Naiyu Shi	2025	Tri-Stage Transformer (TIART) Model for Rural Development Prediction	Investigated a transformer-based model for predicting important factors affecting rural e-commerce development. The research highlights the potential of predictive analytics for identifying rural development priorities.
5	Sayed Nadeem Fatmi, Mohammad Swalehin	2022	Adoption of e-Governance in Rural Areas	Investigated e-governance adoption among rural citizens and Panchayat members, highlighting the importance of digital literacy, citizen awareness, and technological readiness for successful e-Panchayat implementation.
6	C. Vijai, D. Joyce	2020	Cloud-Based e-Governance	Discussed cloud computing for integrating government services and improving accessibility and transparency.

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III. METHODOLOGY

The proposed E-Grampanchayat system follows a systematic methodology that integrates citizen data management, digital service delivery, Artificial Intelligence (AI), centralized database management, and web-based administration. The methodology is designed to simplify Gram Panchayat operations, improve grievance handling, enhance transparency, and support efficient delivery of public services. The system can operate using authorized administrative records, appropriately prepared sample datasets, or simulated data during prototype development, depending on data availability and access permissions.

1. Requirement Analysis and Service Configuration
The first stage involves identifying the administrative requirements of Gram Panchayat offices and the service needs of citizens. The major services considered include citizen registration, property and tax management, certificate applications, government scheme information, and public grievance handling. Functional requirements for user authentication, application processing, complaint tracking, notifications, administrative reporting, and dashboard visualization are defined at this stage. User roles and access permissions are also established to ensure that citizens and authorized officials can access appropriate features.

2. Data Collection and Acquisition
Administrative data is collected from authorized sources or prepared sample datasets, depending on availability. The data may include citizen details, property records, tax information, government scheme descriptions, certificate applications, grievance descriptions, complaint categories, and application statuses. Each record is organized according to its purpose and associated identifiers. Data can be entered through web forms, imported from existing digital records, or received through backend APIs. During prototype development, simulated records can be used to demonstrate system functionality without exposing actual citizen information.

3. Data Validation and Preprocessing
The collected data is validated to identify missing fields, duplicate records, incorrect data types, inconsistent formats, and invalid entries. Appropriate preprocessing techniques, including data cleaning, duplicate removal, field standardization, and missing-value handling, are applied according to the requirements of each dataset. Text-based grievance descriptions are cleaned and prepared for further analysis using Natural Language Processing (NLP) techniques. Sensitive citizen information is protected through appropriate access controls and data-handling procedures. The processed data is then stored in a structured format suitable for administrative operations and AI-based analysis.

4. Feature Extraction and Data Analysis
Relevant features are identified from the processed administrative data to support intelligent service management. For grievance classification, features may include complaint descriptions, keywords, complaint categories, and relevant contextual information. For administrative analytics, variables such as application type, submission date, processing status, resolution time, and scheme registration status can be analyzed where reliable data is available. Exploratory data analysis is performed to identify common complaint categories, service-processing patterns, and recurring administrative issues. These findings can help determine the requirements for AI-assisted grievance handling and administrative reporting.

IV. SYSTEM ARCHITECTURE

The system architecture of the E-Grampanchayat: AI-Powered Smart Village Administration System consists of several interconnected modules designed to manage citizen information, digitize administrative services, process public grievances, and provide information through a centralized web-based platform. The architecture follows a modular, layered approach that simplifies development, testing, maintenance, and future expansion of village administration services.

1. Architecture Overview
The proposed architecture contains the following layers:

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1. Citizen and Service Access Layer: This layer represents the primary users of the system, including citizens, Gram Panchayat officials, and administrators. Citizens can access digital services such as certificate applications, grievance registration, government scheme information, and application tracking. Authorized officials can manage administrative records, process applications, and update grievance statuses through the system interface.

2. Communication and Data Ingestion Layer: This layer manages the exchange of information between the frontend application and the backend server through HTTP requests and RESTful APIs. Citizen applications, grievance submissions, document uploads, and administrative updates are transmitted to the backend for validation and processing. Each application or grievance can be assigned a unique identifier to support tracking and retrieval.

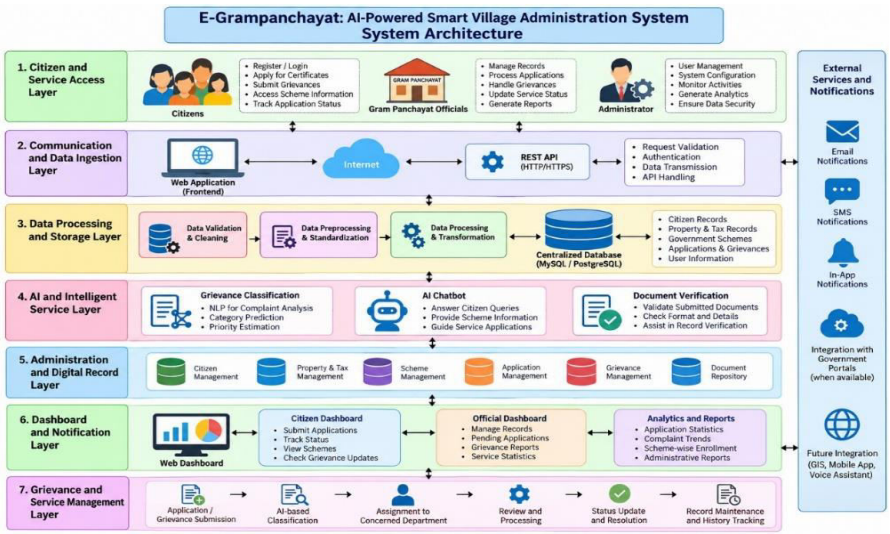
3. Data Processing and Storage Layer: This layer handles input validation, data cleaning, duplicate detection, record standardization, and other preprocessing operations where required. Citizen details, property records, tax information, government scheme data, service applications, and grievance records are stored in a centralized database. Appropriate relationships and access permissions are maintained to support reliable data retrieval and secure information management.

4. Artificial Intelligence and Intelligent Service Layer: This layer supports AI-assisted administrative functions, including grievance classification, complaint prioritization, and chatbot-based citizen assistance. Natural Language Processing (NLP) techniques can analyze complaint descriptions and categorize them according to their content. Machine-learning models can be used where suitable labeled datasets are available. The output may include a suggested complaint category, priority level, or response recommendation, depending on the implemented AI module.

5. Centralized Administration and Digital Record Layer: This layer maintains organized digital records of citizens, properties, taxes, applications, grievances, and government schemes. It supports administrative operations such as application processing, status updates, record retrieval, and service tracking. Changes made by authorized officials are reflected in the relevant records, helping maintain consistent information across the platform.

6. Dashboard and Notification Layer: This layer provides a web-based dashboard for citizens and authorized Gram Panchayat officials. It displays application statuses, pending grievances, service statistics, scheme information, and administrative reports. The notification module can generate updates when applications or complaints change status and communicate relevant announcements to citizens through supported notification services.

7. Grievance and Service Management Layer: This layer enables authorized officials to review citizen requests, assign grievances to the appropriate department, update application progress, and record resolution details. It maintains the history of relevant administrative actions and supports the tracking of unresolved complaints and pending applications. The information generated by this module helps officials monitor service delivery, improve accountability, and make informed administrative decisions.



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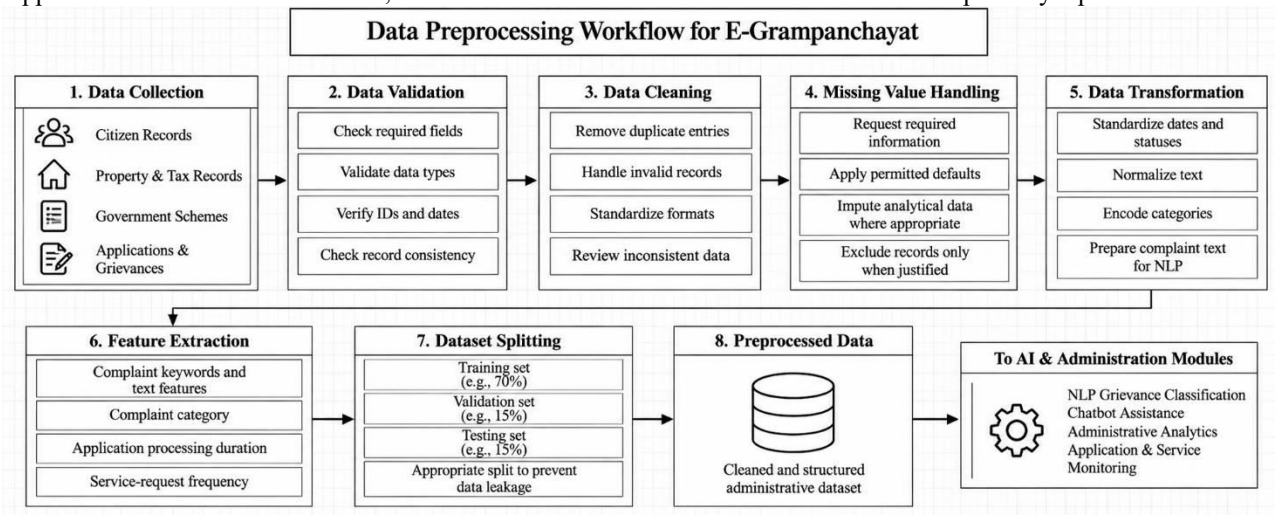
Overall, the proposed architecture integrates citizen-facing services, backend processing, centralized data storage, AI-assisted functionality, and administrative monitoring into a unified platform. Its modular design supports the addition of future features such as multilingual voice assistance, mobile applications, GIS-based village information, and integration with authorized government portals.

V. DATA PREPROCESSING

Data preprocessing is an important stage in the proposed E-Grampanchayat: AI-Powered Smart Village Administration System. The collected administrative data from citizen registrations, property records, tax information, government schemes, service applications, and public grievances may contain missing fields, duplicate entries, inconsistent formats, invalid values, and incomplete records. These issues must be addressed before the data is used for administrative processing, reporting, or Artificial Intelligence (AI)-based analysis to ensure reliable results and consistent information management.

Finally, the preprocessed data is organized for database storage, administrative reporting, and AI model development. Where labeled grievance data is available, it is divided into training, validation, and testing sets for model development and performance evaluation. Appropriate data splitting is used to prevent information leakage between these sets. The resulting processed data is then passed to the relevant system modules for grievance classification, administrative analytics, application tracking, and service monitoring. This preprocessing stage helps improve data consistency, support reliable AI-assisted services, and maintain the overall effectiveness of the E-Grampanchayat platform.



VI. MATHEMATICAL MODEL

The mathematical model of the proposed E-Grampanchayat system represents the process of collecting administrative data, preprocessing records, extracting relevant features, classifying public grievances, managing citizen services, and generating administrative insights. The model combines data processing techniques, Artificial Intelligence (AI), Natural Language Processing (NLP), and rule-based validation to support efficient village administration and improve public service delivery.

1. Input Data Model

Let the administrative dataset be represented as:

$$D=\{(X_i,y_i)\}_{i=1}^{N}$$

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where:

- (N) = total number of administrative records.
- (X_i) = input feature vector for the (i^{th}) record.
- (y_i) = actual grievance category or service label, when available.

The feature vector for an administrative record can be represented as:

$$X_i=[C_i,P_i,T_i,G_i,A_i,S_i]$$

where:

- (C_i) = citizen-related information.
- (P_i) = property and tax information.
- (T_i) = application submission date or processing time.
- (G_i) = grievance description and related features.
- (A_i) = application or service type.
- (S_i) = application or grievance status.

The actual features depend on the administrative module and the availability of relevant data. Sensitive citizen information should be excluded from AI model inputs unless its use is necessary, authorized, and appropriately protected.

2. Data Preprocessing Model

Raw administrative data is transformed into a structured dataset through validation, duplicate removal, missing-value handling, text processing, and feature transformation.

For mean imputation of a missing numerical feature (x_j):

$$x_j^*=\frac{1}{n_j}\sum_{i=1}^{n_j}x_{ij}$$

where (n_j) represents the number of valid observations for feature (j). This method is appropriate only for suitable numerical analytical data, not for filling missing citizen details arbitrarily.

For standardization of a numerical feature:

$$z_{ij}=\frac{x_{ij}-\mu_j}{\sigma_j}$$

where (\mu_j) is the training-set mean and (\sigma_j) is the training-set standard deviation. Standardization is applied when required by the selected machine-learning algorithm.

Text preprocessing may include normalization, removal of irrelevant symbols, tokenization, and preparation of grievance descriptions for Natural Language Processing. Administrative records are also checked for duplicate identifiers, invalid dates, and inconsistent application statuses.

3. Feature Extraction Model

Relevant features are extracted from administrative records to support grievance classification and service analysis.

The frequency of a particular grievance category (k) can be represented as:

$$F_k=\sum_{i=1}^{N}I(y_i=k)$$

where (I(y_i=k)) is 1 when record (i) belongs to category (k), and 0 otherwise.

The average application processing time is calculated as:

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$$\overline{T}=\frac{1}{N}\sum_{i=1}^{N}(t_i^{r}-t_i^{s})$$

where:

- t_i^{s} = application submission time.
- t_i^{r} = application resolution time.
- N = number of resolved applications included in the calculation.

Additional features may include complaint keywords, application type, service-request frequency, complaint category, and processing status. These features help identify common administrative issues and support service-performance analysis.

4. AI-Based Grievance Classification Model

Let f_{θ} represent a trained machine-learning model with parameters θ. The predicted grievance category is:

$$\hat{y}=f_{\theta}(X)$$

where $\hat{y}$ represents the predicted category for a submitted grievance.

For a classification model, the predicted category can be selected using the highest estimated class probability:

$$\hat{y}=\arg\max_{k\in K}P(y=k\mid X)$$

where K is the set of supported grievance categories, such as water supply, sanitation, roads, property tax, and certificate services.

Suitable supervised machine-learning algorithms can be evaluated when labeled grievance data is available. NLP techniques can be used to process complaint descriptions, while a rule-based approach may be used when sufficient training data is unavailable.

The model output assists in categorizing complaints and suggesting the appropriate administrative department. Final decisions and complaint resolution remain the responsibility of authorized officials.

5. Administrative Service Management Model

The status of an application or grievance is represented by a state variable:

$$S_i\in\{\text{Submitted},\text{Pending},\text{UnderReview},\text{Resolved},\text{Rejected}\}$$

The system updates the application state according to authorized administrative actions:

$$S_{t+1}=h(S_t,E_t)$$

where:

- S_t = current application or grievance status.
- E_t = an authorized event, such as review, approval, rejection, or resolution.
- h = the state-transition function implemented by the system.

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The function (h) permits only valid transitions according to the configured administrative workflow. Each transition can be recorded with a timestamp and the identity or role of the authorized user to support traceability and accountability.

6. Centralized Record Synchronization Model

The centralized database maintains the latest available information about citizens, applications, grievances, properties, taxes, and government schemes.

Let the administrative system state at time (t) be:

$$Z_t=[C_t,P_t,A_t,G_t,S_t]$$

where:

- (C_t) = relevant citizen records.
- (P_t) = property and tax records.
- (A_t) = application information.
- (G_t) = grievance information.
- (S_t) = current application and grievance statuses.

When an authorized update occurs, the system state is updated as follows:

$$Z_{t+1}=g(Z_t,E_t)$$

where (g) represents the database update function and (E_t) represents a validated administrative event.

This model describes centralized digital record management rather than a physical digital twin. The system maintains consistent administrative information and makes updated records available to authorized users through the web application.

7. Notification Generation Model

A notification is generated when a relevant administrative event occurs, such as a new application submission, a grievance status change, or an important service update.

The notification rule can be represented as:

$$N_t=\begin{cases}1, & \text{if a configured notification event occurs}\\0, & \text{otherwise}\end{cases}$$

where (N_t=1) indicates that a notification should be generated.

A notification event may be defined as:

$$E_t\in\{\text{Application Submitted},\ \text{Status Changed},\ \text{Grievance Resolved},\ \text{Scheme Announced}\}$$

The system generates notifications according to the configured event rules, user preferences, permissions, and availability of the required notification service. Delivery status can be recorded where supported.

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8. System Evaluation Model

The performance of the AI-based grievance classification module can be evaluated using standard classification metrics when labeled test data is available.

Accuracy:

$$\text{Accuracy}=\frac{TP+TN}{TP+TN+FP+FN}$$

Precision:

$$\text{Precision}=\frac{TP}{TP+FP}$$

Recall:

$$\text{Recall}=\frac{TP}{TP+FN}$$

F1-score:

$$F1=2\cdot\frac{\text{Precision}\cdot\text{Recall}}{\text{Precision}+\text{Recall}}$$

Here, (TP), (TN), (FP), and (FN) represent true positives, true negatives, false positives, and false negatives, respectively. For multiclass grievance classification, these metrics can be calculated for individual categories and summarized using macro or weighted averages.

The overall platform can also be evaluated using average API response time:

$$\overline{T}_{API}=\frac{1}{M}\sum_{i=1}^{M}t_i$$

where (M) is the number of API requests evaluated and (t_i) is the response time of request (i).

Additional evaluation criteria include application-processing time, dashboard loading time, data retrieval performance, access-control effectiveness, and usability. These measurements help assess whether the proposed system can support efficient, reliable, and accessible village administration.

VII. CONCLUSION

The E-Grampanchayat: AI-Powered Smart Village Administration System proposes an integrated approach to modern village administration by combining Artificial Intelligence (AI), web technologies, centralized database management, and digital governance. The system is designed to digitize administrative records, simplify citizen service delivery, manage public grievances, and improve access to government scheme information through a unified platform.

The proposed system integrates citizen services, digital record management, AI-assisted grievance classification, chatbot-based assistance, and a centralized administrative dashboard to provide citizens and Gram Panchayat officials with relevant information and efficient service-management tools. This integration aims to reduce manual paperwork, improve application tracking, support timely grievance resolution, and strengthen transparency and accountability in village administration. The system can be developed and demonstrated using authorized administrative data or sample datasets, with AI-based features implemented according to data availability and system requirements.

The effectiveness of the proposed solution can be evaluated through functional testing, grievance classification metrics, API response time, dashboard performance, security assessment, and usability testing. Since actual performance depends on data quality, the implemented AI models, and administrative workflows, the system must be validated before deployment in real-world Gram Panchayat operations.

Overall, the project provides a modular foundation for intelligent digital governance by integrating online citizen services, centralized record management, AI-assisted processing, and administrative monitoring within a single platform. With further development, the system can be extended to multiple Gram Panchayats, multilingual voice assistance, mobile applications, GIS-based village information, and authorized government portal integration. These

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enhancements could help improve public service accessibility, strengthen administrative efficiency, and support transparent, accountable, and data-driven rural development.

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