

INTELLIGENT DIGITAL GOVERNMENT PLATFORMS: LEVERAGING MACHINE LEARNING AND CLOUD ARCHITECTURE FOR SOCIAL SERVICE DELIVERY

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ABSTRACT

The rapid evolution of digital technologies is transforming how governments design, deliver, and optimize public services. Intelligent Digital Government Platforms represent a new paradigm that integrates machine learning (ML) and cloud-native architectures to enhance efficiency, scalability, and citizen-centric service delivery. This paper explores the architectural foundations, technological enablers, and practical applications of such platforms in modern governance systems.

By leveraging machine learning algorithms, governments can transition from reactive service models to predictive and proactive service delivery, enabling improved decision-making, fraud detection, demand forecasting, and personalized citizen engagement. Simultaneously, cloud computing provides the scalability, resilience, and cost-efficiency required to handle large-scale public sector workloads and data-intensive operations.

The study examines key components including data pipelines, AI/ML models, microservices-based architectures, API gateways, and security frameworks. It also highlights real-world use cases such as welfare distribution, healthcare systems, and smart urban governance. Furthermore, the paper discusses implementation challenges,

including data privacy, interoperability, ethical considerations, and digital divide issues.

Ultimately, this research demonstrates how intelligent digital platforms can redefine public service delivery by fostering transparency, inclusivity, and operational excellence. The convergence of machine learning and cloud architecture is positioned as a critical driver for building agile, responsive, and citizen-centric digital governments of the future.

Keywords: Intelligent Digital Government Platforms, Machine Learning, Cloud Computing, Social Service Delivery, Digital Transformation, AI in Governance, Public Sector Innovation, Data-Driven Decision Making, Microservices Architecture, API Integration, Predictive Analytics, Smart Governance, Cloud-Native Systems, Citizen-Centric Services

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1. INTRODUCTION

Governments across the globe are undergoing a significant transformation driven by rapid advancements in digital technologies, increasing citizen expectations, and the growing need for efficient and transparent public service delivery. Traditional government systems, often characterized by siloed data, legacy infrastructure, and manual processes, are no longer sufficient to address the complexity and scale of modern societal needs. In this context, Intelligent Digital Government Platforms have emerged as a transformative solution that combines machine learning capabilities with cloud-based architectures to enable scalable, data-driven, and citizen-centric governance.

The concept of digital government has evolved from simple e-governance portals to fully integrated platforms capable of delivering end-to-end services across multiple departments. Early initiatives primarily focused on digitizing existing processes, such as online form submissions and basic automation. However, these systems often lacked interoperability, real-time analytics, and adaptability. The next generation of platforms leverages advanced technologies, including machine learning, big data analytics, and cloud computing, to move beyond digitization toward intelligent automation and predictive governance.

Machine learning plays a central role in enabling governments to extract meaningful insights from vast volumes of structured and unstructured data generated across public systems. By applying predictive analytics, classification models, and anomaly detection techniques, governments can anticipate citizen needs, optimize resource allocation, detect fraudulent activities, and improve policy outcomes. For example, predictive models can identify vulnerable populations eligible for social welfare programs, while anomaly detection algorithms can flag irregularities in benefit disbursement systems.

At the same time, cloud computing provides the foundational infrastructure required to support these intelligent systems. Cloud-native architectures offer elasticity, scalability, and high availability, enabling governments to handle fluctuating workloads and large-scale data processing without significant upfront investments in physical infrastructure. Technologies such as microservices, containerization, and serverless computing further enhance the flexibility and modularity of digital government platforms, allowing seamless integration across departments and services.

A key driver behind the adoption of intelligent platforms is the shift toward citizen-centric service delivery. Modern citizens expect personalized, accessible, and real-time interactions with government services, similar to experiences offered by private-sector digital platforms. Intelligent Digital Government Platforms address these expectations by enabling personalized service recommendations, multilingual support, automated assistance through chatbots, and proactive service delivery mechanisms.

Despite their potential, the implementation of such platforms presents several challenges. Governments must address issues related to data privacy, cybersecurity, regulatory compliance, interoperability among legacy systems, and the digital divide that may exclude certain populations from accessing digital services. Additionally, ethical considerations surrounding the use of machine learning—such as bias, transparency, and accountability—must be carefully managed to ensure equitable and trustworthy outcomes.

This paper aims to explore the architectural design, technological components, and practical applications of Intelligent Digital Government Platforms.

2. TECHNICAL ARCHITECTURE OF INTELLIGENT DIGITAL GOVERNMENT PLATFORMS

The effectiveness of Intelligent Digital Government Platforms depends on a robust, scalable, and modular architecture that seamlessly integrates machine learning capabilities with cloud-native infrastructure. This section presents a layered architectural model that enables

efficient data processing, real-time analytics, and secure service delivery across government ecosystems.

2.1 Architectural Overview

The architecture follows a multi-layered approach, where each layer is responsible for specific functionalities while maintaining interoperability and scalability. The key layers include:

1. Data Ingestion Layer
2. Data Processing and Storage Layer
3. Machine Learning and Analytics Layer
4. Application and Service Layer
5. API Gateway and Integration Layer
6. Security and Governance Layer
7. Cloud Infrastructure Layer

This layered design ensures flexibility, allowing governments to modernize individual components without disrupting the entire system.

2.2 High-Level Architecture Diagram

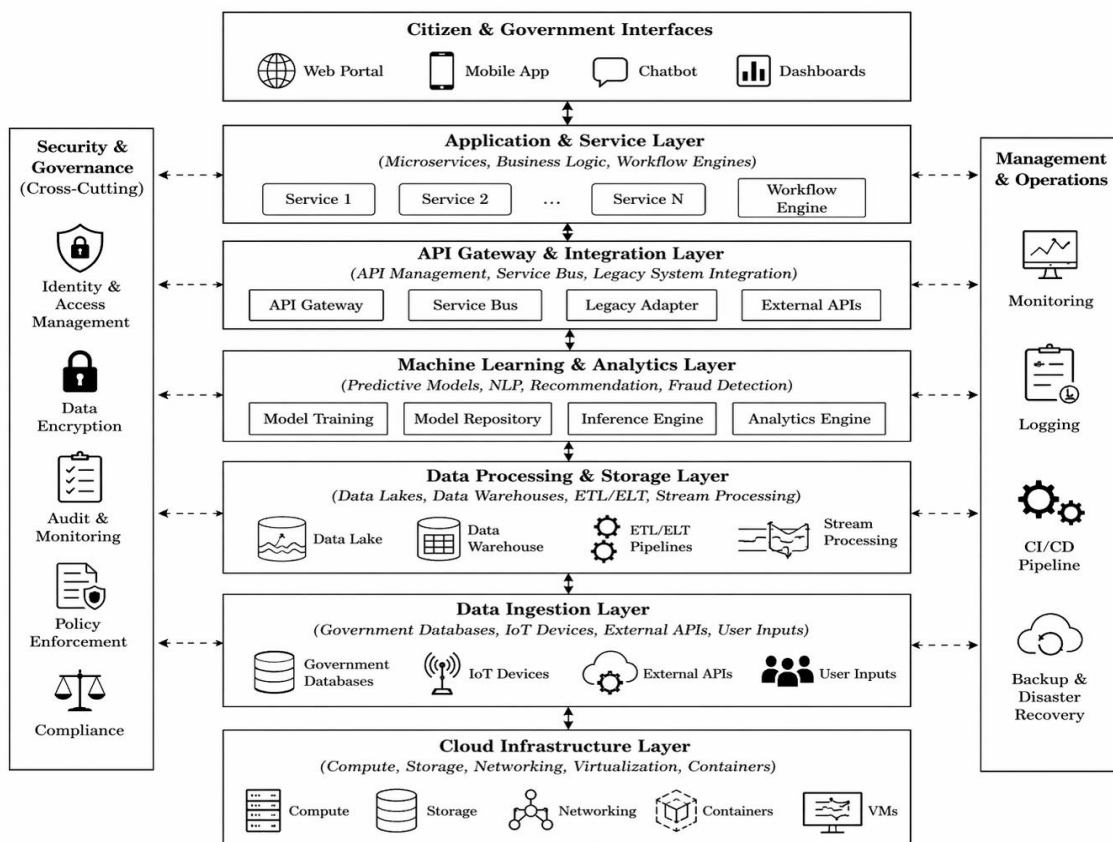


Fig. 1. Intelligent Digital Government Platform Architecture.

Fig. 1. High-Level Architecture of Intelligent Digital Government Platform

2.3 Data Ingestion Layer

The data ingestion layer is responsible for collecting data from multiple heterogeneous sources, including:

- Government databases (tax, healthcare, welfare systems)
- IoT devices and smart city sensors
- Citizen-generated data from applications and portals
- Third-party and external data sources

This layer supports both batch processing and real-time streaming, enabling timely data availability for downstream analytics. Technologies such as message queues and event streaming platforms ensure reliable and scalable ingestion.

2.4 Data Processing and Storage Layer

Once ingested, data is processed, transformed, and stored in scalable repositories. This layer includes:

- **Data Lakes:** for raw, unstructured, and semi-structured data
- **Data Warehouses:** for structured, analytics-ready datasets
- **ETL/ELT Pipelines:** for data transformation and cleansing
- **Stream Processing Engines:** for real-time analytics

The architecture ensures data consistency, quality, and accessibility while supporting large-scale analytical workloads.

2.5 Machine Learning and Analytics Layer

This layer is the core intelligence engine of the platform. It leverages machine learning models and advanced analytics to enable:

- Predictive analytics for demand forecasting and policy planning
- Fraud detection in social benefit programs
- Natural Language Processing (NLP) for chatbots and citizen interaction
- Recommendation systems for personalized service delivery

Model lifecycle management, including training, validation, deployment, and monitoring, is handled through MLOps pipelines, ensuring continuous improvement and governance.

2.6 Application and Service Layer

The application layer consists of microservices that implement business logic and workflows. Key characteristics include:

- **Microservices Architecture:** for modular and independent services
- **Workflow Orchestration:** for automating multi-step government processes
- **User Interfaces:** such as web portals, mobile apps, and dashboards

This layer ensures that services are reusable, scalable, and easily maintainable.

2.7 API Gateway and Integration Layer

Interoperability is critical in government systems where multiple departments must collaborate. This layer provides:

- Centralized API management and routing
- Integration with legacy systems through adapters
- Service mesh for internal communication
- Secure data exchange across departments

API-first design enables seamless service composition and external integration.

2.8 Security and Governance Layer

Security and governance are embedded across all architectural layers to ensure compliance with regulatory requirements and protection of sensitive data. Key components include:

- Identity and Access Management (IAM)
- Data encryption (at rest and in transit)
- Audit trails and monitoring
- Policy enforcement and compliance frameworks

This layer also addresses ethical considerations such as data privacy and algorithmic transparency.

2.9 Cloud Infrastructure Layer

The foundation of the architecture is built on cloud computing, which provides:

- **Elastic Compute Resources:** for dynamic workloads
- **Scalable Storage Solutions:** for large datasets
- **Containerization and Orchestration:** (e.g., Kubernetes)
- **Serverless Computing:** for event-driven services

Cloud platforms enable high availability, disaster recovery, and cost optimization through pay-as-you-go models.

2.10 Key Architectural Benefits

Feature	Benefit
Cloud-Native Design	Scalability and cost efficiency
Microservices Architecture	Flexibility and faster deployment
Machine Learning Integration	Intelligent decision-making and automation
API-Driven Integration	Interoperability across departments
Real-Time Processing	Faster response and proactive service delivery
Strong Security Framework	Trust, compliance, and data protection

This technical architecture forms the backbone of Intelligent Digital Government Platforms, enabling governments to deliver efficient, scalable, and citizen-centric services.

3. MACHINE LEARNING MODELS AND TECHNIQUES FOR SOCIAL SERVICE DELIVERY

Machine Learning (ML) is the intelligence core of modern digital government platforms, enabling data-driven decision-making, automation, and predictive service delivery. By leveraging advanced algorithms, governments can move from reactive governance to proactive and personalized service models, significantly improving efficiency and citizen satisfaction.

3.1 Role of Machine Learning in Government Systems

Traditional rule-based systems are limited in handling large-scale, dynamic, and complex datasets. ML models, in contrast, learn patterns from historical and real-time data, enabling:

- **Predictive service delivery:** anticipating citizen needs
- **Automation of decision-making processes:**
- **Fraud detection and anomaly identification:**
- **Resource optimization and planning:**
- **Personalized citizen engagement:**

These capabilities are particularly critical in domains such as welfare distribution, healthcare, taxation, and urban governance.

3.2 Categories of Machine Learning Models

3.2.1 Supervised Learning Models

Supervised learning is widely used in structured government datasets where labeled data is available.

Common Applications:

- Eligibility prediction for social welfare schemes
- Risk scoring in financial aid programs
- Disease prediction in public healthcare

Techniques: Linear Regression, Logistic Regression, Decision Trees, Random Forest, Gradient Boosting Machines.

3.2.2 Unsupervised Learning Models

Unsupervised learning helps identify hidden patterns in unlabeled datasets.

Common Applications:

- Citizen segmentation for targeted services
- Identifying unusual patterns in transactions

- Clustering regions based on socio-economic indicators

Techniques: K-Means Clustering, Hierarchical Clustering, Principal Component Analysis (PCA).

3.2.3 Deep Learning Models

Deep learning is particularly useful for handling unstructured data such as text, images, and speech.

Common Applications:

- Document processing (ID verification, forms)
- Speech-based citizen interaction systems
- Image-based surveillance and smart city monitoring

Techniques: Artificial Neural Networks (ANN), Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN).

3.2.4 Natural Language Processing (NLP)

NLP enables governments to interact with citizens in natural language.

Applications:

- AI-powered chatbots for grievance redressal
- Multilingual service delivery
- Automated document summarization

Techniques: Text classification, Named Entity Recognition (NER), Sentiment analysis.

3.3 Machine Learning Pipeline

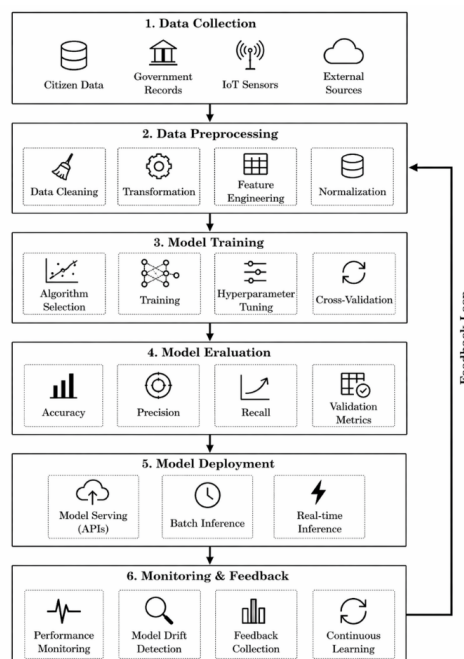


Fig. 2. Machine Learning Pipeline for Social Service Delivery.

Fig. 2. Machine Learning Pipeline for Government Platforms

3.4 Use Case: Intelligent Welfare Distribution

Machine learning enhances social welfare systems by ensuring that benefits reach the right beneficiaries efficiently.

Key Capabilities:

- Predicting eligibility based on socio-economic data
- Detecting duplicate or fraudulent claims
- Prioritizing high-risk or vulnerable populations
- Automating approval workflows

Example Workflow:

1. **Collect citizen data from multiple government sources**
2. **Apply predictive models to assess eligibility**
3. **Use anomaly detection to flag suspicious entries**
4. **Automatically trigger benefit disbursement**

3.5 Real-Time vs Batch Processing in ML Systems

Processing Type	Characteristics	Government Use Case
Batch Processing	Periodic model execution	Monthly welfare eligibility checks
Real-Time Processing	Instant decision-making	Fraud detection in transactions
Hybrid Approach	Combines both	Smart healthcare alerts

3.6 MLOps for Government Platforms

To ensure reliability and scalability, ML systems must adopt MLOps practices, including:

- Continuous Integration and Continuous Deployment (CI/CD)
- Automated model retraining pipelines
- Version control for models and datasets
- Monitoring for model drift and bias

MLOps ensures that ML models remain accurate, transparent, and compliant with regulatory standards.

3.7 Challenges in ML Adoption

Despite its benefits, ML implementation in government systems faces several challenges:

- **Data Quality Issues:** Incomplete or inconsistent datasets
- **Bias and Fairness:** Risk of discrimination in automated decisions
- **Explainability:** Lack of transparency in complex models
- **Scalability:** Handling large and diverse datasets
- **Regulatory Compliance:** Adhering to data protection laws

3.8 Key Benefits

- Improved efficiency and reduced manual workload
- Faster and more accurate decision-making
- Enhanced fraud detection and prevention
- Personalized and proactive service delivery
- Better policy planning through predictive insights

4. CLOUD-NATIVE ARCHITECTURE AND IMPLEMENTATION STRATEGIES

Cloud computing forms the backbone of Intelligent Digital Government Platforms by enabling scalability, resilience, and cost-effective service delivery. When combined with cloud-native design principles, governments can build agile, modular, and highly available systems capable of supporting large-scale social services.

4.1 Cloud-Native Design Principles

Cloud-native architectures are built to fully leverage cloud environments rather than simply migrating legacy systems. Key principles include:

- **Scalability:** Dynamically scale resources based on demand
- **Resilience:** Ensure system availability despite failures
- **Elasticity:** Automatically adjust compute and storage resources
- **Loose Coupling:** Independent services for better flexibility
- **Automation:** Infrastructure provisioning and deployment automation

These principles allow government platforms to handle millions of users and transactions efficiently.

4.2 Microservices-Based Architecture

Microservices architecture divides applications into small, independent services that communicate via APIs.

Key Characteristics:

- Each service handles a specific function (e.g., identity verification, payment processing)
- Services can be developed, deployed, and scaled independently
- Fault isolation ensures system stability

Benefits in Government Systems:

- Faster deployment of new services
- Easier integration across departments
- Improved maintainability of large systems

4.3 Containerization and Orchestration

Containerization packages applications and their dependencies into lightweight, portable units.

- **Containers:** ensure consistency across environments
- **Orchestration platforms (e.g., Kubernetes):** manage deployment, scaling, and availability

Advantages: Rapid deployment and rollback, efficient resource utilization, and simplified environment management.

4.4 Serverless Computing

Serverless architecture allows developers to run code without managing infrastructure.

Key Features: Event-driven execution, automatic scaling, pay-per-use pricing.

Government Use Cases:

- Processing citizen requests
- Triggering notifications (SMS, email alerts)
- Real-time data processing

4.5 Data Management in Cloud Environments

Effective data management is critical for ML-driven government platforms.

- **Cloud Data Lakes:** for raw data storage
- **Cloud Data Warehouses:** for analytics
- **Distributed Databases:** for transactional systems

Key Capabilities: High availability and fault tolerance, real-time data access, and seamless integration with ML tools.

4.6 DevOps and CI/CD Pipelines

Modern government platforms adopt DevOps practices to accelerate development and deployment.

Key Elements:

- Continuous Integration (CI) for code validation
- Continuous Deployment (CD) for automated releases
- Infrastructure as Code (IaC) for environment setup

Benefits: Faster delivery of services, reduced deployment errors, and improved collaboration across teams.

4.7 Multi-Cloud and Hybrid Cloud Strategies

Governments often adopt hybrid or multi-cloud strategies due to regulatory and operational requirements.

4.8 Security in Cloud-Native Systems

Security is critical due to the sensitive nature of government data. Key Practices:

- Zero Trust Architecture
- Identity and Access Management (IAM)
- End-to-end encryption
- Secure API gateways
- Continuous security monitoring

4.9 High Availability and Disaster Recovery

Cloud platforms ensure uninterrupted service delivery through:

- Multi-region deployment
- Load balancing
- Automated backups
- Disaster recovery strategies (RPO/RTO compliance)

These capabilities are essential for mission-critical government services.

4.10 Benefits of Cloud-Native Government Platforms

- Enhanced scalability for large populations
- Reduced infrastructure costs
- Faster innovation and deployment cycles
- Improved reliability and uptime
- Better integration with AI/ML services

4.11 Summary Table: Traditional vs Cloud-Native Systems

Feature	Traditional Systems	Cloud-Native Systems
Scalability	Limited	Highly scalable
Deployment Speed	Slow	Rapid (CI/CD enabled)
Maintenance	High	Automated
Flexibility	Rigid	Highly flexible
Cost Model	Capital-intensive	Pay-as-you-go

5. CHALLENGES, ETHICAL CONSIDERATIONS, AND FUTURE DIRECTIONS

The adoption of Intelligent Digital Government Platforms offers transformative potential for social service delivery. However, the integration of machine learning and cloud-native

architectures introduces a range of technical, ethical, and operational challenges that must be carefully addressed to ensure equitable, secure, and sustainable governance.

5.1 Technical Challenges

5.1.1 Data Quality and Integration Issues

Government data is often fragmented across multiple departments and stored in heterogeneous formats. Inconsistent, incomplete, or outdated datasets can significantly impact the accuracy of machine learning models.

Key Issues:

- Data silos across agencies
- Lack of standardized data formats
- Missing or noisy data

5.1.2 Legacy System Integration

Many government institutions still rely on legacy systems that are not designed for modern cloud or AI integration.

Challenges:

- Limited interoperability with modern APIs
- High cost of modernization or migration
- Risk of service disruption during upgrades

5.1.3 Scalability and Performance

Handling millions of users and large-scale datasets requires highly scalable systems.

Concerns:

- Latency in real-time decision-making
- Resource optimization for peak loads
- Efficient model deployment at scale

5.1.4 Security and Cyber Threats

Government platforms are prime targets for cyberattacks due to the sensitive nature of citizen data.

Threats Include:

- Data breaches and identity theft
- Distributed Denial of Service (DDoS) attacks
- Insider threats

5.2 Ethical Considerations

5.2.1 Data Privacy and Protection

The collection and processing of large volumes of citizen data raise significant privacy concerns.

Key Considerations:

- Compliance with data protection regulations
- Consent-based data usage
- Minimization of data collection

5.2.2 Algorithmic Bias and Fairness

Machine learning models may inadvertently reflect biases present in historical data, leading to unfair outcomes.

Examples: Biased eligibility decisions in welfare programs; discriminatory risk scoring models.

Mitigation Strategies:

- Bias detection and correction mechanisms
- Diverse and representative training datasets
- Regular auditing of ML models

5.2.3 Transparency and Explainability

Black-box AI systems can reduce trust in government decisions.

Requirements:

- Explainable AI (XAI) techniques
- Clear communication of decision logic
- Accountability frameworks

5.2.4 Digital Divide and Inclusivity

Not all citizens have equal access to digital infrastructure or digital literacy.

Challenges: Rural and underserved populations may be excluded; accessibility barriers for elderly and disabled citizens.

Solutions:

- Multi-channel service delivery (online + offline)
- Inclusive design practices

5.3 Governance and Regulatory Challenges

- Ensuring compliance with national and international regulations
- Establishing clear data ownership and accountability
- Managing cross-border data flows in cloud environments

- Standardizing policies across departments

5.4 Operational Challenges

- Skill gaps in AI, cloud computing, and data engineering
- Resistance to organizational change
- Budget constraints in public sector projects
- Coordination across multiple government agencies

5.5 Future Directions

5.5.1 AI-Driven Proactive Governance

Future government platforms will shift from reactive to proactive service delivery using predictive analytics.

- Anticipating citizen needs before requests are made
- Automated benefit enrollment
- Early detection of social and economic risks

5.5.2 Integration of Emerging Technologies

Technology	Potential Impact
Artificial Intelligence	Advanced automation and decision-making
Blockchain	Secure and transparent record-keeping
Internet of Things	Real-time data collection for smart governance
Edge Computing	Low-latency processing for remote regions
5G Networks	High-speed connectivity for digital services

5.5.3 Explainable and Responsible AI

Future systems will prioritize:

- Ethical AI frameworks
- Model transparency and auditability
- Human-in-the-loop decision-making

5.5.4 Hyper-Personalized Citizen Services

- Tailored recommendations based on citizen profiles
- Context-aware service delivery
- Multilingual and voice-enabled interfaces

5.5.5 Interoperable Digital Ecosystems

Governments will move toward unified digital ecosystems where:

- Systems across departments are fully integrated
- Data sharing is seamless and secure
- APIs enable collaboration with private sector services

5.5.6 Sustainable and Green Computing

- Energy-efficient data centers
- Optimized resource utilization in cloud environments
- Environmentally sustainable IT practices

5.6 Summary Table: Challenges vs Solutions

Challenge	Potential Solution
Data Silos	Unified data platforms and standards
Algorithmic Bias	Fairness-aware ML models
Security Risks	Zero Trust and advanced cybersecurity
Digital Divide	Inclusive and multi-channel services
Legacy Systems	Gradual modernization with hybrid models
Skill Gaps	Training and capacity building programs

6. CONCLUSION

The evolution of Intelligent Digital Government Platforms marks a significant shift in how public services are designed, delivered, and optimized in the digital era. By integrating machine learning with cloud-native architectures, governments can transition from traditional, reactive service models to intelligent, proactive, and citizen-centric systems. This transformation enables enhanced operational efficiency, improved decision-making, and more equitable distribution of social services.

Throughout this paper, we examined the architectural foundations of such platforms, highlighting the importance of layered system design, microservices, API-driven integration, and robust cloud infrastructure. The incorporation of machine learning techniques further strengthens these platforms by enabling predictive analytics, fraud detection, and personalized service delivery. Additionally, cloud-native strategies such as containerization, serverless computing, and DevOps practices ensure scalability, flexibility, and rapid deployment.

However, the adoption of these technologies is not without challenges. Issues related to data quality, legacy system integration, cybersecurity, and scalability must be carefully managed. Ethical considerations—including data privacy, algorithmic bias, and digital inclusivity—play a crucial role in ensuring that technological advancements do not inadvertently disadvantage certain populations. Addressing these concerns requires strong governance frameworks, transparent policies, and continuous monitoring.

Looking ahead, the future of digital government lies in the convergence of emerging technologies such as artificial intelligence, blockchain, and edge computing. These innovations

will further enhance interoperability, transparency, and real-time decision-making capabilities. Governments that successfully adopt intelligent digital platforms will be better positioned to deliver responsive, inclusive, and sustainable public services.

In conclusion, Intelligent Digital Government Platforms represent a foundational pillar for modern governance. By leveraging machine learning and cloud architecture effectively, governments can build resilient, scalable, and citizen-focused ecosystems that meet the evolving needs of society while fostering trust, transparency, and innovation.

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