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# A National Big Data Governance Framework for Digital Government Transformation in Saudi Arabia

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***Abstract-*** ***The Kingdom of Saudi Arabia is undergoing a rapid transformation toward a data-driven digital economy under Vision 2030, where big data has emerged as a critical enabler of government efficiency, innovation, and citizen-centric service delivery. Despite significant investments in digital infrastructure and the establishment of regulatory bodies such as the Saudi Data and Artificial Intelligence Authority (SDAIA) and the National Data Management Office (NDMO), challenges persist in achieving unified, scalable, and policy-compliant data governance across government entities. This study proposes a comprehensive National Big Data Governance Framework designed to support digital government transformation in Saudi Arabia. The framework integrates five foundational dimensions: governance structure, data lifecycle management, regulatory compliance, technological infrastructure, and value-driven analytics. It aligns with national regulations, including the Personal Data Protection Law (PDPL), and incorporates global best practices to ensure interoperability, data quality, security, and ethical use of data. The proposed model introduces a multi-layered governance architecture that bridges policy, operational processes, and advanced analytics capabilities. It enables improved data sharing, enhanced decision-making, and optimized public service delivery. This research contributes to the advancement of national data governance by offering a scalable, policy-aligned, and implementation-ready framework tailored to the Saudi digital government ecosystem.***

***Keywords-*** ***Big Data Governance, Digital Government Transformation, Saudi Arabia, Vision 2030, SDAIA, NDMO, Personal Data Protection Law (PDPL), Data Governance Framework, Public Sector Analytics, Artificial Intelligence Governance***

## I. INTRODUCTION

The accelerating pace of digital transformation has fundamentally reshaped how governments operate, deliver services, and engage with citizens. In this context, data has emerged as a strategic national asset, enabling governments to transition from traditional administrative models toward intelligent, data-driven decision-making ecosystems. The concept of digital government, which integrates advanced technologies such as big data analytics, artificial intelligence (AI), and cloud computing into public sector operations, is now central to achieving efficiency, transparency, and innovation in governance.

In the Kingdom of Saudi Arabia, digital transformation is a cornerstone of Vision 2030, a national strategic framework aimed at diversifying the economy and enhancing public sector performance. The Saudi government has made significant investments in digital infrastructure, smart platforms, and e-government services, positioning itself as a regional leader in digital governance. Institutions such as the Saudi Data and Artificial Intelligence Authority (SDAIA) and the Digital Government Authority (DGA) have been established to oversee data governance, policy development, and the implementation of advanced analytics across government entities.

At the core of this transformation lies the exponential growth of data generated from various sources, including healthcare systems, financial transactions, smart city initiatives, IoT devices, and administrative processes. This surge in data volume, variety, and velocity—commonly referred to as big data—presents unprecedented opportunities for enhancing policy formulation, improving service delivery, and enabling predictive governance. However, the effective utilization of big data requires robust governance mechanisms to ensure data quality, consistency, security, privacy, and ethical usage.

Despite Saudi Arabia's progress in establishing regulatory frameworks such as the Personal Data Protection Law (PDPL) and the National Data Management Office (NDMO) standards, several challenges remain. Government entities often operate in silos, resulting in fragmented data systems and

limited interoperability. Inconsistent data quality, lack of standardized governance practices, and varying levels of data maturity across organizations further hinder the realization of a fully integrated digital government ecosystem. Additionally, concerns related to data privacy, cybersecurity, and regulatory compliance necessitate a structured and unified approach to data governance.

To address these challenges, there is a critical need for a comprehensive National Big Data Governance Framework that aligns policy, technology, and organizational capabilities. Such a framework should not only establish clear governance structures and accountability mechanisms but also define standardized processes for data lifecycle management, from data collection and storage to processing, sharing, and utilization. Furthermore, it should incorporate advanced technological infrastructures, including data lakes, cloud platforms, and AI-driven analytics systems, to support scalable and real-time decision-making.

This research aims to develop a holistic and scalable big data governance framework tailored specifically to the Saudi Arabian context. The proposed framework integrates global best practices with national regulatory requirements, ensuring alignment with Vision 2030 objectives and SDAIA's strategic mandate. It emphasizes a multi-layered governance architecture that bridges strategic policy directives with operational implementation and analytical value generation.

The significance of this study lies in its contribution to both academic research and practical implementation. From an academic perspective, it addresses a critical gap in the literature by proposing a unified governance model that integrates policy, technology, and analytics. From a practical standpoint, it provides policymakers, government leaders, and data practitioners with a structured approach to managing big data as a national asset, ultimately enabling more efficient, transparent, and citizen-centric governance.

## II. LITERATURE REVIEW

### 2.1 Big Data Governance: Concepts and Foundations

Big data governance refers to the comprehensive set of policies, standards, roles, and processes that ensure the effective management, quality, security, and ethical utilization of data across organizational and national ecosystems. Traditional data governance frameworks, such as the Data Management Body of Knowledge (DAMA-DMBOK), emphasize structured data environments, focusing on data stewardship, metadata management, data quality, and lifecycle control (Khatri & Brown, 2010; Otto, 2011). However, the emergence of big data has significantly expanded the scope and complexity of governance.

Unlike traditional data systems, big data environments are characterized by high volume, velocity, and variety, including structured, semi-structured, and unstructured data generated from diverse sources such as IoT devices, social media, and real-time transactional systems. This shift introduces several governance challenges that are widely debated in the literature.

One major challenge is governance complexity in real-time and distributed environments. Scholars argue that traditional centralized governance models are insufficient for handling streaming data and decentralized architectures such as data lakes and cloud-based platforms (Janssen & Kuk, 2016). Real-time data processing requires adaptive governance mechanisms that can enforce policies dynamically without compromising performance.

Another key issue is data quality inconsistency in unstructured data environments. While structured datasets can be governed using predefined schemas and validation rules, unstructured data (e.g., text, images, sensor data) lacks standardized formats, making quality assurance more complex (Batini & Scannapieco, 2016). This creates disagreements in the literature regarding whether governance should prioritize strict standardization or flexible, context-driven quality frameworks.

Additionally, interoperability and integration challenges remain critical barriers. In large-scale ecosystems, data is often distributed across multiple

platforms and organizations, leading to fragmentation and limited data sharing. Researchers highlight that without unified governance standards, organizations struggle to achieve seamless interoperability, resulting in duplication, inefficiencies, and inconsistent decision-making (Sun & Medaglia, 2019).

Privacy and ethical concerns further complicate big data governance. The increasing use of personal and sensitive data raises issues related to consent, data ownership, and algorithmic bias. Scholars emphasize the need for governance frameworks that incorporate ethical principles, transparency, and accountability, particularly in AI-driven environments (Sadiq & Indulska, 2017).

To address these challenges, modern big data governance models advocate for hybrid governance approaches, combining centralized policy control with decentralized execution. This includes the adoption of data stewardship roles, automated governance tools, and continuous monitoring mechanisms. Such approaches enable organizations to balance flexibility with control, ensuring both scalability and compliance.

Overall, the literature highlights that big data governance is no longer a static framework but a dynamic and evolving discipline that must adapt to technological advancements, regulatory requirements, and organizational needs.

2.2 Digital Government Transformation and Data-Driven Governance

Digital government transformation refers to the integration of advanced technologies such as big data, artificial intelligence (AI), and cloud computing into public sector operations to enable efficient, transparent, and citizen-centric services.

Leading countries demonstrate how strong data governance enables successful transformation. For example, Estonia implemented the X-Road platform, which allows secure, real-time data exchange across government entities, eliminating data silos and enabling seamless digital services. Similarly, Singapore developed the Smart Nation initiative, supported by centralized data platforms and national data-sharing standards that enhance policy coordination and service delivery. In the United Arab Emirates, the UAE Data Strategy promotes interoperability through unified data standards and open data platforms, enabling cross-government integration.

These examples highlight that successful digital transformation depends on standardized data governance, interoperability frameworks, and centralized coordination mechanisms.

However, challenges persist, particularly in countries with fragmented legacy systems. Common issues include:

- Data silos across government entities
- Lack of interoperability standards
- Resistance to organizational change

Without a robust governance framework, these challenges lead to inconsistent data practices and reduced trust in data-driven decision-making.

2.3 Data Governance Ecosystem in Saudi Arabia

Saudi Arabia has established a strong institutional and regulatory foundation for data governance under Vision 2030. Key entities include the Saudi Data and Artificial Intelligence Authority, which leads national data and AI strategy, and the National Data Management Office, which provides detailed governance standards, policies, and maturity models. In addition, the Personal Data Protection Law strengthens data privacy, security, and regulatory compliance.

While these frameworks are comprehensive, they remain partially fragmented in implementation, creating gaps in achieving a fully unified data governance ecosystem.

- SDAIA provides strong strategic direction; however, it operates at a high policy level, with limited enforcement mechanisms at the operational level across all entities.
- NDMO frameworks offer detailed standards, but adoption varies significantly across government organizations due to differences in data maturity and capabilities.

- PDPL ensures robust data protection, yet it focuses primarily on compliance rather than enabling integrated data sharing and analytics.

Additionally, initiatives such as national data platforms and open data programs have improved accessibility, but interoperability across entities remains inconsistent, and data silos still persist in practice.

Therefore, the key issue is not the absence of frameworks, but the lack of integration between policy, implementation, and analytics layers.
This limitation highlights the need for a unified, multi-layer governance framework that connects strategic direction, operational execution, and value-driven analytics—forming the foundation for this research.

2.4 Global Best Practices in Big Data Governance
Globally, big data governance has evolved into a critical enabler of digital transformation, with organizations adopting structured frameworks to ensure data quality, interoperability, and value generation. Leading institutions such as the Organisation for Economic Co-operation and Development and the World Bank emphasize governance principles including transparency, accountability, data sharing, and cross-border data flows.

In practice, advanced economies implement governance through three key approaches:

- Centralized Data Platforms: Countries like Estonia and Singapore use national data exchange platforms (e.g., X-Road) to enable secure, real-time interoperability across government entities.
- Cloud-Based Architectures: Governments adopt cloud and data lake environments to manage large-scale, heterogeneous datasets, ensuring scalability and real-time processing.
- Data Governance Maturity Models: Frameworks such as DAMA-DMBOK and OECD models are used to assess governance capabilities across dimensions like data quality, compliance, and organizational readiness.

Furthermore, leading organizations integrate AI-driven governance mechanisms, including automated data quality monitoring, metadata management systems, and policy enforcement tools. These technologies enable dynamic governance in complex, real-time data environments.

However, global frameworks are often generic and not context-specific, lacking direct alignment with national regulatory environments or sector-specific requirements. This limits their applicability in countries like Saudi Arabia, where governance must align with national laws, institutional structures, and Vision 2030 objectives.

2.5 Research Gap
Despite the presence of well-established regulatory frameworks and institutional support in Saudi Arabia, a critical gap remains in the integration of governance, technology, and analytics into a unified and operational model.

(1) Why this gap persists:
Current frameworks such as SDAIA policies, NDMO standards, and PDPL primarily operate in isolation—focusing either on policy definition, compliance, or technical guidance. There is limited alignment between these components, and no unified structure that connects strategic governance with operational execution and analytical value generation. Additionally, variations in data maturity across government entities and reliance on legacy systems further hinder consistent implementation.

(2) Resulting practical and theoretical limitations:
This fragmentation leads to several key issues:

- Continued data silos and limited interoperability across entities
- Inconsistent data quality and governance practices
- Reduced ability to support real-time, data-driven decision-making
- A gap between compliance-focused governance and value-driven analytics

From a theoretical perspective, existing studies tend to address governance, technology, or analytics independently, without proposing a holistic, multi-

layered governance architecture tailored to national digital government ecosystems.

(3) How this research addresses the gap:
This study proposes a comprehensive National Big Data Governance Framework that integrates:

- Strategic governance (policies and regulatory alignment)
- Operational processes (data lifecycle and stewardship)
- Technical infrastructure (cloud, data platforms, integration layers)
- Analytics capabilities (AI-driven decision support)

By introducing a multi-layered and pillar-based architecture, the framework bridges the disconnect between policy, implementation, and value creation. It provides a scalable and context-specific model tailored to Saudi Arabia's digital government transformation under Vision 2030.

## III. RESEARCH METHODOLOGY

### 3.1 Research Design and Approach

This study adopts a Design Science Research (DSR) methodology to develop a National Big Data Governance Framework for Saudi Arabia. DSR is appropriate as it focuses on creating practical solutions (artifacts) to real-world problems, particularly in complex socio-technical environments such as digital government.

The research follows four key phases:

1. Problem Identification – Analysis of governance challenges in Saudi Arabia, including data silos, interoperability gaps, and fragmented implementation.
2. Literature Synthesis – Review of global frameworks (e.g., DAMA-DMBOK, OECD) and national regulations (SDAIA, NDMO, PDPL).
3. Framework Development – Design of a multi-layer governance model integrating policy, operations, technology, and analytics.
4. Validation – Conceptual and scenario-based validation using real-world Saudi government use cases to assess scalability, compliance, and applicability.

This approach ensures the framework is both theoretically grounded and practically applicable.

### 3.2 Data Sources and Analytical Inputs

This study utilizes secondary data sources to ensure both theoretical rigor and practical relevance. The selected sources include:

- National policy documents (SDAIA, NDMO, PDPL)
- Digital Government Authority guidelines
- Scopus-indexed academic literature
- Global governance frameworks (OECD, DAMA-DMBOK)

These sources were chosen because they provide authoritative, policy-driven, and empirically validated insights into data governance practices at both national and global levels.

In addition, the study incorporates critical perspectives from existing literature, highlighting limitations such as implementation gaps, interoperability challenges, and governance fragmentation. This ensures that the framework is not only based on best practices but also addresses documented weaknesses in current approaches.

The collected data was analyzed using a thematic synthesis approach, enabling the identification of key governance dimensions, implementation challenges, and design requirements for the proposed framework.

### 3.3 Framework Development Process

The framework was developed using a layered and pillar-based design approach to ensure alignment between strategy, operations, technology, and value generation.

Five core pillars were selected based on recurring themes across literature and regulatory frameworks (DAMA-DMBOK, OECD, SDAIA, NDMO). These pillars represent the minimum essential components required for effective big data governance:

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- Governance Structure – ensures accountability and decision authority
- Data Lifecycle Management – controls data from creation to disposal
- Regulatory Compliance – aligns with PDPL and national policies
- Technology Infrastructure – enables scalable and secure data operations
- Data Value & Analytics – ensures data is transformed into actionable insights

These five pillars were chosen because they collectively address:

- Policy (governance + compliance)
- Execution (lifecycle + technology)
- Value creation (analytics)

This integrated structure ensures the framework is holistic, balanced, and practically implementable, directly addressing the fragmentation identified in the research gap.

3.4 Conceptual Framework Development (Visual Model)

The conceptual framework presents a four-layer governance architecture designed to align policy, execution, and value generation within Saudi Arabia's digital government ecosystem.

The four layers were selected to reflect the end-to-end flow of data governance, from strategic direction to decision-making:

- Strategic Layer – defines national policies, governance principles, and oversight (SDAIA, national strategies)
- Operational Layer – translates policies into processes, roles, and standards (data stewardship, workflows)
- Technical Layer – provides infrastructure for data management (cloud platforms, data lakes, integration tools)
- Analytics Layer – generates value through AI, dashboards, and decision support systems

These layers were chosen because they represent the complete governance cycle:

policy → execution → infrastructure → value

This structure ensures that governance is not limited to compliance but is directly linked to data-driven decision-making and national performance outcomes.

3.5 Data Governance Maturity Assessment Model

To evaluate the readiness of government entities, this study adopts a five-level data governance maturity model, adapted from established frameworks such as DAMA-DMBOK and OECD.

The model was selected because it provides a structured progression from ad hoc practices to optimized, AI-driven governance, enabling organizations to assess current capabilities and define improvement pathways.

| Level | Description | Key Characteristics |
|---|---|---|
| Level 1: Initial | Ad hoc practices | No formal governance structure |
| Level 2: Managed | Basic governance | Limited policies and standardization |
| Level 3: Defined | Formal governance | Roles, policies, and processes established |
| Level 4: Integrated | Cross-entity governance | High interoperability and data sharing |
| Level 5: Optimized | Advanced governance | AI-driven, real-time decision-making |

This model supports the framework by enabling:

- Benchmarking governance maturity across entities
- Identifying gaps in implementation
- Guiding progressive improvement toward data-driven governance

3.6 Data Distribution and Governance Priority

The study defines governance priorities across five key dimensions to reflect their relative importance in enabling effective data governance. These priorities are derived from literature synthesis, regulatory requirements (SDAIA, PDPL), and common failure areas in digital government implementations.

- Data Quality Management (25%) – Ensures reliability and accuracy, forming the

foundation for all analytics and decision-making
- Data Security & Privacy (25%) – Critical for regulatory compliance and public trust (aligned with PDPL)
- Regulatory Compliance (20%) – Ensures adherence to national policies and governance standards
- Data Integration & Interoperability (15%) – Enables cross-entity data sharing and reduces silos
- Advanced Analytics & AI (15%) – Supports value creation through predictive and data-driven insights

These percentages represent priority weighting, not exact measurements, indicating where governance efforts should be focused.

The distribution reflects a balanced approach, where:

- Foundational elements (quality + security) are prioritized
- Enabling capabilities (integration + analytics) are supported
- Compliance ensures alignment with national regulations

3.7 Validation Strategy

The proposed framework is validated using a multi-method approach to ensure both theoretical soundness and practical applicability:

- Comparative Analysis – Alignment with global frameworks (DAMA-DMBOK, OECD) and Saudi regulations (SDAIA, PDPL, NDMO)
- Scenario-Based Validation – Application of the framework to real-world Saudi government use cases (e.g., cross-ministry data sharing) to assess feasibility
- Expert-Informed Evaluation – Validation criteria derived from industry practices and governance standards
- Scalability and Applicability Assessment – Evaluation of the framework's adaptability across entities with different data maturity levels

This approach ensures that the framework is not only conceptually robust but also implementable in real-world digital government environments.

## IV. PROPOSED NATIONAL BIG DATA GOVERNANCE FRAMEWORK

4.1 Framework Overview

The proposed National Big Data Governance Framework (NBDGF) is designed to address the fragmentation identified in the research gap by integrating governance, operations, technology, and analytics into a unified model.

Aligned with Vision 2030 and national regulations (SDAIA, NDMO, PDPL), the framework provides a scalable and interoperable structure that enables consistent data governance across government entities.

Unlike existing approaches that treat policy, implementation, and analytics separately, the NBDGF connects these components into a cohesive, multi-layered architecture, ensuring both compliance and value generation.

4.2 Core Pillars of the Framework

The framework is structured around five core pillars, consistent with the design methodology and literature review:

| Pillar | Description | Key Components |
|---|---|---|
| Governance Structure | Defines roles, policies, and accountability | Data owners, stewards, governance councils |
| Data Lifecycle Management | Manages data from creation to disposal | Collection, storage, processing, sharing |
| Regulatory Compliance | Ensures adherence to national laws | PDPL, SDAIA policies, cybersecurity |
| Technology Infrastructure | Supports scalable data operations | Cloud, data lakes, integration platforms |
| Data Value & Analytics | Enables decision-making | AI models, dashboards, predictive analytics |

These pillars were selected to ensure:

- Policy alignment (governance + compliance)
- Operational execution (lifecycle + technology)
- Value generation (analytics)

This structure directly addresses the lack of integration identified in the research gap.

4.3 Multi-Layer Governance Architecture

he NBDGF adopts a four-layer governance architecture to ensure alignment between policy, execution, infrastructure, and value creation:

1. Strategic Layer
   Defines national policies, governance principles, and regulatory oversight led by SDAIA. It sets direction and ensures alignment with Vision 2030.
2. Operational Layer
   Translates policies into actionable processes, including data stewardship, governance workflows, and standard operating procedures.
3. Technical Layer
   Provides the infrastructure required for implementation, including cloud platforms, data lakes, integration tools, and cybersecurity mechanisms.
4. Analytics Layer
   Focuses on value generation through dashboards, predictive analytics, and AI-driven decision support systems.

Layer Interaction

The layers are interconnected and operate as a continuous flow:

- The Strategic Layer defines policies → implemented through the Operational Layer
- The Operational Layer executes processes → supported by the Technical Layer
- The Technical Layer enables data processing → utilized by the Analytics Layer
- Insights from the Analytics Layer feed back into the Strategic Layer to support evidence-based policymaking

This creates a closed-loop governance system, ensuring continuous improvement, alignment, and value generation.

4.4 Data Lifecycle Governance Model

Effective big data governance requires structured control across the entire data lifecycle, ensuring data quality, security, and compliance at each stage.

The lifecycle model is included because it provides end-to-end governance coverage, directly linking operational processes with regulatory requirements (PDPL, SDAIA standards).

| Stage | Governance Controls | Tools & Technologies |
|---|---|---|
| Data Collection | Validation rules, consent management | APIs, IoT devices, digital forms |
| Data Storage | Encryption, classification, access control | Cloud storage, databases |
| Data Processing | Data quality checks, transformation rules | ETL tools, AI models |
| Data Sharing | Access governance, interoperability standards | APIs, data exchange platforms |
| Data Archiving | Retention policies, compliance checks | Backup systems |
| Data Disposal | Secure deletion, audit trails | Data destruction tools |

This lifecycle ensures that:

- Governance is applied consistently across all stages
- Compliance and security are embedded, not added later
- Data remains reliable and usable for analytics and decision-making

4.5 Governance Operating Model

The NBDGF adopts a federated governance model, balancing centralized control with decentralized execution. This approach is selected because Saudi Arabia's government ecosystem consists of multiple entities with varying levels of data maturity, making a fully centralized model impractical.

Why Federated Model

- Centralized models ensure standardization but limit flexibility
- Decentralized models allow agility but create inconsistency
- A federated model combines both, enabling national alignment while allowing entity-level implementation

This approach aligns with the Saudi context, where SDAIA provides national oversight while ministries operate independently.

Governance Structure and Roles

| Role | Responsibility | Decision Authority |
|---|---|---|
| National Authority (SDAIA) | Defines policies, standards, and oversight | Final authority on governance policies |
| Government Entities | Implement governance frameworks | Operational decision-making |
| Data Stewards | Ensure data quality and lifecycle control | Data-level decisions |
| IT & Security Teams | Manage infrastructure and security | Technical implementation decisions |

Execution in Practice
Governance is executed through:

- Policy Enforcement – National standards issued by SDAIA and monitored across entities
- Data Stewardship Model – Assigned roles ensure accountability at dataset level
- Governance Committees – Cross-entity coordination for data sharing and standards alignment
- Performance Monitoring – KPIs and maturity assessments track compliance and progress

Accountability and Control Mechanisms

- Clear ownership of data assets (data owners/stewards)
- Defined approval workflows for data sharing and access
- Audit trails and compliance checks aligned with PDPL
- Regular governance reviews and maturity assessments

This operating model ensures that governance is not only defined but actively enforced, monitored, and continuously improved.

4.6 Interoperability and Data Integration
Interoperability is a critical component of the NBDGF, enabling secure and seamless data exchange across government entities. It directly addresses the issue of data silos identified in the research gap.

The framework adopts globally recognized best practices, including:

- Standardized data formats and metadata models (aligned with DAMA-DMBOK principles)
- API-based integration architecture to enable real-time data exchange
- National data exchange platforms, similar to Estonia's X-Road model

In the Saudi context, this approach aligns with SDAIA and NDMO initiatives aimed at improving data sharing and integration across ministries.

Implementation Approach
Establishment of common data standards and taxonomies

- Deployment of API gateways for controlled data access
- Use of metadata management systems for data discoverability
- Integration through secure national platforms

Key Benefits

- Eliminates data silos and duplication
- Enhances cross-entity collaboration
- Improves decision-making through integrated data
- Supports real-time, data-driven government services

This ensures that data flows efficiently across the ecosystem while maintaining security, compliance, and governance control.

4.7 Value-Driven Analytics and Decision Intelligence
The NBDGF integrates advanced analytics and artificial intelligence (AI) to enable data-driven and predictive decision-making across government entities.

Key capabilities include:

- Real-time monitoring of national KPIs
- Predictive and prescriptive analytics for policy planning
- AI-driven decision support systems for resource optimization and risk management

AI Governance
To ensure responsible and trustworthy use of AI, the framework incorporates AI governance controls, including:

- Model Validation – Regular testing for accuracy, robustness, and performance
- Bias and Fairness Checks – Monitoring for unintended bias across population groups
- Explain ability and Transparency – Ensuring AI decisions are interpretable and auditable
- Data Governance Alignment – AI models use high-quality, compliant data (aligned with PDPL)
- Continuous Monitoring – Detection of model drift and performance degradation

Strategic Value
This integration ensures that data is not only governed but also transformed into actionable insights, enabling:

- Proactive policymaking
- Improved public service delivery
- Enhanced risk detection (e.g., fraud, resource inefficiencies)

By embedding AI governance within the broader data governance framework, the NBDGF ensures ethical, reliable, and value-driven use of advanced analytics.

4.8 Framework Contributions
The proposed NBDGF makes the following key contributions:

- Integrated Governance Model – Combines policy, operations, technology, and analytics into a single unified framework
- Saudi-Specific Alignment – Directly aligned with SDAIA, NDMO, and PDPL, addressing local regulatory and institutional needs
- Multi-Layer Architecture – Bridges the gap between strategic governance and operational execution
- AI-Enabled Governance – Incorporates analytics and AI governance for value-driven decision-making
- Practical Implementation Focus – Provides clear structures, roles, and processes for real-world adoption

These contributions address the fragmentation identified in the research gap and provide a scalable, implementation-ready framework for digital government transformation.

## V. RESULTS AND DISCUSSION

5.1 Framework Evaluation Overview
The proposed NBDGF is evaluated using scenario-based and comparative analysis, rather than empirical results. This approach assesses its effectiveness across key dimensions: data quality, interoperability, compliance, and decision-making.

5.2 Governance Capability Impact

| Dimension | Before | After (With NBDGF) | What Changed |
|---|---|---|---|
| Data Quality | Inconsistent | Standardized | Stewardship + lifecycle controls |
| Integration | Fragmented | Interoperable | APIs + common standards |
| Compliance | Partial | Aligned | PDPL-based controls |
| Decision-Making | Reactive | Predictive | AI + analytics integration |
| Security | Weak | Strong | Access control + monitoring |

5.3 Interoperability Outcomes
Improvement is achieved through:

- API-based integration
- Standardized metadata
- National data exchange alignment

These mechanisms are widely validated in global practices (e.g., Estonia model), supporting feasibility.

5.4 Compliance Alignment
Alignment is ensured by embedding:

- PDPL controls → consent, data protection
- SDAIA policies → governance standards
- Audit mechanisms → traceability and accountability

This ensures compliance is built into processes, not applied afterward.

5.5 AI Governance Impact
The proposed framework incorporates structured AI governance mechanisms to ensure that advanced analytics are used in a responsible, transparent, and reliable manner within government operations.

Key controls include:

- Model Validation and Monitoring – AI models are regularly tested for accuracy, robustness, and stability across different data scenarios. Continuous monitoring mechanisms detect model drift and performance degradation over time.
- Bias and Fairness Controls – The framework introduces checks to identify and mitigate bias in datasets and algorithms, ensuring equitable outcomes across different population groups.
- explain ability and Transparency – AI models are required to provide interpretable outputs, enabling policymakers to understand how decisions are generated and ensuring accountability.
- Governance Alignment – AI systems operate within established data governance policies (e.g., PDPL), ensuring that data used for model training and inference complies with privacy and regulatory requirements.

These controls ensure that AI adoption in government is not only effective but also ethical, auditable, and aligned with public trust requirements.

5.6 Limitations
Despite its strengths, the proposed framework has several limitations:

- Conceptual Nature – The framework is primarily theoretical and has not yet been validated through large-scale empirical implementation within government entities.
- Organizational Readiness – Successful adoption depends on the maturity level of government organizations, which may vary significantly in terms of governance capabilities and infrastructure.
- Resource and Skill Requirements – Implementation requires skilled professionals in data governance, analytics, and AI, as well as investment in modern data infrastructure.
- Change Management Challenges – Resistance to organizational change and legacy system constraints may impact the pace of adoption.

These limitations highlight the need for phased implementation and future empirical validation.

5.7 Strategic Implications
The adoption of the proposed framework has significant strategic implications for Saudi Arabia's digital transformation agenda:

- Data-Driven Policymaking – Enables government entities to move from reactive to predictive decision-making using integrated and high-quality data.
- Cross-Entity Collaboration – Facilitates seamless data sharing and coordination across ministries, improving efficiency and service delivery.
- Enhanced Governance and Transparency – Strengthens accountability through standardized governance practices, audit mechanisms, and compliance controls.
- Scalable Digital Transformation – Provides a structured and adaptable model that supports national initiatives under Vision 2030,

including smart cities and AI-driven governance.

Overall, the framework positions data as a strategic national asset, supporting sustainable and innovation-driven public sector development.

5.8 Scenario-Based Validation:
To strengthen the validation of the proposed framework, a real-world scenario-based application is demonstrated using the Absher platform, one of Saudi Arabia's most widely used digital government systems.

Scenario Description
Absher provides integrated digital services for citizens and residents, including identity management, visa services, traffic violations, and public service access. The platform requires secure, real-time data exchange across multiple government entities, such as the Ministry of Interior, Passport Authority, and other national systems.

Governance Challenges
- Data Silos – Different entities maintain separate databases
- Interoperability Issues – Limited real-time integration across ministries
- Data Privacy Risks – Handling sensitive personal and biometric data
- Inconsistent Data Quality – Variations across source systems

Application of NBDGF
The proposed framework addresses these challenges as follows:

1. Strategic Layer
- SDAIA defines unified data governance policies for cross-ministry integration
- PDPL ensures privacy, consent, and data protection standards

2. Operational Layer
- Standardized data-sharing protocols between ministries
- Defined roles (data owners, stewards) for accountability

3. Technical Layer
- API-based integration enables real-time data exchange
- Cloud infrastructure and national data platforms ensure scalability and security

4. Analytics Layer
- AI-driven insights for service optimization (e.g., processing time, user demand patterns)
- Predictive analytics for proactive service delivery

Expected Outcomes
Applying the NBDGF to Absher would result in:

- Seamless interoperability across government entities
- Improved data quality and consistency
- Enhanced security and PDPL compliance
- Faster and more efficient service delivery
- Data-driven decision-making for service optimization

Validation Insight
This scenario demonstrates that the NBDGF is practically applicable in real-world Saudi digital government systems, supporting:

- Cross-entity integration
- Secure data governance
- Scalable digital service delivery

It validates the framework's ability to bridge policy, implementation, and analytics in a unified operational model.

## VI. CONCLUSION AND FUTURE RESEARCH

6.1 Conclusion
This study has presented a comprehensive National Big Data Governance Framework designed to support digital government transformation in the Kingdom of Saudi Arabia. In alignment with Vision 2030, the research emphasizes the critical role of data as a strategic national asset that enables intelligent decision-making, operational efficiency, and citizen-centric service delivery.

The proposed framework integrates five core pillars—governance structure, data lifecycle management, regulatory compliance, technological infrastructure, and value-driven analytics—into a unified and scalable model. By adopting a multi-layered architecture consisting of strategic, operational, technical, and analytics layers, the framework ensures seamless alignment between national policies and practical implementation across government entities.

The findings of this study demonstrate that a well-structured governance framework can significantly enhance data quality, interoperability, and regulatory compliance while reducing risks associated with data privacy and cybersecurity. The incorporation of advanced analytics and artificial intelligence further enables predictive and data-driven governance, allowing policymakers to make informed decisions in real time.

Moreover, the framework addresses key challenges currently faced by Saudi Arabia's digital government ecosystem, including data silos, inconsistent governance practices, and limited cross-entity integration. By introducing standardized processes, clearly defined roles, and interoperable systems, the framework promotes a cohesive and efficient data governance environment.

From a practical perspective, this research provides policymakers, government leaders, and data practitioners with an implementation-ready model that can be adapted across various sectors, including healthcare, finance, smart cities, and public administration. It also strengthens the national data governance ecosystem by aligning with regulatory bodies such as SDAIA and the National Data Management Office (NDMO), ensuring compliance with the Personal Data Protection Law (PDPL).

6.2 Future Research Directions

While this study provides a robust conceptual framework, several avenues for future research can further enhance its applicability and impact.

First, empirical validation of the proposed framework is recommended through case studies and pilot implementations within Saudi government entities. This would provide practical insights into the framework's effectiveness, scalability, and adaptability in real-world scenarios.

Second, future research can explore the integration of emerging technologies such as block chain for secure data sharing, edge computing for real-time data processing, and federated learning for privacy-preserving analytics. These technologies have the potential to further strengthen data governance and enhance trust in digital systems.

Third, there is a need to develop quantitative models and performance metrics to measure the effectiveness of data governance initiatives. Key performance indicators (KPIs) related to data quality, compliance, interoperability, and analytics maturity can provide a structured approach to monitoring progress.

Additionally, future studies can examine the human and organizational aspects of data governance, including change management, data culture, and skill development. Building a data-driven culture within government entities is essential for the successful implementation of governance frameworks.

Finally, comparative studies between Saudi Arabia and other leading digital governments can provide valuable insights into best practices and lessons learned, further refining the proposed framework.

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