

National Spatial Data Infrastructure Implementation in Developing Countries: A Systematic Review of Governance Challenges, Technical Bottlenecks, And Lessons for Nigeria's NGDI

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Abstract- National Spatial Data Infrastructure (NSDI) provides an institutional and technical framework for coordinating the production, management, sharing, and use of geospatial information. However, implementation in developing countries remains uneven, with persistent governance and technical constraints limiting the effectiveness and sustainability of national spatial-data systems. This study systematically reviewed empirical evidence on NSDI implementation in developing countries to synthesise governance and technical barriers, identify factors associated with stronger or weaker implementation outcomes, and derive lessons for Nigeria's National Geospatial Data Infrastructure (NGDI). The review followed a systematic search, eligibility, appraisal, extraction, and thematic synthesis process guided by the PRISMA 2020 framework. Sixteen relevant publications were identified, comprising 13 empirical or comparative studies and three conceptual or methodological studies. The evidence covered countries primarily in Africa and Asia. The findings indicate that institutional fragmentation, weak inter-agency coordination, inadequate policy integration, insufficient financing, limited human capacity, poor interoperability, inconsistent standards, inadequate metadata, weak data-sharing mechanisms, and deficient technical infrastructure are the principal constraints affecting NSDI implementation. Comparatively stronger systems were associated with clear institutional responsibilities, sustained leadership and financing, common standards, interoperable infrastructure, stakeholder participation, and long-term strategic planning. The review further demonstrates that the relative importance of these factors varies according to national institutional and socioeconomic contexts. For Nigeria, the evidence supports an integrated strategy combining stronger NGDI governance, enforceable geospatial standards, sustainable financing, distributed capacity development, formal data-sharing arrangements, interoperable technical infrastructure, and continuous performance monitoring. The study concludes that the

effective strengthening of NGDI requires governance and technical investments to be pursued as complementary components of a coherent national infrastructure.

Keywords: National Spatial Data Infrastructure; NSDI; National Geospatial Data Infrastructure; NGDI; geospatial data; governance; interoperability; developing countries; systematic review; Nigeria.

I. INTRODUCTION

The proliferation of geographic information technologies has generated vast volumes of spatial information across government agencies, private organisations, research institutions, and civil society. Yet the mere availability of datasets does not ensure their effective use. Where spatial information is produced in institutional/organisational silos, stored in incompatible formats, governed through fragmented institutional arrangements, or restricted by weak data-sharing protocols, its potential value for national development remains unrealised. National Spatial Data Infrastructure (NSDI) precisely addresses this coordination challenge by providing an integrative framework for the production, management, dissemination, and exchange of geospatial information across institutions and administrative levels (Masser, 2005; Elderink et al., 2008).

An NSDI is a multidimensional socio-technical system that extends beyond datasets, standards, and technologies to encompass policies, legislation, institutional arrangements, human capacity, financial mechanisms, and stakeholder participation (Elderink et al., 2008; Al Shamsi et al., 2011). Its effectiveness therefore depends on the alignment of governance

structures with technical capabilities. Empirical assessments of NSDI readiness in developing countries consistently identify a common set of constraints, including inadequate funding, shortages of skilled personnel, weak institutional coordination, limited interoperability, inconsistent metadata practices, and deficient data-sharing cultures (Eelderink et al., 2008; Al Shamsi et al., 2011; Mwange et al., 2018). These factors are not independent; rather, they interact to produce implementation environments in which formal NSDI institutions may exist but remain operationally ineffective.

NSDI development in Sub-Saharan Africa has proceeded slowly and unevenly, with wide variation in institutional maturity and readiness across countries (Makanga & Smit, 2010; Mwange et al., 2018). Human and financial resource deficits constitute particularly acute constraints in the region (Mwange et al., 2018). Similar patterns are evident in South Asia. In Bangladesh, institutional fragmentation, inadequate coordination, and persistent deficiencies in skilled human resources continue to impede sustainable NSDI development despite formal policy commitments (Rahman & Szabó, 2023). In Pakistan, institutional, technical, and human-capacity barriers interact to constrain implementation, indicating that technological investment alone is insufficient to overcome systemic deficiencies (Ali et al., 2025). These cross-regional observations support the view that NSDI underperformance in developing countries stems not from isolated deficiencies but from the interaction of governance weaknesses and technical limitations.

Technical barriers compound these governance challenges. Effective NSDI operation requires spatial datasets that are discoverable, accessible, interoperable, and reusable across organisational and technological boundaries. However, empirical studies document persistent problems involving incompatible data formats, inconsistent standards, inadequate metadata, heterogeneous coordinate reference systems, poor data quality, obsolete datasets, and insufficient infrastructure (Rahman & Szabó, 2020; Gelagay, 2019). The consequences are tangible, including duplication of data-production efforts, difficulties in integrating multi-source datasets,

restricted accessibility, and inefficient allocation of public resources. Under such conditions, an NSDI may exist as a formal institutional arrangement while remaining functionally fragmented and unable to deliver seamless national access to reliable spatial information.

These challenges are especially pronounced in Nigeria. The country's geospatial information environment is structurally complex, involving federal and state government institutions, specialised surveying and mapping agencies, academic and research organisations, and private-sector practitioners. Coordinating these actors to facilitate data sharing and utilisation was central to the rationale for establishing Nigeria's National Geospatial Data Infrastructure (NGDI). Nevertheless, empirical studies have documented persistent weaknesses in policy integration, standards enforcement, institutional coordination, and data-sharing arrangements (Idrees et al., 2012; Oyugi & Adepoju, 2013). More recent assessments indicate measurable progress in Nigeria's spatial data infrastructure readiness; however, institutional and technical constraints continue to affect its sustained development (Odeyemi & Adeoti, 2026).

Despite the expanding empirical literature on NSDI implementation, existing evidence remains fragmented. Studies typically examine discrete dimensions—such as governance, technical infrastructure, interoperability, data quality, or financial constraints—in isolation and within single-country contexts. Consequently, there is limited consolidated understanding of which challenges are recurrent across developing countries, which governance–technical interactions most critically undermine implementation effectiveness, and which practices are transferable across national contexts. This gap is particularly consequential for Nigeria, where policymakers require evidence-based guidance on how institutional reforms and technical investments can be more effectively aligned to strengthen the NGDI.

Against this background, the present study undertakes a systematic review of NSDI implementation in developing countries. Specifically, the study seeks to: (i) synthesise the governance and technical barriers

reported across empirical studies; (ii) identify common patterns and context-sensitive factors that differentiate successful from stalled implementations; and (iii) derive evidence-based recommendations for strengthening Nigeria's NGDI. By systematically integrating findings across diverse national contexts, the review seeks to advance a comprehensive understanding of the institutional, policy, governance, and technical conditions that shape NSDI implementation and sustainability, while providing an evidence-based foundation for improving Nigeria's NGDI.

II. METHODOLOGY

This study adopted a systematic review approach to synthesise empirical evidence on National Spatial Data Infrastructure (NSDI) implementation in developing countries. The review focused on governance and technical barriers, factors associated with variations in implementation outcomes, and practices with potential relevance to Nigeria's National Geospatial Data Infrastructure (NGDI). The review process was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 framework to promote transparency in the identification, selection, appraisal, and synthesis of evidence (Page et al., 2021).

2.1 Review Protocol

A review protocol was developed to define the scope and procedures of the study before evidence synthesis. It specified the review questions, search concepts, eligibility criteria, study-selection process, quality-assessment approach, data-extraction fields, and synthesis procedures. The review addressed three questions: what governance and technical barriers to NSDI implementation are reported in developing countries; what common and context-specific factors distinguish successful or relatively mature systems from weak or stalled implementations; and what lessons from these experiences can inform the strengthening of Nigeria's NGDI. Given the methodological diversity of NSDI research, the review accommodated quantitative, qualitative, comparative, mixed-method, case-study, institutional-assessment, and readiness studies. Conceptual and methodological publications were also retained where they provided

established frameworks relevant to the interpretation and classification of empirical findings.

2.2 Search Strategies

Relevant literature was identified through searches of major academic and specialist sources, including Scopus, Web of Science, ScienceDirect, SpringerLink, Taylor & Francis Online, Google Scholar, the International Journal of Spatial Data Infrastructures Research (IJS DIR), and institutional repositories. Reference lists and citation trails of relevant publications were also examined to identify additional studies. Search terms combined concepts relating to NSDI, implementation, governance, technical capacity, readiness, effectiveness, sustainability, and developing countries. Core terms included "National Spatial Data Infrastructure," "NSDI," "Spatial Data Infrastructure," "NSDI implementation," "SDI readiness," "spatial data governance," "interoperability," "metadata," "data sharing," "institutional coordination," "technical barriers," "implementation challenges," and "success factors." The search principally covered publications from 2005 to 2026, while reference and citation searches were used to capture relevant foundational studies published outside the main date range. The resulting evidence base comprised 16 distinct publications considered relevant to the review.

2.3 Eligibility Criteria

Studies were included where they: (i) examined NSDI or national-level spatial data infrastructure; (ii) addressed implementation, readiness, governance, technical operation, effectiveness, sustainability, barriers, or success factors; (iii) concerned one or more developing-country contexts; (iv) provided sufficient methodological or analytical information to support interpretation; and (v) were available in English.

Studies were excluded when they focused solely on local or project-level GIS applications, spatial-data production without an NSDI implementation dimension, theoretical discussions without substantive evidence, or publications lacking sufficient methodological or analytical content. Duplicate publications reporting substantially the same evidence were consolidated, with the most complete version retained for analysis. For synthesis purposes, the included publications were classified as

empirical/comparative studies or conceptual/framework studies. The former provided the principal evidence for the review, whereas the latter supported the analytical structure and interpretation of findings.

2.4 Study Selection and Bias Assessment

Study selection followed the PRISMA sequence of identification, screening, eligibility assessment, and inclusion (Page et al., 2021). Retrieved publications were examined against the predefined eligibility criteria, and potentially relevant studies were assessed in greater detail before final inclusion. The selection process was documented to provide a transparent account of the evidence base. Methodological quality was assessed according to study design. The appraisal considered the clarity of the research purpose, appropriateness of the design, adequacy of sampling or case selection, transparency of data collection and analysis, consistency between evidence and conclusions, and acknowledgement of relevant limitations. Greater weight was assigned to studies providing clear methodological procedures and findings directly supported by empirical evidence. The assessment also considered potential selection and publication bias. Countries with more advanced or better-documented NSDI programmes may be more visible in the literature, whereas countries with limited institutional documentation may be underrepresented. In addition, findings from individual national contexts were interpreted cautiously where institutional or socioeconomic conditions differed substantially from those of other countries.

2.5 Data Extraction and Synthesis

A structured extraction framework was used to record information consistently across the selected studies.

The extracted variables included bibliographic details, country or region, research design, data source or sample, NSDI maturity, governance and institutional arrangements, policy and legal conditions, financing, human capacity, technical infrastructure, standards, interoperability, metadata, data quality, data sharing, stakeholder participation, implementation barriers, enabling factors, outcomes, sustainability considerations, and implications for Nigeria. The evidence was synthesised using narrative and thematic analysis. A statistical meta-analysis was not undertaken because of substantial heterogeneity in research designs, assessment frameworks, national contexts, indicators, and definitions of NSDI effectiveness and readiness.

Thematic coding grouped related findings into broader domains, including governance and institutional coordination; policy and legislation; financial resources; human capacity; technical infrastructure; standards and interoperability; data quality and metadata; data sharing; and stakeholder participation. Cross-country comparison was then used to distinguish recurrent patterns from factors that appeared to be specific to particular institutional or national contexts. Finally, the identified practices and enabling conditions were examined for their relevance to Nigeria. Transferability was considered in relation to the nature of the problem addressed, the similarity of the institutional context, the resources required for implementation, and the evidence of improvement in coordination, technical performance, data sharing, participation, or sustainability. This provided the basis for deriving evidence-based recommendations for strengthening the NGDI.

Table 2.1: Summary of Reviewed Studies

Author(s) / Year	Topic of the Study	Country/Region	Study Focus	Method/Approach	Key Findings on Factors Influencing NSDI Effectiveness/Sustainability
Eelderink, Crompvoets & de Man (2008)	Towards key variables to assess National Spatial Data Infrastructures (NSDIs) in developing countries	Colombia, Cuba, Nepal, Indonesia, Nigeria & Ethiopia	Identified key variables for assessing NSDI development in developing countries	Comparative multi-country assessment and expert-based analysis	Identified 14 key variables, including digital spatial-data availability, willingness to share, human capital, capacity building, awareness, delivery mechanisms, funding, long-term vision, institutional arrangements, leadership, sociopolitical stability, interoperability, metadata and national SDI initiatives.
Al Shamsi, Ahmad & Desa (2011)	Development of critical successful factors model for spatial data infrastructure implementation	Developing-country context	Developed a critical-success-factor model for SDI implementation	Critical success factor analysis	Identified organisation, coordination, institutional agreements, strategic planning, communication, computing infrastructure, online services, awareness, standards, financial support and spatial-data availability as high-priority factors. Leadership, political support, interoperability, expertise, metadata and user involvement were also important.
Mwange, Mulaku & Siriba (2018)	Reviewing the status of national spatial data infrastructures in Africa	12 African countries	Assessed NSDI readiness and implementation status	Survey, web research and UN e-Government data; SDI-readiness assessment	Countries differed considerably in NSDI readiness. Human and financial resources, institutional arrangements, legal frameworks, data

					availability and technical capacity influenced implementation prospects.
Putra, Sekimoto & Shibasaki (2019)	Toward the evolution of national spatial data infrastructure development in Indonesia	Indonesia	Examined the development of Indonesia's NSDI and factors affecting stakeholder participation	Stakeholder questionnaire, stakeholder analysis, cost analysis and SWOT analysis	Low stakeholder participation was associated with inadequate technological, financial and human resources. Local governments faced infrastructure and human-capacity limitations, while funding was concentrated at central institutions.
Rahman & Szabó (2023)	Assessing the status of National Spatial Data Infrastructure (NSDI) of Bangladesh	Bangladesh	Assessed the maturity and development of Bangladesh's NSDI	14-variable NSDI assessment framework	Identified funding, willingness to share, human capital, capacity building, awareness, delivery mechanisms, strategic vision, institutional arrangements, leadership, sociopolitical stability, metadata and interoperability as important dimensions of NSDI development.
Ali, Ahmad, Nawaz & Sattar (2025)	Factors impeding spatial data infrastructure implementation in lower-middle-income economies	Pakistan / lower-middle-income economies	Examined factors constraining SDI implementation	Stakeholder survey and semi-structured interviews	Institutional, technical and human-related factors were identified as major barriers. Weak institutional integration, inadequate technical capacity and human-resource limitations constrained implementation.
Oyugi & Adepoju (2013)	National Spatial Data Infrastructure implementation in Kenya and Nigeria	Kenya & Nigeria	Examined implementation of NSDI components	Comparative assessment and documentary analysis	Despite stakeholder goodwill and available human and technological resources, implementation remained inadequate.

					Weak integration into national development policies, inadequate data sharing and weak standards enforcement affected implementation.
Makanga & Smit (2010)	A review of national spatial data infrastructure development in Africa	29 African countries	Examined the status and level of NSDI development	Cross-country survey and regional assessment	NSDI implementation was generally slow. Institutional environments, policy conditions, resource availability and implementation arrangements contributed to differences among countries.
Idrees, Saeidi, Yusuf & Shariff (2012)	Comparing approaches and strategies for NSDI implementation between the developed and developing world	Canada, Switzerland, Nigeria & Malaysia	Compared NSDI implementation strategies	Comparative assessment of institutional arrangements, policies, infrastructure and SDI components	Political will, social and political environment, accountability and transparency influenced successful and sustained implementation. Developing countries faced additional institutional and resource constraints.
Idrees, Shariff & Saeidi (2015)	Factors explaining differences in NSDI development status between the developed and developing world	Canada, Switzerland, Malaysia & Nigeria	Explained differences in NSDI development status	Comparative assessment using key NSDI variables	Regulatory frameworks, national interests, developmental policies and institutional conditions explained differences in NSDI development. Integration into national development agendas was important.
Gelagay (2019)	Geospatial data sharing barriers across organisations and the possible	Ethiopia	Examined organisational and technical barriers to spatial-data sharing	Institutional assessment and analysis of data-sharing practices	Poor data quality, incompatible datasets, technological limitations and inadequate data-sharing mechanisms constrained spatial-data integration.

	solution for Ethiopia				
Rahman & Szabó (2020)	National Spatial Data Infrastructure (NSDI) of Bangladesh — Development, progress and way forward	Bangladesh	Examined NSDI development and implementation challenges	Review of studies, government documents and spatial-data initiatives	Institutional fragmentation, duplication of data production, inconsistent practices and weak coordination affected NSDI development. Stronger coordination and standardisation were required.
Ali & Imran (2021)	The evolution of national spatial data infrastructure in Pakistan— Implementation challenges and the way forward	Pakistan	Examined NSDI evolution and implementation challenges	Institutional and stakeholder analysis	Insufficient financial, technological and human resources, fragmented institutional responsibilities and inadequate coordination constrained implementation.
Kok & van Loenen (2005)	How to assess the success of National Spatial Data Infrastructures?	International/comparative	Examined approaches for evaluating NSDI success	Comparative assessment and development of SDI success indicators	Emphasised organisational evolution, leadership, vision, communication and institutional capacity as important conditions for successful NSDI development.
Zahra, Ali, Nawaz & Sattar (2022)	Analysis of factors affecting adoption of volunteered geographic information in the context of National Spatial Data Infrastructure	Pakistan	Examined factors influencing VGI adoption as an NSDI data source	Empirical analysis of factors affecting VGI adoption	Demonstrated that participation, perceived usefulness, data availability and institutional acceptance influence the potential integration of volunteered geographic information into NSDI.
Odeyemi & Adeoti (2026)	Assessing Nigeria's Spatial Data Infrastructure (SDI)	Nigeria	Assessed Nigeria's current SDI readiness	Primary-data assessment combined with UN DESA data and SDI-	Reported a Nigerian SDI-readiness index of 0.8434 for 2024, providing recent evidence of Nigeria's level of readiness and

	Readiness Index			readiness indicators	the conditions underlying its SDI development.
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III. RESULTS AND DISCUSSION

3.1 Evidence Distribution and Characteristics of the Reviewed Studies

The systematic review identified 16 relevant publications, comprising 13 empirical or comparative studies and 3 conceptual or methodological studies.

The empirical evidence covered a range of developing-country contexts, with the greatest concentration in Africa and Asia. The studies varied considerably in geographical scope, research design, and analytical approach (Table 3.1).

Table 3.1: Distribution of Reviewed Evidence by Country/Region and Study Type

Country/Region	Nature of Studies		Total	Principal Focus
	Empirical/ Comparative	Conceptual/ Framework		
Nigeria	2	2	4	Governance, implementation, readiness, institutional and policy factors
Ethiopia	1	1	2	Data sharing, technical compatibility, institutional barriers
Kenya	1	–	1	NSDI implementation and institutional factors
South Africa, Botswana, Malawi, Tanzania & Zimbabwe	1	–	1	Regional NSDI readiness, institutional and technical capacity
29 African countries	1	–	1	Continental NSDI development and implementation
Bangladesh	2	–	2	NSDI development, technical capacity, institutional coordination
Pakistan	4	–	4	NSDI readiness, implementation barriers, technical and institutional factors
Indonesia	1	–	1	Stakeholder participation, financing, human and technical resources
Multi-country developing-country studies	–	1	1	Variables for assessing NSDI in developing countries
Comparative developed/developing-country studies	–	1	1	NSDI success, implementation strategies and institutional development
Total	13	3	16	

Note: Country counts refer to study coverage rather than unique countries because several publications examined multiple countries.

The geographical distribution shows a clear concentration of evidence in Africa and Asia, particularly in countries where NSDI development has been actively studied through readiness assessments, institutional evaluations, and implementation analyses. Pakistan accounted for the largest number of country-specific publications. The methodological approaches ranged from stakeholder surveys and comparative assessments to institutional analyses, readiness-index applications, case studies, document reviews, and critical-success-factor analysis. The reviewed studies examined dimensions extending from legal and institutional arrangements to infrastructure, standards, data sharing, human resources, financing, and stakeholder engagement (Eelderink et al., 2008; Al Shamsi et al., 2011; Mwange et al., 2018).

A broad pattern emerged from the evidence: NSDI implementation in developing countries was generally uneven and incomplete. More developed arrangements were characterised by clearer institutional responsibilities, stronger coordination, better technical integration, and more established data-sharing mechanisms. Less mature arrangements were associated with fragmented responsibilities, inadequate resources, weak interoperability, limited human capacity, and insufficient policy support (Mwange et al., 2018; Rahman & Szabó, 2023).

3.2 Governance and Technical Barriers to NSDI Implementation

3.2.1 Governance and Institutional Barriers

Institutional fragmentation was one of the most consistently reported governance barriers. Spatial information is frequently produced and managed by multiple agencies operating under separate mandates, with limited mechanisms for coordination or integration. Eelderink et al. (2008) identified institutional arrangements, leadership, willingness to share, and long-term strategic vision among the

critical variables affecting NSDI development in developing countries. Evidence from Bangladesh similarly indicated that institutional fragmentation and weak coordination contributed to duplication of spatial-data production and inconsistent practices among data-producing organisations (Rahman & Szabó, 2020; Rahman & Szabó, 2023).

African evidence showed comparable conditions. Makanga and Smit (2010) reported slow and uneven NSDI development across African countries, while Mwange et al. (2018) found substantial differences in national readiness linked partly to variations in institutional arrangements, legal frameworks, resources, and coordination mechanisms. The findings indicate that establishing a formal NSDI initiative does not by itself guarantee effective integration among participating institutions.

Weak policy integration was another important governance barrier. Studies involving Nigeria found that NSDI components were not sufficiently incorporated into broader national development priorities, while weaknesses in standards enforcement and data-sharing arrangements reduced the effectiveness of implementation (Idrees et al., 2012; Oyugi & Adepoju, 2013). Comparative evidence further suggests that political commitment, regulatory support, accountability, and institutional leadership contribute to more sustained NSDI development (Idrees et al., 2015; Al Shamsi et al., 2011).

The governance evidence consequently points to three closely related deficiencies: unclear institutional responsibilities, weak inter-organisational coordination, and inadequate policy or regulatory support. These deficiencies affect the ability of agencies to establish common priorities, allocate resources, adopt standards, and contribute consistently to national spatial-data systems.

Table 3.X: Synthesis of Governance and Technical Barriers to NSDI Implementation

Barrier category	Specific barrier	Countries/regions reporting the barrier	Supporting studies	Implication for NSDI implementation
Governance	Institutional fragmentation	Nigeria, Ethiopia, Bangladesh, Pakistan, African countries	Eelderink et al. (2008); Gelagay (2019); Rahman & Szabó (2020); Mwange et al. (2018)	Weakens coordination and promotes duplication of spatial-data activities
Governance	Weak inter-agency coordination	Nigeria, Bangladesh, Pakistan, Africa	Idrees et al. (2012); Rahman & Szabó (2023); Mwange et al. (2018)	Limits integration of institutional datasets and services
Governance	Weak policy/legal support	Nigeria, Kenya, Africa, Pakistan	Idrees et al. (2015); Oyugi & Adepoju (2013); Mwange et al. (2018)	Reduces institutional commitment and implementation continuity
Governance	Inadequate data-sharing arrangements	Nigeria, Ethiopia, Bangladesh, Pakistan	Oyugi & Adepoju (2013); Gelagay (2019); Rahman & Szabó (2020)	Restricts access, integration, and reuse of spatial information
Governance	Limited stakeholder participation	Indonesia, Bangladesh, Pakistan	Putra et al. (2019); Rahman & Szabó (2023)	Reduces data contribution, system ownership, and utilisation
Technical	Poor interoperability	Ethiopia, Bangladesh, Pakistan, Africa	Gelagay (2019); Rahman & Szabó (2020, 2023)	Prevents seamless exchange and integration of datasets
Technical	Inconsistent standards	Bangladesh, Ethiopia, Pakistan	Gelagay (2019); Rahman & Szabó (2020)	Creates incompatibility among datasets and systems
Technical	Inadequate metadata	Bangladesh, Pakistan, Ethiopia	Rahman & Szabó (2020, 2023); Gelagay (2019)	Reduces dataset discoverability and fitness-for-use assessment
Technical	Poor data quality/currency	Ethiopia, Bangladesh, Pakistan	Gelagay (2019); Rahman & Szabó (2020)	Limits reliability and integration of spatial datasets
Technical	Inadequate technical infrastructure	African countries, Indonesia, Bangladesh, Pakistan	Mwange et al. (2018); Putra et al. (2019); Rahman & Szabó (2023)	Restricts storage, processing, dissemination, and online access

3.2.2 Technical Barriers

The principal technical barriers were poor interoperability, inconsistent standards, inadequate metadata, data-quality problems, incompatible formats, heterogeneous coordinate reference systems, outdated datasets, and inadequate technical

infrastructure. These problems were reported across both African and Asian contexts. In Ethiopia, Gelagay (2019) found that differences in data structures, formats, software environments, and organisational practices constrained geospatial data sharing. Bangladesh experienced similar problems,

particularly inconsistent metadata practices and difficulties integrating datasets produced independently by different organisations (Rahman & Szabó, 2020). The issue was not merely the absence of digital data but the limited usability of available information across organisational boundaries. Interoperability problems were closely associated with weak standardisation. Where institutions apply different specifications for data formats, reference systems, metadata, and quality, datasets covering similar locations may remain difficult to combine. The technical deficiency therefore has an institutional dimension because common standards require coordination, agreement, adoption, and enforcement. Metadata deficiencies further limited data discovery and reuse. Evidence from Bangladesh and Pakistan indicated weaknesses in the availability and consistency of metadata, while readiness assessments identified standards and online geospatial services as areas requiring continued improvement (Rahman & Szabó, 2023). Similarly, inadequate infrastructure restricted the ability of institutions to provide reliable mechanisms for storing, accessing, exchanging, and disseminating spatial information. The technical evidence therefore indicates that many developing countries possess significant volumes of spatial information but lack the interoperable systems, common standards, metadata, infrastructure, and quality controls required to transform dispersed datasets into an integrated national resource.

3.3 Integrated Governance–Technical Interpretation

The evidence demonstrates that governance and technical barriers are not independent categories. Institutional fragmentation encourages the development of separate data systems, while the absence of common standards and interoperability reinforces those institutional divisions. Similarly, technical improvements are unlikely to produce sustainable results where agencies lack clear responsibilities, incentives, or institutional mechanisms for data sharing. This relationship is evident across the reviewed cases. Bangladesh

illustrates how institutional fragmentation can contribute to duplication and inconsistent data practices, while Ethiopia demonstrates how incompatible organisational and technical environments can directly restrict data exchange (Gelagay, 2019; Rahman & Szabó, 2020). Evidence from African countries similarly shows that technical capacity and institutional readiness vary together rather than independently (Mwange et al., 2018). The implication for Nigeria is that NGDI improvement should not be approached as a purely technological undertaking. Investments in geoportals, databases, network infrastructure, standards, and interoperability need to be supported by effective institutional coordination, clearly defined mandates, enforceable data-sharing arrangements, and sustained policy commitment. The evidence thus supports an integrated approach in which governance reform and technical development are mutually reinforcing components of NSDI implementation.

3.4 Common Patterns and Context-Sensitive Factors in NSDI Implementation

The comparison of the reviewed studies revealed that differences in NSDI implementation outcomes were associated with variations in institutional coordination, policy commitment, resource availability, technical integration, stakeholder engagement, and strategic continuity. Although countries differed in their political, administrative, economic, and technological circumstances, several common patterns were evident. At the same time, the relative importance of individual factors varied according to national context.

3.4.1 Comparative Evidence on Implementation Patterns

The principal factors associated with relatively effective or mature NSDI implementation and those associated with weak or stalled implementation are summarized in Table 3.2.

Table 3.2: Common and Context-Sensitive Factors Differentiating NSDI Implementation Outcomes

Implementation dimension	Characteristics associated with relatively effective implementation	Characteristics associated with weak or stalled implementation	Studies
Institutional coordination	Clearly defined roles, a recognised coordinating institution, and established inter-agency mechanisms	Overlapping mandates, institutional silos, weak coordination, and fragmented responsibilities	Eelderink et al. (2008); Mwange et al. (2018); Rahman & Szabó (2023)
Policy and legal support	NSDI embedded in national policies, legislation, and development strategies	Weak policy integration, incomplete legal support, and poor enforcement	Al Shamsi et al. (2011); Idrees et al. (2015); Oyugi & Adepoju (2013)
Leadership and political commitment	Strong institutional leadership and sustained political support	Limited political commitment and dependence on individual projects or institutions	Eelderink et al. (2008); Al Shamsi et al. (2011); Idrees et al. (2012)
Financial resources	Sustained funding for data, infrastructure, capacity building, and institutional coordination	Short-term or inadequate funding concentrated on isolated technical activities	Mwange et al. (2018); Putra et al. (2019); Rahman & Szabó (2023)
Human capacity	Availability of skilled geospatial, ICT, database, and data-management personnel	Shortage, uneven distribution, or inadequate retention of skilled personnel	Eelderink et al. (2008); Mwange et al. (2018); Putra et al. (2019)
Technical infrastructure	Adequate networks, databases, geoportals, servers, and digital services	Inadequate infrastructure and limited access to online spatial-data services	Al Shamsi et al. (2011); Putra et al. (2019); Rahman & Szabó (2023)
Standards and interoperability	Consistent standards, metadata, data models, and interoperable systems	Incompatible formats, inconsistent standards, weak metadata, and isolated systems	Gelagay (2019); Rahman & Szabó (2020); Rahman & Szabó (2023)
Data sharing	Established rules, agreements, incentives, and institutional willingness to share	Data silos, restrictive practices, and limited willingness or capacity to share	Eelderink et al. (2008); Gelagay (2019); Oyugi & Adepoju (2013)
Stakeholder participation	Participation of public agencies, local governments, private sector, academia, and other users	Participation concentrated among central institutions with limited involvement of other stakeholders	Putra et al. (2019); Rahman & Szabó (2023)
Strategic continuity	Long-term vision, implementation planning, and continuity across administrative periods	Project-based development, discontinuity, and weak long-term strategic direction	Eelderink et al. (2008); Idrees et al. (2015); Rahman & Szabó (2023)

The comparison indicates that no single factor adequately explains differences in NSDI implementation outcomes. Rather, relatively effective systems tend to combine several favourable

conditions. Conversely, weak performance commonly occurs where multiple deficiencies reinforce one another. This finding supports the multidimensional

conception of NSDI advanced by Eelderink et al. (2008) and Al Shamsi et al. (2011).

3.4.2 Common Patterns Across Developing Countries
The most consistent pattern was the importance of institutional coordination. Countries with mechanisms for defining responsibilities and coordinating data-producing organisations generally demonstrated greater capacity to integrate spatial information. By contrast, systems characterised by institutional fragmentation tended to experience duplication, inconsistent practices, and restricted data exchange (Eelderink et al., 2008; Mwange et al., 2018; Rahman & Szabó, 2023). A second recurring pattern concerned sustained resource commitment. Financial and human resources were repeatedly identified as enabling conditions for NSDI development. Mwange et al. (2018) identified resource limitations as an important concern across African countries, while Putra et al. (2019) showed that uneven distribution of financial and human resources limited participation, particularly at subnational levels. The evidence suggests that national investments are most effective when they support not only technical infrastructure but also organisational development, capacity building, and system maintenance.

Policy continuity and leadership formed another common differentiating factor. NSDI requires long-term development because spatial datasets, standards, institutional arrangements, and technical platforms cannot normally be established and stabilised within a single project cycle. Studies comparing NSDI development across countries found that political commitment, strategic vision, institutional leadership, and integration into national development priorities supported continuity, whereas weak policy integration increased the likelihood of fragmented or project-dependent implementation (Idrees et al., 2012; Idrees et al., 2015; Al Shamsi et al., 2011). The evidence also shows that technical maturity tends to follow institutional maturity rather than develop independently of it. Countries with stronger coordination mechanisms are better positioned to establish common standards, develop interoperable systems, maintain authoritative datasets, and implement consistent metadata practices. Conversely, institutional fragmentation often produces technically isolated systems even where individual agencies

possess adequate technology (Gelagay, 2019; Rahman & Szabó, 2020).

3.4.3 Context-Sensitive Factors

The factors influencing effective NSDI implementation vary according to national institutional structures and resource conditions, although common patterns exist across countries. In Africa, institutional capacity and resource constraints are influential, with differences in legal frameworks, human resources, infrastructure, and financing producing varied levels of readiness (Mwange et al., 2018). In Indonesia, unequal distribution of resources between central and local institutions limits broad participation (Putra et al., 2019). Bangladesh illustrates how institutional fragmentation can restrict data integration and sharing despite progress in national infrastructure, while Pakistan shows how interconnected institutional, technical, and human-capacity constraints require coordinated and sequenced interventions (Rahman & Szabó, 2020; Rahman & Szabó, 2023; Ali & Imran, 2021; Ali et al., 2025). Nigeria shares several of these challenges but also has a distinct federal administrative structure and dispersed geospatial information ecosystem; therefore, its NSDI outcomes are shaped by political, regulatory, institutional, and developmental-policy conditions, indicating that international practices must be adapted to the national context (Idrees et al., 2012; Idrees et al., 2015).

3.4.4 Successful and Stalled Implementations

The synthesis suggests that relatively successful NSDI implementations are characterised less by the presence of a single advanced technology than by the alignment of institutional, financial, technical, and human resources around a sustained national strategy. Such systems tend to have identifiable leadership, clear institutional responsibilities, established data-sharing mechanisms, technical standards, and mechanisms for maintaining participation across organisational boundaries. Stalled implementations, in contrast, commonly display a mismatch between formal aspirations and operational capacity. A country may establish an NSDI policy, coordinating body, or geoportal but still experience limited practical integration because funding is inadequate, institutions retain separate mandates, technical standards are inconsistently applied, or agencies are reluctant or

unable to share information. This distinction is evident across the reviewed African and Asian studies (Mwange et al., 2018; Gelagay, 2019; Rahman & Szabó, 2023). The synthesis therefore indicates that NSDI maturity is better understood as an institutional–technical continuum than as a binary condition of having or not having an NSDI. Countries may possess formal NSDI structures while remaining weak in operational integration, whereas others may demonstrate stronger practical coordination even where their formal architecture is still developing. The quality of implementation consequently depends on the extent to which governance arrangements, resources, technical systems, and stakeholder relationships function as an integrated national infrastructure.

3.6 Evidence-Based Lessons for Strengthening Nigeria’s NGDI

The comparative evidence presented in Table 3.3 provides several lessons relevant to strengthening Nigeria’s National Geospatial Data Infrastructure (NGDI). The experiences reviewed indicate that effective NSDI development depends on coordinated governance, sustainable resources, interoperable technical systems, clear data-sharing arrangements, and long-term strategic planning. However, these practices require adaptation to Nigeria’s institutional and federal administrative context rather than direct replication.

Table 3.3: Evidence-Based Practices and Their Implications for Nigeria’s NGDI

Identified practice	Evidence from reviewed countries	Rationale	Implication for Nigeria’s NGDI
Establishment of a strong national coordinating mechanism	South Africa, Botswana, Rwanda and other African cases	Central coordination reduces institutional fragmentation and clarifies responsibilities among data-producing organisations (Mwange et al., 2018).	Strengthen the coordinating authority of the NGDI and clearly define the responsibilities of participating federal and subnational institutions.
Integration of NSDI into national development policy	Nigeria, Malaysia and comparative cases	Policy integration provides institutional legitimacy and continuity beyond individual projects or administrations (Idrees et al., 2012, 2015).	Position NGDI as national digital and development infrastructure rather than as a specialised surveying and mapping initiative.
Development and enforcement of common spatial-data standards	Bangladesh, Ethiopia and Pakistan	Common standards improve consistency, data exchange, interoperability and reuse (Gelagay, 2019; Rahman & Szabó, 2020).	Establish enforceable national specifications covering data formats, metadata, coordinate reference systems, quality and data exchange.
Sustained financing	Africa, Indonesia and Bangladesh	Long-term financial support enables data production, system maintenance, infrastructure development and capacity building (Mwange et al., 2018; Putra et al., 2019).	Develop predictable NGDI financing that supports both technical infrastructure and recurrent activities such as maintenance, updating and capacity development.
Distributed capacity development	Indonesia, Bangladesh and African countries	Concentrating expertise in central institutions limits participation by local and sectoral organisations (Putra et al., 2019; Rahman & Szabó, 2023).	Expand technical and institutional capacity beyond federal institutions to states, local authorities, academia and other strategic stakeholders.

Institutional data-sharing arrangements	Ethiopia, Bangladesh and Nigeria	Formal sharing mechanisms reduce data silos and support integration across organisations (Gelagay, 2019; Rahman & Szabó, 2020).	Establish clear rules, agreements and procedures governing access, custodianship, licensing and exchange of NGDI datasets.
Interoperable digital infrastructure	Pakistan, Bangladesh and African cases	Interoperable systems allow independently produced datasets to operate as components of a national infrastructure.	Prioritise interoperable databases, metadata catalogues, application programming interfaces and national geospatial services rather than isolated agency platforms.
Stakeholder participation mechanisms	Indonesia, Bangladesh and Pakistan	Broader participation increases data contribution, utilisation and institutional ownership (Putra et al., 2019; Rahman & Szabó, 2023).	Establish mechanisms for sustained participation by government agencies, private organisations, academia, professional bodies and other users.
Long-term strategic planning	Developing-country comparative studies	Strategic continuity reduces dependence on short-term projects and supports progressive institutional maturation (Elderink et al., 2008; Idrees et al., 2015).	Adopt a phased NGDI implementation roadmap with measurable institutional, technical and service-delivery milestones.
Continuous monitoring of NSDI readiness and performance	Bangladesh, Pakistan and African readiness assessments	Periodic assessment identifies implementation gaps and allows priorities to be adjusted as institutional and technical conditions change.	Institutionalise periodic assessment of NGDI readiness, interoperability, data availability, service utilisation, stakeholder participation and sustainability.

3.6.1 Governance and Institutional Coordination

The evidence strongly supports strengthening NGDI as a coordinated national infrastructure rather than a collection of agency-specific systems. Experiences from Africa, Bangladesh, Indonesia, and Pakistan show that clear institutional roles and effective coordination improve integration, while fragmented mandates promote duplication and weak data exchange (Mwange et al., 2018; Putra et al., 2019; Rahman & Szabó, 2023). Nigeria should therefore strengthen institutional coordination, clarify responsibilities, and establish effective mechanisms for resolving overlaps among participating institutions.

3.6.2 Technical Integration and Data Sharing

International evidence indicates that technical investment is most effective when supported by common standards and institutional data-sharing arrangements. Problems involving incompatible

datasets, inadequate metadata, and fragmented platforms have limited NSDI performance in several developing countries (Gelagay, 2019; Rahman & Szabó, 2020). For NGDI, priority should therefore be given to national standards, metadata requirements, interoperability specifications, dataset custodianship, and clear procedures for data access and exchange.

3.6.3 Financing, Capacity and Strategic Continuity

Sustainable financing and human capacity are essential for maintaining NSDI systems beyond their initial development. Evidence from Africa, Indonesia, and Bangladesh shows that inadequate or unevenly distributed resources constrain participation and long-term operation (Mwange et al., 2018; Putra et al., 2019; Rahman & Szabó, 2023). NGDI planning should consequently provide for recurrent financing, continuous professional development, and capacity building at federal and subnational levels.

Long-term strategic planning is equally important. NSDI development requires progressive improvement in institutional arrangements, datasets, standards, infrastructure, and services. A phased NGDI roadmap would provide a basis for prioritising interventions and assessing progress through measurable milestones (Eelderink et al., 2008; Idrees et al., 2015).

IV. DISCUSSION

The findings demonstrate that NSDI implementation in developing countries is fundamentally shaped by the interaction of governance, institutional, technical, financial, and human-capacity conditions. Across the reviewed evidence, implementation difficulties were rarely attributable to a single deficiency. Instead, fragmented institutional mandates, inadequate coordination, weak policy integration, insufficient financing, limited technical capacity, poor interoperability, and weak data-sharing practices frequently occurred together. This supports the multidimensional view of NSDI in which institutional and technical components must develop concurrently for spatial data to function as a shared national resource (Eelderink et al., 2008; Al Shamsi et al., 2011). The predominance of governance-related barriers is particularly significant. Studies across Africa and Asia indicate that the existence of formal NSDI structures does not necessarily result in effective implementation where responsibilities are unclear or agencies retain isolated data-management practices (Mwange et al., 2018; Rahman & Szabó, 2023). Institutional fragmentation can produce duplication of data production, inconsistent standards, and limited willingness to share information. This suggests that the effectiveness of an NSDI depends not only on establishing a coordinating institution but also on providing that institution with sufficient authority, clearly defined responsibilities, and mechanisms for inter-agency collaboration.

Technical barriers reinforce these institutional problems. Incompatible data formats, inadequate metadata, inconsistent standards, poor data quality, and weak interoperability limit the ability of agencies to integrate and reuse spatial information (Gelagay, 2019; Rahman & Szabó, 2020). The evidence therefore challenges a technology-centred view of NSDI development. Investment in hardware, software,

geoportals, and databases is unlikely to produce sustainable benefits where institutions lack common standards and agreed procedures for data exchange.

The comparison of relatively mature and weak systems further indicates that successful implementation is associated with the alignment of governance, resources, technical systems, and stakeholder relationships around a sustained national strategy. Financial and human resources were repeatedly identified as enabling conditions, while political commitment, leadership, policy continuity, and stakeholder participation helped determine whether NSDI initiatives progressed beyond isolated projects (Mwange et al., 2018; Putra et al., 2019; Rahman & Szabó, 2023). This finding implies that NSDI maturity should be understood as a continuing process of institutional and technical development rather than a binary condition. Context also matters. The evidence shows that resource constraints are particularly important in several African settings, subnational capacity is significant in decentralised systems such as Indonesia, and institutional fragmentation is prominent in Bangladesh and Pakistan. Consequently, there is no universal implementation model. International practices need to be adapted to national administrative structures, resource conditions, institutional relationships, and policy environments. For Nigeria, the implications are substantial. The reviewed Nigerian and comparative studies indicate that the challenges affecting NGDI are consistent with broader developing-country patterns, particularly in relation to institutional coordination, policy integration, standards, and data sharing (Idrees et al., 2012; Oyugi & Adepoju, 2013). The evidence suggests that strengthening NGDI should therefore move beyond isolated technical projects towards an integrated governance and infrastructure strategy. Such a strategy should connect institutional reform with technical interoperability, sustainable financing, capacity development, and stakeholder participation.

V. CONCLUSION

This systematic review shows that NSDI implementation in developing countries remains uneven and is constrained by interconnected governance and technical deficiencies, particularly fragmented institutional responsibilities, weak

coordination, inadequate policy support, insufficient financing, limited human capacity, poor interoperability, inconsistent standards, inadequate metadata, and weak data-sharing mechanisms. More effective implementations are associated with clear institutional roles, sustained leadership and financing, interoperable technical systems, stakeholder participation, and long-term strategic planning. For Nigeria, the evidence indicates that strengthening the NGDI requires an integrated approach that combines governance reform, technical interoperability, sustainable financing, capacity development, effective data sharing, and continuous performance monitoring, with international practices adapted to the country's institutional and federal context.

5.1 Recommendations

1. Strengthen NGDI governance and coordination by clearly defining institutional responsibilities, improving inter-agency collaboration, and embedding NGDI within national development and digital policies.
2. Improve technical interoperability and data sharing through enforceable national standards for data formats, metadata, coordinate reference systems, quality, access, and exchange, supported by interoperable national geospatial platforms.
3. Ensure sustainable financing and capacity development by providing predictable funding for infrastructure, data updating, maintenance, and continuous training, while extending technical capacity beyond federal institutions to state and other key stakeholders.

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