

Building the Foundation for a National Spatial Data Infrastructure in Armenia: Current Status and Future Prospects

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Abstract:

The establishment of a National Spatial Data Infrastructure (NSDI) in Armenia commenced in 2019, marking a pivotal step toward the development of an integrated framework for spatial data management at the national level. Since then, a series of significant actions have been taken to lay the groundwork for this infrastructure, including the adoption of the Integrated Cadastre Concept (2019), the formulation of a strategic program for Integrated Cadastre (2021), and the enactment of the Spatial Data Law (2023), alongside other relevant legal instruments. This study provides a comprehensive analysis of these milestones and investigates the technical, legal, and institutional prerequisites for the successful establishment of the NSDI in Armenia. It critically examines the challenges and opportunities inherent in the process, highlighting key factors such as inter-agency collaboration, data standardization, and capacity-building that are essential to its realization. Additionally, the research identifies current limitations, including deficiencies in technical infrastructure, the need for specialized human resources, and the necessity for greater public awareness. Drawing upon the Armenian experience, the study explores the potential for further development of the NSDI, assessing its alignment with broader national objectives of economic development, governance reform, and sustainable development. The findings offer valuable insights for policymakers in Armenia and other countries, particularly regarding the facilitation of spatial data exchange, the implementation of regular data updates and standardization protocols, and the creation of effective legal and institutional mechanisms for spatial data management across government sectors.

Keywords: NSDI, Spatial Data Management, Spatial Data Systems, Geospatial Policy

1. Introduction

1.1 Overview of NSDI Concept

The Spatial Data Infrastructure (SDI) is a comprehensive framework that integrates spatial data management, technology, standards, policies, and institutional structures to support effective decision-making at local, national, and international levels^{1,2,3,4}. The NSDI concept refers to the coordinated efforts to organize, manage, and distribute spatial data across various sectors and stakeholders within a country. It includes not only the technological infrastructure required to collect and store spatial data but also the legal and institutional

frameworks that govern data usage, sharing, and protection. At its core, an NSDI aims to create an integrated environment where spatial data is accessible, standardized, and interoperable, thus allowing for better data-driven decision-making and policy development^{5,6}.

NSDI systems typically involve several key components: geospatial data, metadata standards, data-sharing protocols, and policies that promote the consistent and standardized collection and use of spatial information^{7,8}. These infrastructures are vital for enabling seamless communication and collaboration between various

¹ Rajabifard and Williamson, "Spatial Data Infrastructures: Concept, SDI Hierarchy and Future Directions."

² Rajabifard, Feeney, and Williamson, "Spatial Data Infrastructures: Concept, Nature and SDI Hierarchy."

³ Craglia, "Reviews: Developing Spatial Data Infrastructures: From Concept to Reality."

⁴ Dale and Allan, "Developing Spatial Data Infrastructures - from Concept to Reality."

⁵ Rajabifard et al., "National SDI Initiatives."

⁶ Masser, Rajabifard, and Williamson, "Spatially Enabling Governments through SDI Implementation."

⁷ Oliveira et al., "Design of a Corporate SDI in Power Sector Using a Formal Model."

⁸ Morales Guarin, de By, and Lemmens, "On the Design of Sustainable SDI Components."

governmental and non-governmental entities, which is essential for addressing complex issues^{9,10}.

1.2 Importance of NSDI for national development

In Armenia, the development of a NSDI is a key enabler of national progress, offering substantial benefits for governance, economic development, and sustainability. An NSDI provides the necessary framework for the effective management of spatial data, which is essential for informed decision-making in critical areas such as urban planning, infrastructure development, environmental protection, and natural resource management¹¹. Given Armenia's mountainous terrain, complex land-use patterns, and natural resource constraints, the ability to manage spatial data effectively can help address both the opportunities and challenges inherent in these areas. By organizing and systematizing geospatial information, an NSDI enhances the government's ability to plan for the future, ensuring that decisions are based on accurate and reliable data.

A well-developed NSDI also promotes greater coordination across Armenia's diverse governmental sectors. Currently, spatial data in Armenia is often fragmented across different ministries and agencies, leading to inefficiencies and missed opportunities for synergies. Through the standardization and interoperability of data, an NSDI can reduce these silos, fostering improved collaboration between ministries involved in land management, urban planning, environmental protection, and public¹². The increased availability of standardized spatial data will allow the Armenian government to streamline decision-making processes and enhance transparency, helping to combat corruption and increase accountability in governance.

Economically, an NSDI can stimulate private sector investment and innovation, both of which are critical for Armenia's economic development. Access to high-quality, up-to-date spatial data facilitates investment in key sectors such as infrastructure, real estate, agriculture, and energy, which are central to Armenia's growth. For example, accurate geospatial data is crucial for identifying optimal locations for new infrastructure projects, assessing the potential for agricultural expansion, and improving land management practices. Furthermore, NSDIs can unlock new opportunities for the development of geospatial technologies and services,

creating avenues for innovation in sectors such as transportation¹³, logistics, healthcare^{14,15}, and tourism^{16,17}.

In the context of sustainable development, an NSDI will play a crucial role in managing Armenia's natural resources, promoting environmental sustainability, and building resilience to natural disasters. The country's susceptibility to seismic activity, landslides, and climate change-related hazards makes the integration of spatial data into disaster risk management^{18,19} and environmental protection strategies especially important. By enabling better management of land resources and providing tools for environmental monitoring, an NSDI can help Armenia mitigate the impacts of these threats and support more sustainable development.

2. Methodology

This study employs a mixed-methods approach to investigate the development of a NSDI in Armenia. Given the multidisciplinary nature of NSDI implementation, the research integrates perspectives from geography, public policy, law, and information technology. This approach enables a comprehensive examination of the technical, legal, and institutional dimensions of NSDI development.

The initial phase of this study involves a comprehensive, systematic review of the existing literature, legal frameworks, and policy documents pertinent to the development of a NSDI in Armenia. Concurrently, the research conducts an analysis of Armenia's national laws, regulations, and institutional structures governing spatial data management, assessing the adequacy of the existing legal and regulatory framework in facilitating the development and implementation of an NSDI.

The legal analysis focuses on several critical aspects, including data governance, interoperability, access rights, privacy concerns, and mechanisms for data sharing. By evaluating these factors, the study identifies key legal and regulatory barriers that may hinder the effective deployment of an NSDI in Armenia. The insights gained from this analysis inform policy recommendations designed to create a coherent, interoperable, and legally

⁹ Commission et al., The Role of Spatial Data Infrastructures in the Digital Government Transformation of Public Administrations.

¹⁰ Chafiq et al., "Spatial Data Infrastructure. Benefits and Strategy."

¹¹ Zivkovic, "National Spatial Data Infrastructure (NSDI) for Resilient Territorial Development: Building a National Disaster Risk Register (DRR) for Serbia."

¹² Lyashchenko et al., "Methods And Means Of Ensuring The Interoperability Of The Components Of The National Geospatial Data Infrastructure."

¹³ Dueker, "Access to Data: National Spatial Data Infrastructure."

¹⁴ Yasobant and K, "Geographic Information System Applications in Public Health: Advancing Health Research."

¹⁵ Akingbemisilu, "A Critical Evaluation of Government Role in Spatial Data Infrastructures for Healthcare Decision-Making."

¹⁶ Wei, "Research on the Application of Geographic Information System in Tourism Management."

¹⁷ Adesina, Okwandu, and Nwokediegwu, "Geo-Information Systems in Urban Planning: A Review of Business and Environmental Implications."

¹⁸ Walia, "The Importance of GIS in Disaster and Emergency Management."

¹⁹ Ayawa et al., "Geographic Information System (GIS) For Disaster Management."

robust spatial data infrastructure capable of supporting a national NSDI framework.

3. Literature Review

The development of a NSDI in Armenia has been an emerging area of study, with only a few significant works published to date. While research in this field is still developing, there are a few key contributions that outline the conceptual, technical, environmental, and legal dimensions of NSDI in Armenia.

One of the early and foundational studies in this area is “Toward the Development of an Integrated Spatial Data Infrastructure in Armenia”²⁰. This work highlights the importance of building a reliable and integrated geospatial infrastructure in Armenia to meet the growing need for spatial data management and sharing. The authors argue that, as a developing country, Armenia faces a significant challenge in creating an efficient SDI that can support national development and integrate with the international geospatial community.

Another contribution to the literature is the study “Paving the Way Toward an Environmental National Spatial Data Infrastructure in Armenia”²¹. This paper specifically focuses on the environmental aspect of NSDI, reflecting Armenia’s pressing ecological challenges, particularly those arising from the legacy of Soviet-era industrialization and the mismanagement of natural resources.

The legal and institutional challenges associated with the development of NSDI in Armenia are examined in the work, titled “Legal Aspects of National Spatial Data Infrastructure of the Republic of Armenia”²². This study delves into the legal framework necessary to regulate the collection, sharing, and use of spatial data in Armenia, which is a critical component of the NSDI development process. One of the key points highlighted in this paper is the need for a comprehensive legal framework to define the availability, ownership, and access to geospatial data at various levels of government.

However, despite these contributions, the research remains preliminary, and there is a need for more in-depth studies that address the full scope of NSDI implementation in Armenia. Future research will need to build on these foundational works by exploring more specific technical solutions, institutional mechanisms, and legal frameworks that can facilitate the development of a sustainable and functional NSDI.

4. Current Status of NSDI in Armenia

The development of NSDI in Armenia began in 2019 and has progressed in stages, with several milestones achieved in terms of conceptual frameworks, legal

frameworks, and institutional structures. However, despite these advancements, the SDI is still in its developmental phase, facing multiple challenges that must be addressed to ensure the effective integration of spatial data across various sectors. This section provides an overview of the existing spatial data systems in Armenia and highlights the challenges that hinder the full implementation and optimization of SDI.

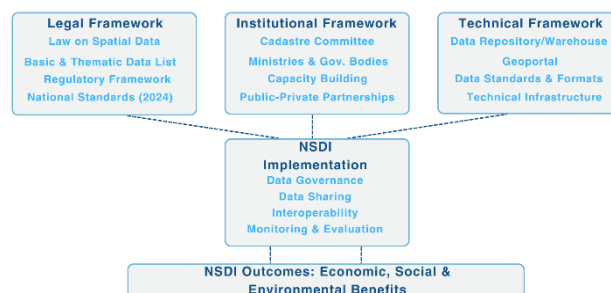


Figure 1. NSDI Conceptual Framework Diagram

4.1 Existing Spatial Data Systems

Armenia's existing spatial data systems are based on a variety of sector-specific cadastres, managed by different governmental bodies. These cadastres include systems for land management, forest resources, water resources, nature protection, and urban planning, among others. These systems are responsible for collecting, storing, and managing data related to their specific domains. For example, the Land Cadastre, Forest Cadastre, Water Resource Cadastre, and Environmental Protection Cadastre are some of the main data systems in place.

While these data systems play a crucial role in spatial data management, they often operate in silos, leading to inefficiencies in data sharing and integration. This fragmented approach complicates the development of a comprehensive NSDI, where interoperability and seamless data exchange across sectors are essential.

4.2 Policy and Legal Framework

The Armenian government has taken a number of legal and policy steps to establish a coherent framework for spatial data management and to support the development of an NSDI. Key legislative documents, such as the Law on Spatial Data (2023)²³, provide the legal foundation for NSDI development and outline the responsibilities of different authorities involved in data collection and sharing.

In 2022, the Armenian government adopted the decision on the "Approval of the List of Basic and Thematic Data for the NSDI and Standardization Guidelines"²⁴ which set out the mandatory data attributes and standards for spatial data across various sectors. This initiative aimed to

²⁰ Astsatryan et al., Toward to the Development of an Integrated Spatial Data Infrastructure in Armenia.

²¹ Asmaryan et al., Paving the Way toward an Environmental National Spatial Data Infrastructure in Armenia.

²² Petrosyan and Efendyan, “Legal Aspects of National Spatial Data Infrastructure of Republic of Armenia.”

²³ Republic of Armenia, “Law on Spatial Data.”

²⁴ Government of the Republic of Armenia, “Decision No. 1569-N.On Approving the List of Basic and Thematic Spatial Data and the Guidelines for Their Standardization in the National Spatial Data Infrastructure of the Republic of Armenia.”

standardize the collection, processing, and sharing of spatial data, ensuring that data from different sources could be integrated into a common NSDI platform.

In addition to these core legal documents, several other regulatory acts have been developed in accordance with the Law on Spatial Data to further define specific aspects of spatial data management in Armenia. These include the definition of accessible spatial data for use by public authorities, local self-government bodies, as well as legal and physical persons²⁵. A regulation has been established that defines how authorized state body (Cadastre Committee of Armenia) should provide spatial data to stakeholders, ensuring that data is made available in a consistent and transparent manner²⁶. Another regulation sets the rules for issuing or denying permits for the creation, development, or collection of basic spatial data and metadata, as well as for aerial photography work conducted for spatial data creation purposes in the Republic of Armenia²⁷.

Further regulations establish the creation, maintenance, and procedures for the publication of the national spatial data fund, which holds publicly accessible spatial data collected by state bodies²⁸. These regulations also govern the conditions under which foreign physical or legal persons, stateless individuals, international organizations, and foreign governments can access or request spatial data from Armenia, outlining the criteria for granting or denying such permissions²⁹. A regulation also defines the procedures for the collection, dissemination, and use of spatial data that may contain state or official secrets, ensuring that sensitive information is protected appropriately³⁰.

Lastly, regulations specify the model contract for periodic data updates and the process through which authorized public body will provide updated spatial data³¹.

Methodological, technical and operational guidelines for spatial data management have not yet been developed, which poses a challenge for ensuring that spatial data systems adhere to consistent technical and procedural standards.

Additionally, significant progress in standardization has been achieved during 2021-2023 through an Asian Development Bank grant. International partners developed 12 national spatial data standards that were officially approved in 2024 by the "National Body for Standardization and Metrology" CJSC under the Ministry of Economy of the Republic of Armenia. These comprehensive standards address crucial aspects of spatial data management, including cadastral parcels, addressing systems, administrative units, data quality metrics, geographic nomenclature, building information, metadata frameworks, relief data parameters, land cover classification, surface water delineation, and transportation networks. The adoption of these standards represents an important advancement toward establishing consistent technical specifications for Armenia's spatial data infrastructure.

4.3 Challenges in Data Availability and Quality

As Armenia progresses toward the development of a NSDI, several challenges hinder the efficient availability, accessibility, and quality of spatial data. These challenges affect both the effective implementation of NSDI and the broader goals of integrating spatial data across various sectors of governance and public services. The main challenges in data availability and quality are outlined below:

4.3.1 Lack of standardized spatial data and metadata

One of the primary challenges faced by the Armenian spatial data infrastructure is the lack of standardized spatial data and metadata. Different government bodies, institutions, and private organizations often collect spatial data using varied formats, making it difficult to integrate and share information across sectors. The absence of standardized metadata—critical information that provides context about the data, such as its source, accuracy, and update frequency—further complicates the ability to assess and use the data effectively. This lack of consistency prevents the seamless integration of spatial data from various sources into a unified NSDI platform, leading to potential data quality issues and delays in decision-making.

²⁵ Government of the Republic of Armenia, "Decision No. 1499-N On Approving the List of Accessible Spatial Data for Use by Public Administration and Local Self-Government Bodies, as Well as Legal and Physical Entities."

²⁶ Government of the Republic of Armenia, "Decision No. 86-N On Establishing the Procedure for Processing Public Spatial Data."

²⁷ Government of the Republic of Armenia, "Decision No. 626-N On Establishing the Procedure for Granting Permits and Conditions for the Creation, Development, or Collection of Basic Spatial Data and Metadata Related to the Territory of the Republic of Armenia, Including the Implementation of Aerial Photography Work for the Purpose of Spatial Data Creation, for Physical or Legal Entities, Including Foreign Entities, Based on the Results of Their Activities in the Territory of Armenia."

²⁸ Government of the Republic of Armenia, "Decision No. 434-N On Approving the Procedure for the Creation, Storage, and Dissemination (Publication) of the State Spatial Data (Cartographic and Geodetic) Fund of the Republic of Armenia."

²⁹ Government of the Republic of Armenia, "Decision No. 1282-N On Establishing the Procedure and Conditions for Granting Permits for the Processing of Spatial Data by Foreign Physical or Legal Entities, Stateless Individuals, International Organizations, and Foreign States."

³⁰ Government of the Republic of Armenia, "Decision No. 1783-N On Establishing the Procedure for the Collection,

Processing, Distribution, and Use of State Secret Classified Spatial Data."

³¹ Government of the Republic of Armenia, "Decision No. 1303-N On Approving the Model Form of the Agreement for the Cadastre Committee's Public Information Dissemination Services and Establishing the Procedure for the Processing of Information."

Several key ministries are responsible for administering various state cadastres, but inconsistencies in data formats and metadata persist across these systems. For instance, the Ministry of the Environment manages the state cadastres for forests (2008 No. 133-N), water resources (2017 No. 68-N), specially protected nature areas (2008 No. 259-N), waste (2007 No. 144-N), flora (2008 No. 1440-N), and fauna (2008 No. 1441-N). The Ministry of Territorial Administration and Infrastructures oversees the state cadastre of mineral deposits (2012 No. 1571-N), while the Ministry of Education, Science, Culture and Sports administers the state cadastre of immovable monuments of history and culture (2009 No. 104-N), and the Urban Development Committee maintains the State Urban Development Cadastre (1999 No. 802). The Ministry of Economy is responsible for the Cadastre of Agricultural Lands (Decision No. 179, March 6, 1991)³².

However, the absence of consistent legal frameworks and formalized procedures for compiling thematic data layers in these sectors has hindered the integration of their respective data into a cohesive NSDI. Despite the significant role played by the Ministry of Territorial Administration and Infrastructures, the Ministry of High-tech Industry, and the Ministry of Economy in generating thematic data, there is a lack of legal acts that explicitly define their powers to manage certain cadastres or registers. This gap further contributes to the challenges of achieving data standardization and interoperability within the NSDI.

4.3.2 *Incomplete or outdated datasets*

Another significant challenge is the incompleteness or outdated nature of many existing datasets. Due to inconsistent data collection practices and a lack of regular updates, many datasets do not accurately reflect the current state of affairs. This issue is particularly prominent in fields such as land use, infrastructure, and natural resource management, where changes occur frequently. The absence of up-to-date data undermines the reliability of the NSDI, limiting its effectiveness in supporting planning, policy-making, and disaster response. Furthermore, incomplete datasets lead to gaps in spatial analysis, affecting the quality of decision-making processes.

4.3.3 *Gaps in spatial data sharing across sectors*

Despite efforts to create a more integrated spatial data system, there are significant gaps in the sharing of spatial data across different sectors of government. Various ministries and agencies often operate in silos, with little cross-sectoral coordination. This lack of collaboration leads to duplicated efforts, inefficiencies, and missed opportunities for data integration. For example, data

collected by environmental agencies may not be readily accessible to urban planning authorities, and vice versa. As a result, the NSDI may not fully leverage the wealth of spatial data collected by different institutions, limiting the scope and utility of the infrastructure for both public and private users.

4.3.4 *Issues with data interoperability and integration*

A critical challenge facing Armenia's NSDI is ensuring data interoperability and effective integration across different platforms, systems, and sectors. While spatial data may be collected and stored by various government entities, their integration into a cohesive, nation-wide system requires overcoming technical and organizational barriers. These barriers include differences in software platforms, data models, and protocols used by various agencies. The lack of common standards for data exchange and interoperability complicates the integration of spatial data into the NSDI, preventing the creation of a unified system that can serve all sectors effectively. Without seamless data integration, the potential benefits of a robust NSDI—such as improved decision-making, more efficient resource management, and enhanced public services—cannot be fully realized.

4.4 International Context and Best Practices

The development of NSDIs has become a key priority for many countries globally, driven by the recognition of the critical role that spatial data plays in economic development, governance, and sustainability. Armenia's efforts to establish a NSDI are part of this broader global trend, and by drawing from international best practices, Armenia can better position itself within the global geospatial ecosystem. The following sections highlight global trends in NSDI development and Armenia's position within this international context.

4.4.1 *Global Trends in NSDI Development*

The global movement towards the creation of NSDIs has been significantly influenced by the increasing importance of geospatial data for a wide range of applications. Many countries are making substantial investments in the development of NSDIs to facilitate the effective management and utilization of spatial data for public and private sector needs^{33,34,35}. The establishment of national geospatial data portals has been a critical element of this trend, allowing both public and private sector users to access and use geospatial data. Countries like the United States³⁶, Canada, and the European

³² Government of the Republic of Armenia, "Decision No. 672-L On Approving the Action Plan for the Creation of an Integrated Cadastre and the Program of Actions Derived from the Action Plan."

³³ Crompvoets et al., "Assessing the Worldwide Developments of National Spatial Data Clearinghouses."

³⁴ Makanga and Smit, "A Review of the Status of Spatial Data Infrastructure Implementation in Africa."

³⁵ Crompvoets et al., "Governance of National Spatial Data Infrastructures in Europe."

³⁶ Steven, "The US National Spatial Data Infrastructure: What Is New?"

Union³⁷ have been leaders in promoting and investing in NSDIs.

A key challenge and priority in NSDI development is ensuring that geospatial data from different sources can be integrated and shared seamlessly. International standards for spatial data, such as those developed by the Open Geospatial Consortium (OGC) and the European Union's INSPIRE (Infrastructure for Spatial Information in the European Community) Directive, have been crucial in promoting interoperability between different systems and datasets^{38,39}. The INSPIRE Directive, for example, requires member states to make their geospatial data accessible and interoperable, facilitating cross-border data sharing across Europe.

A global trend is the adoption of open data policies by governments, making spatial data publicly available and fostering innovation^{40,41}. Open data initiatives not only improve transparency but also create opportunities for the private sector to develop new applications that leverage government geospatial data. Additionally, public-private partnerships (PPPs) have become more common, as governments collaborate with technology companies to enhance data collection, sharing, and analysis capabilities.

Beyond simply collecting spatial data, global trends emphasize the need for making data accessible and usable for a broad range of stakeholders. Many countries are focusing on the development of user-friendly data portals, dashboards, and APIs (application programming interfaces) that allow both technical and non-technical users to easily access, visualize, and analyse geospatial data⁴². These platforms are designed to cater to various sectors, such as government, academia, businesses, and the general public, to facilitate data-driven decision-making. AI-powered tools are also being used to enhance these platforms, enabling users to interact with spatial data in more intuitive ways and gain deeper insights from the data^{43,44,45}. By integrating AI with NSDIs, governments can provide more efficient and effective services to citizens and improve the overall management of spatial resources.

4.4.2 Armenia's Position within the Global Geospatial Ecosystem

Armenia, though a small country geographically, is increasingly integrating itself into the global geospatial ecosystem by adopting legal, technical, and institutional frameworks that align with global NSDI standards. While Armenia is still in the process of fully developing its NSDI, its efforts are gradually positioning it within the international context of geospatial data management.

Armenia's efforts to establish a national framework for spatial data management have been guided by international standards and best practices. The adoption of the Law on Spatial Data and the Government Decision on the Approval of the List of Basic and Thematic Data for NSDI and Standardization Guidelines reflects Armenia's commitment to aligning its legal and technical frameworks with international norms, such as the INSPIRE Directive and the standards set by the ISO. The focus on standardizing data attributes, metadata, and protocols for data sharing is in line with global best practices for ensuring data interoperability and accessibility.

4.5 Technological and Institutional Building Blocks for an Armenian NSDI

The successful establishment of a NSDI in Armenia will rely on a combination of robust technological frameworks and well-established institutional structures. The technological building blocks involve the development of key infrastructure components such as data repositories, geoportals, and geospatial data standards. Armenia's NSDI will need to integrate existing spatial data sources.

A crucial element of Armenia's NSDI will be the establishment of a centralized data repository or data warehouse, which will aggregate and store spatial data from various government agencies, private entities, and academic institutions. This data warehouse will need to adopt open data policies, allowing for transparent access to both government and private sector stakeholders. One of the central technological components will be the development of a geospatial data portal or geoportal. This platform should allow users to access, visualize, and analyze spatial data in a user-friendly manner, whether they are experts or non-technical users.

Furthermore, institutional frameworks must be put in place to govern the collection, sharing, and usage of geospatial data. This includes establishing clear roles and responsibilities for data management, as well as regulations for data protection, privacy, and security.

The capacity of the institutions involved in geospatial data management will be critical for the long-term sustainability of the Armenian NSDI. This will require the development of human resources, including GIS professionals, data analysts, and legal experts, as well as the establishment of institutional relationships between various government ministries, local governments, and the private sector. Additionally, public-private partnerships (PPPs) can play a significant role in financing and developing the technical infrastructure

³⁷ Vandenbroucke et al., "INSPIRE State of Play. Development of the NSDI in 32 European Countries between 2002 and 2007."

³⁸ Reichardt, "Open Geospatial Consortium Standards."

³⁹ Reed, "The Open Geospatial Consortium and Location Service Standards."

⁴⁰ Zuiderwijk and Janssen, "Open Data Policies, Their Implementation and Impact: A Framework for Comparison."

⁴¹ ye, "Open Data and Open Source GIS."

⁴² Association and Ayats, "User-Friendly Geoportal Interfaces for Geospatial Resource Discovery."

⁴³ Song et al., "Advances in Geocomputation and Geospatial Artificial Intelligence (GeoAI) for Mapping."

⁴⁴ Li et al., "GeoAI for Science and the Science of GeoAI."

⁴⁵ Janowicz et al., "GeoAI: Spatially Explicit Artificial Intelligence Techniques for Geographic Knowledge Discovery and Beyond."

needed for an NSDI, enabling greater innovation and efficiency in data collection and management.

5. Future Prospects and Opportunities

The development of a NSDI for Armenia presents significant future prospects and opportunities for the country. The integration of geospatial data into national planning, governance, and private sector activities could bring about transformative changes in how Armenia manages its resources, develops infrastructure, and responds to challenges such as climate change, urbanization, and social inequalities.

An Armenian NSDI offers the opportunity to streamline decision-making processes across multiple sectors. Spatial data, when fully integrated into national governance systems, can facilitate evidence-based decision-making, improving efficiency and resource allocation. For instance, the government can use geospatial data to optimize urban planning, monitor environmental conditions, and enhance infrastructure development. Furthermore, the integration of spatial data can support better coordination between different ministries, local governments, and other stakeholders, ensuring that spatial data is shared and used effectively across sectors.

The advancement of the Armenian NSDI will also create opportunities for the private sector, as it opens up the possibility for new business models and services based on geospatial data. Industries such as real estate, agriculture, logistics, and tourism could benefit greatly from access to reliable and updated geospatial data. Additionally, emerging technologies like Artificial Intelligence (AI), machine learning, and drone-based data collection will create new opportunities for improving data accuracy, analysis, and application. By fostering an innovation ecosystem around geospatial data, Armenia can attract technology companies and startups, contributing to the growth of its digital economy.

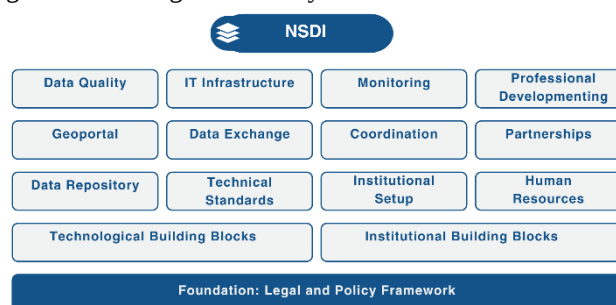


Figure 2. NSDI Building Blocks

5.1 Policy Recommendations for NSDI Development

The Armenian government should prioritize several key policy measures to ensure the successful development and implementation of its NSDI:

5.1.1 Standardization and Harmonization of Data

Establish mandatory data standards, including metadata formats, that are aligned with international standards.

This will facilitate data interoperability across sectors and agencies, ensuring that spatial data can be seamlessly integrated into the NSDI platform.

5.1.2 Capacity Building and Training

Strengthen the human resource capacity for spatial data management by providing training programs for government officials, GIS professionals, and academics. Capacity building should also focus on equipping local governments with the skills needed to manage and use spatial data in their day-to-day operations.

5.1.3 Public-Private Partnerships (PPPs)

Establish and encourage PPPs for the development of geospatial data platforms, technologies, and services. Collaboration with the private sector will enable the government to leverage technical expertise, reduce costs, and accelerate the development of the NSDI.

5.1.4 Institutional Coordination

Strengthen the institutional framework for the NSDI, ensuring that there is a clear structure for data governance, coordination, and oversight. The development of inter-ministerial committees or working groups can help align efforts across different sectors.

5.1.5 Legal and Regulatory Framework

Further refine and strengthen the legal and regulatory framework to support data sharing and integration, ensuring that issues such as data privacy, security, and intellectual property are adequately addressed.

5.2 Potential Economic, Social, and Environmental Benefits

The implementation of a robust NSDI in Armenia is expected to generate numerous economic, social, and environmental benefits, contributing to sustainable development and improved governance.

5.2.1 Economic Benefits

Access to accurate and up-to-date geospatial data can facilitate more efficient and cost-effective decision-making in sectors such as urban planning, agriculture, and infrastructure development. For example, the government could use spatial data to optimize land-use planning and zoning regulations, reducing costs and improving the quality of urban development. In agriculture, spatial data can be used to monitor crop conditions, predict harvests, and optimize water usage, leading to increased productivity and reduced environmental impact. Furthermore, an effective NSDI can attract foreign investments in geospatial technologies and services, fostering economic growth in Armenia's tech sector.

5.2.2 Social Benefits

An Armenian NSDI can improve public services by enabling better targeting of resources and services. For example, geospatial data can be used to enhance disaster management and response efforts by identifying vulnerable areas and planning evacuation routes. It can

also help in monitoring public health trends, providing data for planning healthcare infrastructure, and addressing social inequalities. Moreover, transparent access to geospatial data can empower citizens, allowing them to better engage in public decision-making and advocacy.

5.2.3 Environmental Benefits

The availability of high-quality spatial data will significantly enhance Armenia's ability to manage its natural resources and monitor environmental changes. For example, geospatial data can help the government monitor deforestation, water quality, and biodiversity, supporting more informed conservation efforts. It can also play a critical role in addressing climate change, enabling the monitoring of environmental hazards and the development of adaptation strategies. The use of spatial data in environmental monitoring can lead to more sustainable land use, better protection of ecosystems, and improved management of natural resources.

6. Conclusion

The development of a NSDI in Armenia presents a transformative opportunity to enhance the management and utilization of spatial data across various sectors of the economy, governance, and society. As the global demand for geospatial data continues to grow, Armenia is positioned to leverage this resource to support national development goals, including economic growth, disaster management, environmental sustainability, and social welfare.

The legal and policy framework established by the Armenian government, including key legislative documents and strategic decisions, provides a strong foundation for the development of a cohesive and integrated NSDI. The establishment of clear standards and institutional responsibilities, along with ongoing capacity-building efforts, is essential for ensuring the successful implementation and long-term sustainability of the NSDI.

However, several challenges remain, particularly in the areas of data availability, quality, and interoperability. The lack of standardized data formats, incomplete or outdated datasets, and gaps in spatial data sharing across sectors must be addressed to ensure the seamless integration of spatial data into the NSDI. Overcoming these challenges will require coordinated efforts across government agencies, the private sector, and other stakeholders to create a unified, accessible, and high-quality spatial data ecosystem.

Looking ahead, the potential economic, social, and environmental benefits of a well-functioning NSDI in Armenia are substantial. The adoption of open data policies, the promotion of public-private partnerships, and the integration of emerging technologies such as Geo-AI and remote sensing into data collection and analysis will further enhance the effectiveness of the NSDI. As Armenia strengthens its technological and institutional frameworks, it will be able to unlock new

opportunities for innovation, sustainable development, and improved governance.

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