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Proposing an integrated conceptual framework for implementing spatial data infrastructure by systematically reviewing and analyzing SDI maturity models

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Abstract

This study deals with the absence of a uniform global scale for spatial data infrastructure (SDI) maturity assessment, and presents a five-layer holographic conceptual framework derived from a systematic literature review and evaluation of metadata. The literature review identified key maturity models—NGDA[1], ANZLIC[2], INSPIRE[3], SDIOGI[4], and hierarchical perspectives (Building Block and Umbrella)—alongside metadata standards ISO 19115/19139, FGDC[5], Dublin Core, and GEMET. The methodology comprises four phases: First, selecting twenty seminal articles from Web of Science, IEEE Xplore, and ScienceDirect; second, screening studies via inclusion/exclusion criteria; third, extracting and coding dimensions and indicators into detailed tables; and then conducting a comparative matrix synthesis. Based on a systematic review of SDI maturation models, we identified five core dimensions - organizational, political, technical, qualities and human resources - common across a leading framework. We integrated these into a new five-layer hollow conceptual framework, centers quality and continuous improvement to drive adaptive, feedback-driven maturation. By utilizing established best practices and international standards (e.g. Inspire, ISO 19115), this entirely conceptual model requires no field data, and offers athletes and decision makers a pragmatic tool for strategic planning and results monitoring. It establishes a universal goal for SDI maturity assessment and paves the way for future empirical validation across different contexts.

Keyword: Maturity Assessment; Conceptual Framework; Metadata Standards; Continuous Improvement.

1 National Geospatial Data Assets
2 Australia and New Zealand Land Information Council
3 Infrastructure for Spatial Information in Europe
4 Spatial Data Infrastructure On-Going Improvement
5 Federal Geographic Data Committee

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1. Introduction

In recent years, Spatial Data Infrastructures (SDIs) have emerged as the backbone for managing and sharing geospatial information across interdisciplinary projects. Numerous maturity models—such as the NGDA framework in the United States, ANZLIC in Australia, and INSPIRE standards in Europe—have been proposed to assess the capabilities and developmental stages of SDIs. However, these models work largely isolated - each with their own dimensions, indicators and evaluation methods - reflecting distinct geographical contexts and institutional structures. This fragmentation inhibits intersections of maturity assessments among countries and organizations and excludes the establishment of a uniform global benchmark index for SDI maturity. Furthermore, the spread of different models not only generates confusion among researchers and decision makers, but also complicates the practical distribution, design and improvement of SDIs. The absence of a comprehensive, comparative evaluation of these models further hides their respective limitations and strengths, and prevents systematic aggregation and adoption of best practice. Consequently, there is a compelling need for a systematic, comparative study that critically examines existing frameworks and proposes an integrated model to evaluate the SDI maturity on a global scale.

The importance of evaluating the SDI maturity can be understood through both international and regional frameworks. Internationally, the EU's Inspire initiative has established standards to ensure interoperability and seamless data exchange between member states. In North America, the NGDA framework aims to spread federal geospatial computer practices to states and local units. Regularly programs such as ANZLIC in Australia and the UN Geoss have shown that maturity assessments can quickly identify and correct structural deficiencies. Despite these initiatives, the absence of a universally approved scale that addresses the different requirements and mandates of these frameworks of these frameworks and the connection of SDI projects. Therefore, the development of an integrated framework for SDI maturity assessment is important - not only to harmonize processes at both global and regional levels, but also to speed up decisions and reduce development and maintenance costs for geospatial infrastructure.

The primary aim of this study is to develop an integrated framework for assessing the maturity of Spatial Data Infrastructures on a global scale. The specific objectives are:

1. To review and categorize existing SDI maturity models in the literature—including the NGDA, ANZLIC, INSPIRE frameworks and other established approaches—without any primary data collection.
2. To conduct a theoretical analysis of each model's dimensions and characteristics from a structural and conceptual standpoint, identifying strengths and limitations based solely on documented sources.
3. To develop a conceptual taxonomy of SDI maturity components, detailing key dimensions and their conceptual interrelations through a systematic literature study.

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4. To design an integrated conceptual framework for SDI maturity assessment grounded entirely in theoretical principles and documented best practices, with no requirement for practical implementation or local datasets.
5. To provide scholarly guidance and research recommendations for applying the conceptual framework in future studies and for advancing maturity models, emphasizing theoretical rigor and qualitative research methodology.

2. Literature review

SDI is the relevant set of technologies, policies, and organizational arrangements that facilitate access to spatial data and their usability. The term Spatial Data Infrastructure (SDI), while seemingly self-explanatory, is actually a complex concept that has attracted various definitions. For instance, the Global Spatial Data Infrastructure (GSDI) Association has stated that SDIs provide a foundation for the discovery, evaluation, and application of spatial data. The definition of GSDI includes geographic data, metadata, framework, services, clearinghouse, standards, partnerships, education, and communication (Parida & Tripathi, 2018). In this context, "infrastructure" refers to a reliable and supportive environment, akin to a road or telecommunications network, that facilitates access to geographic information through a minimum set of standard procedures, protocols, and specifications. SDI should be more than just a single dataset or database; it encompasses geographic data and attributes, sufficient documentation (metadata), tools for discovering, visualizing, and evaluating data (catalogs and web mapping) and a means of accessing geographic data. To be functional, an SDI must include the necessary organizational arrangements for its coordination and management at local, regional, national, and/or supranational scales. Researchers have identified several key components common to all SDI implementations: people, access networks, policies, technical standards, and data set (Figure 1). SDI provides an environment where people and systems can interact with technology to use, manage, and produce geographic data (Gomes et al., 2024).

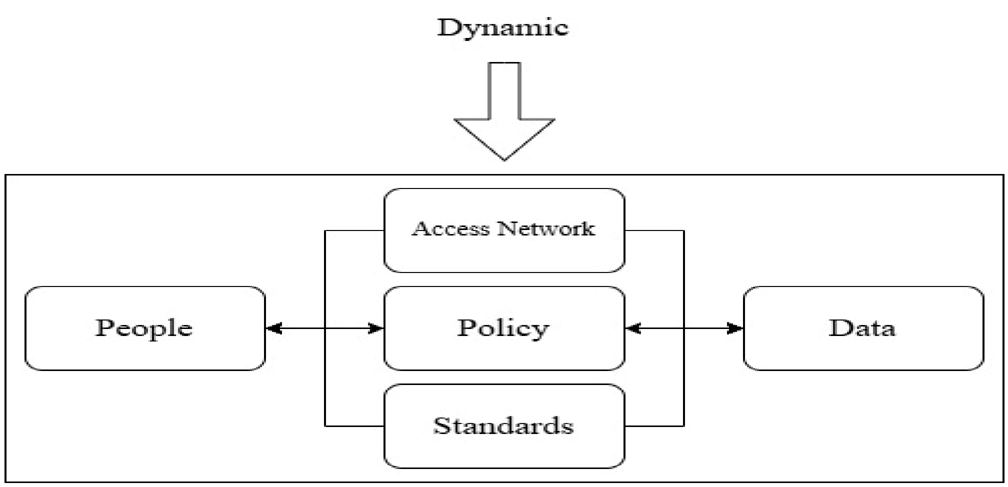

Figure 1. Components of SDI (Ian Williamson et. al. ,2003)

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A spatial data infrastructure (SDI) can work at various interconnected levels, including global, regional, national, state, local and businesses. These levels represent a hierarchy where spatial data and related services are administered and shared, often with addictions and interactions between them. For example, local datasets can contribute to a national SDI, which in turn can match regional or global standards and initiatives. Similarly, Corporate SDIs can operate within and contribute to wider national or even international frameworks (Oliveira et al., 2015). Following the examination of SDI structure, the discussion now turns to the tools that can integrate different levels or enable interaction among SDIs at the same level. The evaluation and assessment of a Spatial Data Infrastructure (SDI) are vital for understanding its efficiency, identifying areas for improvement, and demonstrating its value to stakeholders. This process involves defining clear goals, establishing relevant performance indicators and using appropriate calculations to measure SDI's performance against these goals. Evaluation helps to measure influence, find strengths and weaknesses, inform decisions, strengthen accountability and promote SDI sustainability. Performance indicators are quantitative and are assessed through calculations such as data availability and quality, use and effect of SDI, and its sustainability and governance. The selection of indicators and metrics depends on the specific goals and maturity of the SDI, and their regular calculation provides valuable insights for ongoing development and enhancement (Mahpour et al, 2022; Maphale & Smit, 2021). Various approaches have been proposed for modeling SDI development. Some of these models include the umbrella view, the building block view, and the generative view. These perspectives offer hierarchical approaches, both top-down and bottom-up, for modeling the development of an SDI.
Having examined the structure and evaluation of SDIs, we now turn to maturity models, which provide staged frameworks for assessing and developing SDI capabilities.

2.1. Existing Maturity Models

1. NGDA Framework (USA): Defines five maturity stages—Preparation, Service Development, Partnership, Integration, and Sustenance—emphasizing federal-state collaboration.
2. ANZLIC Model (Australia/New Zealand): Outlines six maturity levels addressing structural, procedural, and institutional aspects, from initial data awareness to automation and innovation.
3. INSPIRE Compliance (EU): Lacks a formal maturity scale but uses technical, metadata, and service requirements to gauge member states' alignment with the INSPIRE Directive.
4. SDIOGI (SDI Ongoing Improvement): A cyclical approach based on the Theory of Constraints, focusing on identifying and resolving bottlenecks while evaluating performance and continuous improvement.

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5. Building Block and Umbrella Views: Provide hierarchical top-down and bottom-up perspectives for SDI development, either by component layers or all-encompassing umbrella systems.

2.2. Metadata

Geospatial metadata must adhere to international standards to ensure interoperability and discoverability. Principal standards include ISO 19115 for metadata structure and content, ISO 19139 for its XML implementation, the U.S. FGDC standard, Dublin Core for general data cataloging, and GEMET as a multilingual environmental thesaurus. These standards establish a uniform framework for defining mandatory fields, formats, and shared vocabularies (Cooper et al., 2025; Yoo & Kim, 2021).

Despite the dissemination of maturity models and robust meta standards, there is no integrated conceptual structure that consolidates the main dimensions and indicators for a uniform global evaluation of SDI maturity. In addition, existing evaluations usually depend on practical implementations and local data sets, while systematic theoretical and comparative studies remain scarce. This fragmentation complicates the model options and the evaluation methodology for researchers and decision makers and emphasizes the need for a theoretically rooted structure based only on the literature review and best practices to evaluate the maturity of SDI globally.

3. Methodology

This study uses a systematic literature review that includes four primary phases: (1) Identification and collection of peer-reviewed articles on SDI maturation models and metadata standards from leading databases; (2) Screening and application of inclusion/exclusion criteria to ensure relevance and quality; (3) Systematic extraction and conceptual coding of each model's dimensions and indicators; and (4) comparative analysis that leads to the synthesis of an integrated conceptual framework. This completely theoretical process requires neither field data nor complex empirical analysis, and chairs exclusively on documented sources and scientific evaluation. The complete workflow for these steps is depicted in Figure 2.

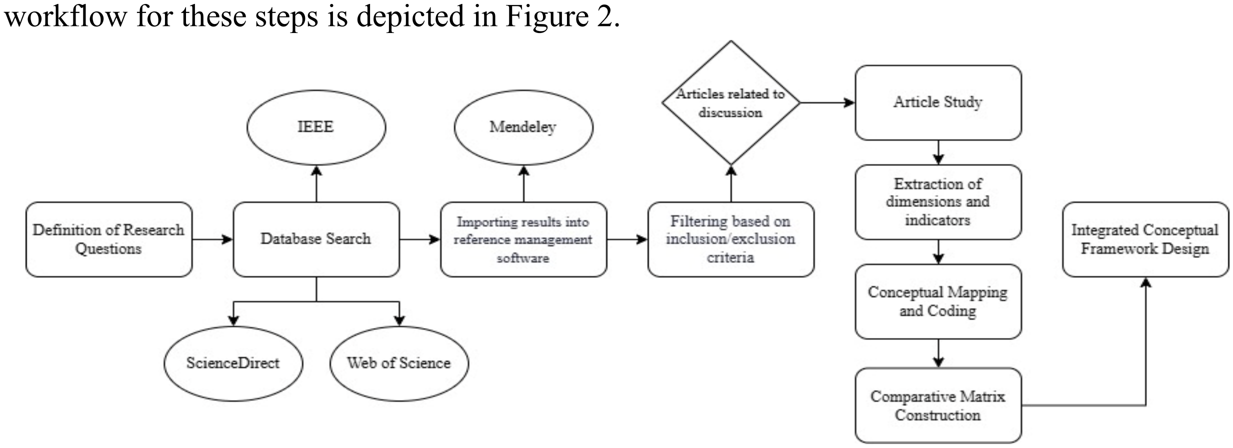

Figure 2. Workflow of research methodology

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First, research questions and keyword combinations are formulated based on the study's objectives and identified gaps. Selected databases include Web of Science, IEEE Xplore, and ScienceDirect. Initial results are imported into a reference manager (e.g., Mendeley), and titles and abstracts are independently reviewed by two researchers to minimize bias and maximize accuracy.
To guarantee the quality and relevance of sources, the following criteria are defined:

- Inclusion Criteria:
  1. Peer-reviewed journal articles or reputable conference proceedings.
  2. Primary focus on SDI maturity models or infrastructure evaluation.
  3. Specification of dimensions, indicators, or theoretical frameworks for maturity assessment.
  4. English-language publications from 2010 onward.
- Exclusion Criteria:
  1. Descriptive articles lacking a clear evaluation model or framework.
  2. Case studies with limited field data and no broad theoretical contribution.
  3. Conference abstracts without full-text availability.
  4. Sources without accessible full text.

Following two screening rounds (title/abstract and full text), approximately 20 studies were selected for final analysis.
Each selected study is meticulously reviewed to extract reported dimensions and indicators. The process entails:

1. Extraction Template: A table with columns for "Model Name," "Dimension," "Indicator," "Definition," and "Reference" is established.
2. Independent Coding: Two researchers independently code each article and populate the template.
3. Reconciliation Phase: Discrepancies between coders are resolved through discussion, referencing original texts.
4. Conceptual Coding: Similar dimensions and indicators are grouped into conceptual categories (e.g., "Organizational Structure," "Technical Processes," "Institutional Interactions").
5. Matrix Construction: A comparative matrix is generated to display which dimensions and indicators each maturity model covers.

This descriptive, theory-driven methodology obviates the need for local data collection or processing, providing a robust foundation for designing the integrated conceptual framework.

4. Results

4.1. Comparative Analysis:

As part of a systematic review of Spatial Data Infrastructure (SDI) maturity models, this section presents a comprehensive analysis of prior studies in the field. Table 1 offers a structured summary

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of key research, detailing information such as authors, publication year, core focus, applied SDI maturity framework, and methodology of each study. This review is designed to identify common patterns, strengths and limitations in existing models, as well as to uncover research holes in the literature. Selected studies were curated based on criteria including explicit focus on SDI maturity, geographical diversity and methodological innovation. The comparative analysis of these frameworks establishes a critical basis for developing the integrated conceptual model proposed in the subsequent parts of this article.

Table 1. An overview of the 20 selected studies, detailing each article's authorship, publication year, examined SDI maturity frameworks, and study type

No	Authors/ Year	Title	Framework or maturity model	type of study
1	(Ilić, 2009)	Global Spatial data infrastructure	GSDI	Conceptual
2	(Oliveira et al., 2015)	Building a Thematic Spatial Data Infrastructure and Situation-Aware for Global Events	GSDI	Usage
3	(She et al., 2019)	Bridging open source tools and Geoportals for interactive spatial data analytics	Architectural Framework	Usage
4	(Akingbemisilu, 2024)	A Critical Evaluation of Government Role in Spatial Data Infrastructures for Healthcare Decision-Making	NSDI / CGDI / UNSDI / INSPIRE	Experimental
5	(Sjoukema et al., 2017)	Evolving Spatial Data Infrastructures and the Role of Adaptive Governance	NSDI	Experimental
6	(Çalikoğlu & Łuczak, 2024)	Multidimensional assessment of SDI and HDI using TOPSIS and bilinear ordering	Sustainable Development Index / INSPIRE	Conceptual
7	(Parida & Tripathi, 2018)	Odisha Spatial Data Infrastructure (OSDI) – Its Data Model, Meta Data and Sharing Policy	GSDI / NSDI	Usage
8	(Izdebski, 2018)	Analysis of the cadastral data published in the Polish Spatial Data Infrastructure	NSDI	Conceptual
9	(Chipatiso, 2023)	Analyzing the nexus between Spatial Data Infrastructure Development and e-Government	NSDI / SDI Development	Review
10	(Maphale & Smit, 2021)	A Theoretical Proposition for Spatial Data Infrastructure On-Going Improvement	SDIOGI	Review
11	(Kalantari Oskouei et al., 2019)	An analysis of the national spatial data infrastructure of Iran	NSDI	Conceptual
12	(Yoo & Kim, 2021)	Strategic Analysis for Governance Development of National Spatial Data Infrastructure Portal in Korea	NSDI / NSDIP	Review
13	(Cooper et al., 2025)	Geospatial data quality training for the South African Spatial Data Infrastructure – Lessons learnt from training geospatial data custodians	NSDI / SASDI	Review
14	(Wetzel et al., 2024)	Spatial data infrastructure components to provide regional climate information services	SDI Development	Review

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No	Authors/ Year	Title	Framework or maturity model	type of study
15	(Ran & Nedovic-Budic, 2024)	Online Decision Support Infrastructures for Integrating Spatial Planning and Flood Risk Management Policies	SDI Development	Conceptual
16	(Hill et al., 2024)	An integrated geospatial data model for active travel infrastructure	SDI Development	Conceptual
17	(Ahmad et al., 2024)	A Review of Pakistan's National Spatial Data Infrastructure Using Multiple Assessment Frameworks	NSDI	Review
18	(Ukueku et al., 2025)	Improving HIV case finding using spatial data infrastructures in Anambra State, Nigeria a pre-post intervention study	NSDI	Experimental
19	(Zwirowicz-Rutkowska & Michalik, 2024)	Spatial Data Infrastructure and Mobile Big Data for Urban Planning Based on the Example of Mikolajki Town in Poland	NSDI / PSDI	Usage
20	(Gomes et al., 2024)	Brazil Data Cube Workflow Engine a tool for big Earth observation data processing	SDI Development	Conceptual

Following the systematic review of prior studies in Table 1, the next step involves identifying and categorizing the core dimensions and indicators that define SDI maturity models. Table 2 provides a structured presentation of the most critical components extracted from prominent maturity models, including technical, governance, institutional, human, and infrastructural criteria. This table not only offers a framework for understanding each model's specific focus on distinct aspects of SDI but also establishes an analytical foundation for their systematic comparison in Table 3. By conducting a comparative examination of these dimensions, overlaps, divergences, and conceptual gaps among the models can be elucidated. Such insights significantly contribute to the development of the proposed integrated framework, ensuring broader and more balanced coverage of SDI maturity elements.

Table 2. Outlines the core dimensions and specific indicators identified for each SDI maturity model, mapping how each framework assesses key aspects of infrastructure development

No	Model	Dimension	Indicator
1	GSDI	Organizational	Existence of governance body
2	GSDI	Technical	Availability of catalog services
4	NSDI	Policy	Presence of national metadata policy
5	NSDI	Institutional	Stakeholder partnership mechanisms
6	SDI Readiness	Human Resources	Staff training programs in SDI
7	GSDI	Data Quality	Metadata completeness rate
10	SDIOGI	Continuous Improvement	Frequency of maturity reassessments
16	SDI Dev.	Technical Processes	Use of standard OGC web services
17	NSDI	Policy	Clarity of data sharing regulations
20	SDI Dev.	Workflow Automation	Implementation of data cube engine

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By building on the structural insight from Table 2, it is important to organize these important dimensions within a conceptual framework and analyze their context. Table 3 categorizes systematically related dimensions in thematic clusters (eg "data management", "technical abilities" and "institutional integration"), which enables a deeper understanding of model convergence and divergence. By illustrating how indicators are distributed over conceptual categories, this table clarifies the mechanisms that operate SDI maturity and establish a basis for identifying areas that require reinforcement or further development in the proposed model. Such structured analysis acts as a critical step in transforming fragmented findings into a continuous and actionable framework.

Table 3. Taxonomy of SDI Maturity Dimensions

Conceptual Category	Associated Dimensions
Organizational	Governance body; Stakeholder engagement
Technical	Catalog services; Web service standards
Policy	Metadata policy; Data sharing regulations
Institutional	Partnership mechanisms; Management roles
Continuous Improvement	Reassessment frequency; Feedback loops
Data Quality	Completeness; Accuracy
Human Resources	Training programs; Expertise levels
Workflow Automation	Pipeline tools; Engine implementations

The conceptual classification in Table 3 reveals that the common dimensions across SDI maturity models can be organized into eight primary groups (organization, technical, policy, institutional, continuous improvement, data quality, human resources and workflow automation). This categorization not only reflects the diversity of domains influencing spatial infrastructure maturity but also uncovers recurring patterns in existing literature. For example, the stated emphasis on technical criteria and data quality emphasizes the strategic priority of robust infrastructure and reliable data, while the focus on continuous improvement and automation emphasizes the need for SDI -adaptation to technological advances. Such a structured analysis promotes a comprehensive understanding of the interaction between critical dimensions and development priorities, which is central to creating the proposed integrated framework with improved context and practical relevance.

Table 4. Presence of Dimensions in Each Maturity Model. *Columns are*
Org.: Organizational, *Tech.*: Technical, *Policy*: Policy, *Inst.*: Institutional, *CI*: Continuous Improvement, *DQ*: Data Quality, *HR*: Human Resources, *WA*: Workflow Automation

Model	Org.	Tech.	Policy	Inst.	CI	DQ	HR	WA
GSDI	✓	✓	✓	✓	–	✓	–	–
NSDI	✓	–	✓	✓	–	–	–	–
SDI Readiness	–	–	✓	–	–	–	✓	–

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Model	Org.	Tech.	Policy	Inst.	CI	DQ	HR	WA
SDIOGI	–	–	–	–	✓	–	–	–
SDI Dev.	–	✓	–	–	–	–	–	✓

Table 4 offers a comprehensive overview of dimension coverage across various SDI maturity models, mapping the analytical focus and scope of each framework. The results highlight that macro-level models such as GSDI and NSDI, by simultaneously addressing dimensions like *organizational*, *policy*, and *institutional*, exhibit a holistic and multi-faceted structure. This reflects the necessity for cross-sectoral alignment in SDI development. In contrast, specialized models such as SDIOGI and SDI Development predominantly concentrate on one or two specific dimensions (e.g., *workflow automation* or *continuous improvement*), demonstrating a targeted approach to addressing operational challenges at micro-level implementation. The disparity in coverage not only reveals methodological gaps between macro and micro models but also justifies the integration of their strengths into the proposed framework. This analysis provides an empirical basis for prioritizing dimensions in the design of an integrated model, ensuring a balanced synthesis of strategic breadth and operational specificity.

In this section, we first conducted a systematic critical evaluation of existing SDI maturity frameworks and prior studies through Table 1, incorporating peer-reviewed revisions to enhance methodological robustness. Subsequently, Table 2 enabled the systematic extraction of core dimensions and indicators, revealing foundational elements across models. These dimensions were then clustered into eight conceptually and operationally coherent groups in Table 3, grounded in theoretical and practical synergies. The analytical process culminated in Table 4, which delineates the granular coverage of each conceptual group across maturity models, facilitating a structured comparative assessment. Collectively, this hierarchical analysis—integrating methodological rigor and conceptual insights—provides the scaffolding for designing the integrated conceptual framework elaborated in the following section.

4.2. Integrated Conceptual Framework:

To address the identified gaps and consolidate the finest dimensions and indicators from various maturity models, we propose an integrated conceptual framework comprising five interrelated layers: (1) Governance & Policy, (2) Organizational & Institutional, (3) Technical & Infrastructure, (4) Quality & Continuous Improvement, and (5) Human Resources & Automation. These layers are arranged holographically[6]—each functioning autonomously while simultaneously contributing to the whole.

[6] From the perspective of social and philosophical sciences, holographic refers to views that emphasize the internal connection of components and see the "whole in the component" (The Web of Life, n.d.).

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Governance & Policy Layer

Encompasses metadata standards (ISO 19115/19139, FGDC, Dublin Core), legal regulations, and strategic policies. Its purpose is to establish a formal foundation for SDI processes and oversight. Key indicators include the existence of a national metadata policy, clarity of data-sharing regulations, and compliance with international directives (INSPIRE, GSDI).

Organizational & Institutional Layer

Drawn from the NGDA and ANZLIC frameworks, this layer focuses on management structures, inter-agency collaboration, and stakeholder engagement mechanisms. Indicators include the presence of a dedicated governance body, coordinating committees, and public–private partnership arrangements.

Technical & Infrastructure Layer

Based on GSDI and SDI Development perspectives, it covers catalog services (CSW/WMS/WFS), service-oriented architectures, and data workflow automation. Essential metrics include API availability, OGC standards compliance, and data source integration capabilities.

Quality & Continuous Improvement Layer

Inspired by the SDIOGI model, this layer is responsible for ongoing maturity monitoring. It defines metrics such as metadata completeness rates, periodic reassessment cycles, and feedback loop mechanisms to ensure the framework adapts to evolving requirements and technologies.

Human Resources & Automation Layer

Integrates human capacity indicators (training programs, expertise levels) and automation tools (batch processing, data pipeline engines). This layer ensures teams possess the necessary skills and that processes are executed automatically.

Figure 3 presents a holographic, five-team conceptualization of our integrated SDI maturity frame, with each concentric ring that works autonomously, but still contributes to the whole. In the core, the quality and continuous improvement layer (yellow) defines the feedback-driven calculations-metadata completeness rates, periodic re-evaluation intervals and two-way feedback looping-which continuously evaluates and delineates the infrastructure. Enclosing this is human resources and automation layers (light green), which ensures that trained personnel and automated workflows can quickly implement quality insights. The technical and infrastructure ring (TEAL) provides OGC compatible catalog and web services (CSW, WMS, WFS), API connection and service-oriented architecture that forms the basis for data access and work flight automation. The organizational and institutional team (blue) establishes governing bodies, coordination committees and stakeholder partnerships to translate technical abilities into coordinated action. Finally, the outermost governance and policy ring (ROS) codify national and international metadata policy (eg

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inspires compliance, ISO 19115), legal regulations and strategic directives that guide the total SDI goals. Between each adjacent layer symbolizes two-way arrows continuously information exchange and iterative adaptation, ensuring that political adjustments, organizational changes, technical upgrades and improvements to human-automation live back in the central quality engine and circulate in the entire system.

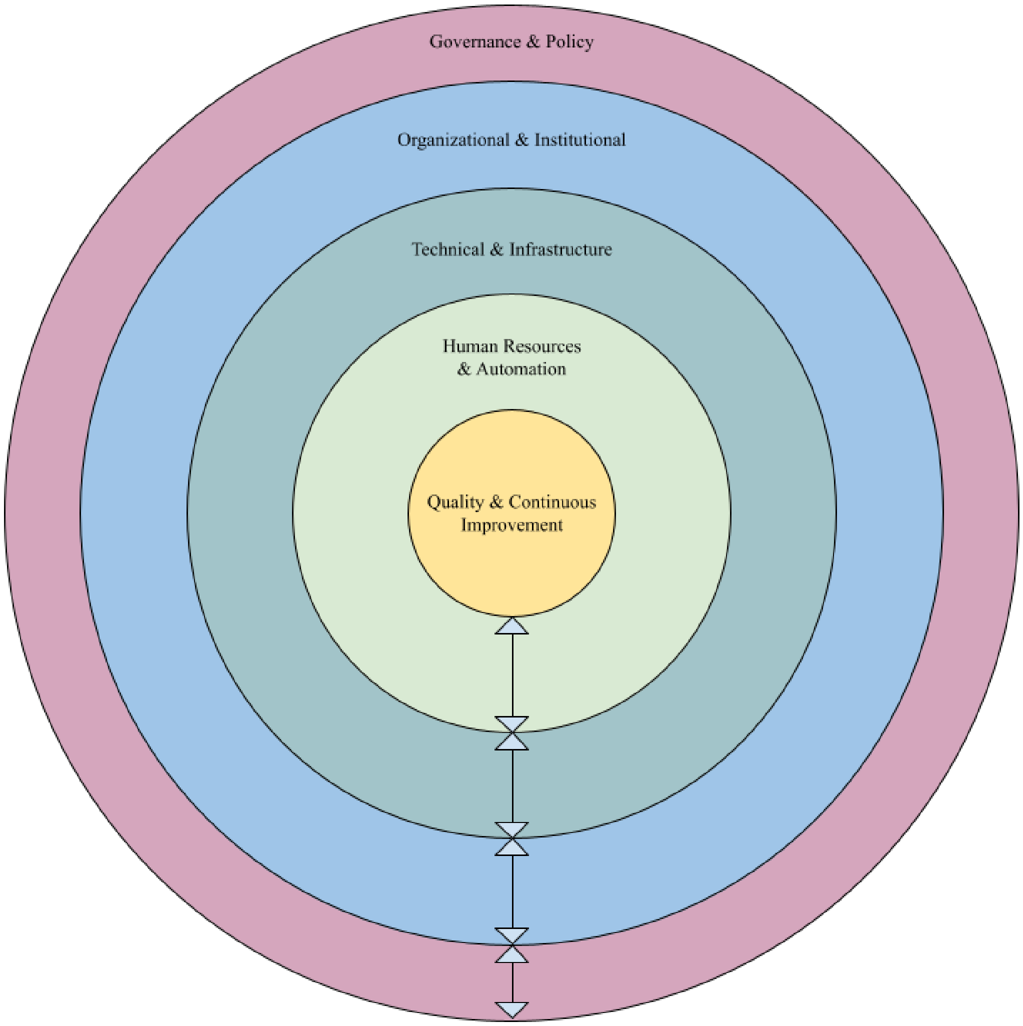

Figure 3. Conceptual Framework

By adopting this framework, SDI researchers and managers can comprehensively and systematically assess infrastructure maturity, pinpoint weaknesses, and design strategic development roadmaps. Moreover, this purely conceptual model—requiring neither local data nor initial implementation—enables long-term planning and establishes a universal standard for global SDI maturity assessment.

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5. Conclusion

By synthesizing a systematic review of SDI maturity models with metadata standards, this study proposes an integrated conceptual framework composed of five holographic layers: Governance & Policy, Organizational & Institutional, Technical & Infrastructure, Quality & Continuous Improvement, and Human Resources & Automation. This innovative structure maintains alignment with international criteria (INSPIRE, GSDI) while charting clear pathways for policy revision, inter-agency coordination, and ongoing enhancement. At the Governance & Policy layer, continuous development and periodic revision of national metadata policies are emphasized, ensuring a robust legal foundation and harmonization with global directives. The Organizational & Institutional layer promotes optimized organizational capacities through tailored public–private partnership mechanisms and clearly defined coordination bodies. The Technical & Infrastructure layer reinforces data accessibility and flexibility by prioritizing OGC-compliant web services and automated data workflows. The Quality & Continuous Improvement layer, armed with periodic reassessment metrics and bidirectional feedback channels, safeguards the framework's adaptability to emerging requirements. Finally, the Human Resources & Automation layer, through targeted training programs and advanced automation tools, ensures that SDI teams remain skilled and processes stay efficient. Without reliance on field data or intricate empirical analyses, this framework acts as a powerful tool for managers and policymakers, enabling strategic planning and establishing a global evaluation standard for SDI maturity. Implementing this model will allow organizations to systematically identify weaknesses, set development priorities, and guarantee that spatial data infrastructures progress toward sustainability and innovation.

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