

A Conceptual Model for Integrating Geospatial Standards into GIS Audit Framework

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Abstract

Geospatial standards ensure consistency, interoperability, and effective information sharing by harmonizing technical specifications while addressing the needs of developers, end users, and other stakeholders. Similarly, a GIS audit framework provides a structured approach for assessing GIS performance through predefined parameters covering four key areas: data quality, software utilization, personnel competency, and operational procedures. While GIS audit parameters evaluate performance and compliance, limited research has formalized a model linking these parameters to internationally recognized geospatial standards. Yet, both are inherently interconnected and together form a cohesive foundation for ensuring quality, integrity, and compliance in GIS management. This paper employs a mapping and analytical approach to align geospatial standards with corresponding GIS audit parameters across technical, procedural, and policy dimensions. From this analysis, a conceptual model is developed to formalize the observed relationships and demonstrate how integrating geospatial standards into GIS audit frameworks enhances audit accuracy, interoperability and quality assurance. In this context, audit accuracy refers to the precision and reliability of audit findings in reflecting the true state of GIS compliance and performance, distinct from audit comprehensiveness or general effectiveness. The model provides a transferable structure for strengthening spatial data governance and accountability across institutional and national contexts. The findings reveal strong alignment between geospatial standards and GIS audit parameters in key quality-related dimensions, while identifying gaps in domain-specific extensions, usability, workflow integration, staff competency and procedural controls. Based on these insights, the paper recommends the development of domain-specific quality extensions, usability and workflow integration guidelines, capacity-building initiatives, and harmonized procedural standards to achieve more comprehensive and effective GIS audits globally. The model links geospatial standards with GIS audit parameters, strengthening theoretical and practical under-

standing of standards-based geospatial governance.

Keywords

Geospatial Standards, GIS Audit Parameters, GIS Best Practices, Compliance, Data Quality, Spatial Data Management

1. Introduction

1.1. Background of Geospatial Standards and GIS Audits

The need for geospatial standards and Geographic Information System (GIS) audit parameters is rooted in the growing reliance on GIS across multiple sectors [1]. As the use of spatial data increases, so does the rising demand for common guidelines and protocols to guarantee its accuracy, consistency and interoperability [2].

Recognizing this, international organizations such as ISO/TC 211 and Open Geospatial Consortium (OGC) began developing formal geospatial standards [3]. These efforts aimed to unify geospatial data practices across platforms, regions, and disciplines, laying the foundation for the modern geospatial data infrastructure [4].

Like any other system, the concept of GIS audit evolved in response to institutional needs for performance evaluation, transparency and accountability [5]. In this paper, a GIS audit is defined as a systematic, standards-based process that evaluates the performance, quality, and compliance of GIS components against predefined technical and organizational benchmarks. As GIS implementations grow more complex and strategic [6], organizations require structured methods to assess how well GIS is aligned with both internal goals and external standards [7]. GIS audits act as a strategic governance tool to monitor effectiveness, identify gaps and drive improvements in spatial data management.

Understanding the evolution of standards and audits offers crucial insight into how their intersection has influenced current practices for maintaining data quality, supporting compliance and ensuring the long-term sustainability of GIS.

1.2. The Role of Geospatial Standards in Shaping GIS Audit Parameters

Geospatial standards provide recommended practices that facilitate development, sharing and use of geospatial data and information [8]. Two key international organizations at the forefront of developing geospatial information standards [4] include ISO/TC 211 and Open Geospatial Consortium (OGC) [9]. Among these, ISO/TC 211 serves as the primary body responsible for developing standards that support the effective management and utilization of geospatial information [10]. Over the years, ISO TC 211 has recommended adoption of standardized approaches to ensure that geospatial data is reliable, consistent, interoperable, and legally com-

pliant [11]. The standards help to ensure that geospatial information is used in a reliable, consistent and legally compliant manner [12]. Additionally, standards ensure that the information is easily shared, analyzed, and interpreted globally [4]. ISO/TC 211 standards cover a wide range of GIS-related domains, including data quality, metadata, spatial referencing, data exchange, and system functionality among others [10]. Their adoption enhances the accuracy, efficiency, and interoperability of geospatial data and systems, making them indispensable for both national and international applications [10].

At the same time, auditing GIS is critical to evaluating the extent to which GIS tools and processes are effectively utilized [13]. The GIS audit framework provides a tool for evaluating GIS performance, guided by a set of predefined parameters. The parameters are used to evaluate the performance, quality, and compliance of GIS implementation. These parameters ensure that GIS operations align with the technical and operational specifications defined by existing geospatial standards. Within the framework of GIS audit, data quality, software utilization, GIS competency and operational procedures are thematic areas vital for evaluating quality of GIS. Each theme comprises appropriate audit parameters that guide the audit process. For example, data quality parameters present basic elements that define quality components in a GIS dataset. They are used to evaluate the extent to which GIS datasets meet their intended specifications, integrity and usability, based on principles outlined in ISO 19113 [12] and categorized under ISO 19157; Geospatial data quality, *i.e.*, lineage, positional accuracy, accuracy of attributes, logical consistency and completeness [14].

GIS software utilization parameters provide a checklist for auditing GIS software from a user-centric perspective. They evaluate core functionalities that support a wide range of GIS applications. Geospatial standards lay out key features and capabilities that a GIS software should support [4]. For example, interoperability is a major aspect within a GIS software whose specifications are defined in standards such as Web Map Service (WMS), Web Feature Service (WFS), and Web Coverage Service (WCS), to enable a GIS software (commercial or open source) to communicate and exchange data seamlessly [15]. Likewise, ISO TC 211 standards, such as ISO 19163, define standards for geospatial data exchange formats [7]. Integration of these and other geospatial standards defines the basis on which a GIS software audit parameter is aligned.

GIS competency parameters outline necessary skills and knowledge areas for GIS proficiency. These are structured with respect to ISO/TR 19122 standards that provide guidelines on assessing the knowledge, skills, and behaviors suitable for effectively working in a GIS environment [16]. Finally, GIS procedure parameters entail evaluating GIS operational procedures, workflows and security practices [17]. The parameters are structured based on geospatial standards that support GIS procedures and workflows with respect to data management, security, and other quality requirements. Considerations should be made to align GIS procedures with geospatial standards that are highly relevant to GIS audit. For example,

incorporating ISO 19113 guidelines ensured that GIS audit procedures met required standards of quality [18].

Integrating geospatial standards into the GIS audit framework is vital in ensuring effective audit parameters that not only evaluate technical performance but also uphold the principles of data quality, interoperability, and regulatory compliance. This alignment elevates GIS audits beyond routine evaluations, transforming them into strategic tools that drive accountability, consistency, and continuous improvement across GIS.

By anchoring GIS audit parameters in globally recognized geospatial standards, organizations can achieve fit-for-purpose GIS outcomes, promote the adoption of best practices and ensure that geospatial standards are actively implemented rather than remaining theoretical guidelines.

1.3. Purpose and Scope of the Paper

The purpose of this paper is to examine the relationship between geospatial standards and GIS audit parameters, with particular focus on how their integration enhances GIS audit effectiveness, strengthens quality assurance, and ensures compliance, ultimately promoting more efficient and reliable GIS operations.

It seeks to bridge the gap between theoretical standards and their practical application by analyzing how audit parameters are derived from, and aligned with, internationally recognized standards.

The scope focuses on analyzing the relationship between geospatial standards and GIS audit parameters, with particular emphasis on how internationally recognized standards inform and shape the development of audit mechanisms within GIS environments. It includes an examination of geospatial standards related to GIS data quality and functionality, primarily those developed by bodies such as ISO/TC 211 and OGC. Additionally, it analyzes GIS audit parameters structured around key thematic areas: data quality, software utilization, GIS competency and procedural workflows.

The paper highlights challenges of applying global geospatial standards, including the limitations faced during their implementation. It aims to contribute a practical framework for standardized GIS audits, promoting compliance and encouraging the adoption of global best practices.

2. Relationship between Geospatial Standards and GIS Audit Parameters

Geospatial standards and GIS audit parameters are integral components of effective and efficient GIS management and operation. Both are aimed at standardizing critical elements to ensure the quality, consistency, efficiency, and overall effectiveness of GIS [7]. They support meaningful and structured GIS implementation for both professional and non-professional users, ensuring accessibility, usability and adherence to best practices across all levels of expertise [19]. However, while they are closely related, geospatial standards and GIS audit parameters serve dis-

tinct purposes. Geospatial standards focus primarily on the standardization of geospatial information, defining how data should be collected, structured, shared and maintained to ensure interoperability and consistency across systems [8]. They primarily emphasize the importance of interoperability, ensuring that geospatial information can be seamlessly accessed, exchanged, and used across various platforms, systems and institutional boundaries [20]. On the other hand, GIS audit parameters are closely tied to the standardized evaluation of GIS operations within practical, real-world environments, focusing more on system performance and compliance rather than system diversity or interoperability. Despite their conceptual differences, both geospatial standards and GIS audit parameters are fundamental in ensuring that GIS implementation aligns with best practices, regulatory frameworks and overall institutional objectives [21]. Together, they reinforce accountability, quality assurance and continuous improvement in geospatial information management.

The core relationship between geospatial standards and GIS audit parameters lies in their focus on defining and documenting quality elements essential for fit-for-purpose GIS implementation [22]. GIS audit parameters are aligned with the expectations set by existing geospatial standards, ensuring that GIS operations remain compliant with established industry norms and recognized best practices [4]. The standards establish a consistent and interoperable framework for capturing, processing, storing, and sharing geographic information [4]. Building on these standards, GIS audit parameters offer measurable metrics to assess the effectiveness, compliance, and operational quality of GIS implementations [23].

The ISO/TC 211 geospatial standards are organized into several thematic parameters [7], each addressing specific aspects of geographic information and geomatics [24]. Similarly, GIS audit is structured around a set of distinct parameters, each targeting a specific aspect of GIS evaluation while remaining aligned with established geospatial standards. These standards serve as benchmarks for auditing, offering clear guidelines that support both assessment and corrective action. During the audit process, each parameter is evaluated based on its compliance with the accepted norms and best practices defined in the relevant standards, ensuring consistency, accountability, and continuous improvement in GIS operations.

Furthermore, geospatial information standards related to spatial data quality directly influence the audit parameters used to assess data quality in GIS. These parameters are designed to evaluate the accuracy, consistency, completeness and reliability of spatial data in accordance with international standards, particularly ISO 19157: *Geographic Information Data Quality* [25]. The standard outlines key aspects of data quality, with emphasis on characteristics such as accuracy, completeness, consistency, and other essential attributes of geospatial data [26]. For each of these aspects, the standards provide clear definitions and criteria for assessing geospatial data quality [4]. Within the GIS audit framework, these aspects are translated into specific parameters that must be evaluated in accordance with

the defined data quality standards.

Geospatial standards offer a structured framework of best practices, specifications, and protocols for effective GIS implementation. Alongside this, GIS audit parameters are presented as a checklist to evaluate and verify a system's adherence to these standards. Together, they function as a complementary framework for ensuring GIS compliance and supporting the delivery of fit-for-purpose geospatial products and services [27]. GIS audit parameters are grounded in the benchmarks established by geospatial standards, ensuring that GIS operations are conducted effectively, efficiently and in line with recognized best practices [4]. Both geospatial standards and GIS audit parameters work together to ensure that operations within a GIS meet defined quality standards and performance expectations [28]. This is achieved through predefined guidelines set by geospatial standards and the systematic evaluation processes carried out using audit parameters.

In general, GIS audit parameters provide a structured means to evaluate whether geospatial standards are being appropriately and consistently applied within an established GIS environment.

Challenges within the Framework of Geospatial Standards

International geoinformation standardization organizations represented by ISO/TC 211 and OGC have been successively established in the world, and regional geoinformation standards frameworks represented by INSPIRE have also been formed and popularized [29]. However, challenges with existing standards have led different countries and organizations to establish more systematic national geo-information standards and frameworks. These challenges include specific national, regional, legal, technical, and cultural needs that may not be fully met by existing international standards [30].

While existing international geospatial standards are developed with a global perspective, they may not fully address the specific needs and contextual realities of individual countries or regions. For example, localized aspects such as national measurement conventions, indigenous spatial practices, and country-specific geodetic reference systems are often underrepresented or inadequately covered in these global standards [31]. For example, Kenya utilizes three major coordinate systems: Cassini, East Africa War System and Universal Transverse Mercator (UTM) [32]. The coexistence of these systems poses significant challenges for users attempting to integrate datasets across different spatial references, often leading to inconsistencies and reduced data interoperability. Countries like China have developed comprehensive national geoinformation standard systems that are more open, unified and systematic [29]. Such localized standardization efforts ensure greater consistency in geospatial data management and highlight the importance of adapting international standards to national contexts.

Additionally, technical complexities associated with some geospatial standards may require specialized knowledge for implementation, especially for smaller organizations that may lack specialized expertise or resources [33]. This is largely

because adapting these standards often demands substantial investments in training, technology, and other supporting resources [34]. Although the developed standards by ISO/TC 211 and OGC among other entities have been globally recognized [3] their adaptation and implementation issues still remain a problem especially at some national level where they may opt to use geospatial information which do not rely on standards, leading to inconsistencies and limited interoperability [4]. Given these challenges, it is evident that geospatial standards play a critical role in ensuring long-term success, consistency and sustainability of geospatial information management [12]. Their adaptation, therefore, requires comprehensive strategies aimed at helping GIS users understand the value and relevance of geospatial standards. Strategic initiatives such as the GIS audit framework, not only promote best practices but also provide practical platforms for GIS professionals to apply and operationalize these standards within their organizations.

3. Strategic Role of GIS Audit in Enforcing Standards

Beyond serving as a technical evaluation tool, GIS audit plays a strategic role in institutionalizing the use of geospatial standards within a GIS operational environment. As organizations increasingly depend on spatial data to inform critical decisions, there is a growing need not only to adopt standards but to actively enforce them [30]. GIS audits respond to this need by offering a structured mechanism to ensure that standards are not only acknowledged but also consistently practiced throughout the lifecycle of GIS operations.

GIS audits enhance governance by clearly demonstrating how well geospatial standards are being followed, making compliance something that can be tracked, evaluated, and acted upon. This clarity helps organizations shift from informal GIS practices to a more accountable, standards-based approach [35]. In this way, audits go beyond simply identifying problems, but become essential tools in broader quality assurance efforts that shape institutional practices and support long-term strategic planning [36].

Strategically, GIS audits help identify areas of weakness or non-conformance that may otherwise go unnoticed, especially in decentralized or complex GIS implementations [37]. These findings form the basis for corrective actions, capacity-building efforts, and system improvements, thereby closing the loop between policy and practice [21]. The audit process, when applied consistently, becomes a vehicle for continuous improvement, helping institutions align evolving technologies and workflows with the rigor of international standards.

Furthermore, audits can drive strategic investment by highlighting the technical and organizational gaps that hinder compliance [37]. For example, audit results may reveal the need for upgraded software tools, improved documentation practices, or enhanced staff training. In this way, audits inform not only operational decisions but also resource allocation and institutional priorities.

In environments where geospatial information is subject to national or sector-

specific regulation, GIS audits also serve a regulatory function, that validates adherence to legal and procedural frameworks [38].

Ultimately, the strategic value of GIS auditing lies in its ability to embed geospatial standards into everyday practice [39]. It translates abstract principles into clear performance goals, promotes accountability, and helps build reliable, well-managed GIS that provide high-quality information.

3.1. Methodology

The paper adopts a document analysis approach to determine the relationship between international geospatial standards and the effectiveness of GIS audit implementation. Specifically, it explores how these standards inform and strengthen the four core thematic areas of GIS audit: data quality, software utilization, personnel competency and operational procedures. The analysis draws on two primary sources of information:

a) Geospatial Standards Documents: Mainly the ISO 19100 series such as (Quality Principles) [12] and Open Geospatial Consortium (OGC) technical specifications [9], which outline global principles for geospatial data quality, interoperability, metadata management and service delivery.

b) GIS Audit Documents: Comprising the established framework structure, thematic areas, indicators, and assessment criteria that guide GIS audit processes [13].

The objective is to identify how geospatial standards contribute to defining, evaluating and harmonizing GIS audit parameters. Accordingly, the study is guided by the following research question:

How can existing geospatial standards be systematically integrated within GIS audit frameworks to enhance audit accuracy?

This question frames the analysis and supports the development of a conceptual model that maps geospatial standards to the four thematic areas of GIS audit: data quality, software utilization, personnel competency, and operational procedures. The model is designed to demonstrate how globally recognized standards can operationalize measurable audit dimensions, strengthening both technical consistency and governance accountability.

3.2. Analytical Approach

A comparative mapping analysis was conducted to identify areas of correspondence between geospatial standards and the GIS audit thematic areas. Each standard was examined for its relevance and alignment across three dimensions: technical, procedural and policy aspects [40]. Technical aspects emphasize the overall accuracy and reliability of GIS processes, including the precision of spatial operations and analytical outputs. Procedural aspects address workflows, documentation, usability, and training. Policy aspects ensure compliance with governance frameworks, national regulations, and institutional mandates. A mapping matrix was developed to visualize these relationships as provided in **Table 1**.

This approach ensures that the mapping is both comprehensive and practical, capturing not only the existence of standards but also their applicability in different audit contexts.

Table 1. Standards-based GIS audit evaluation criteria.

GIS Audit Parameter	Relevant Geospatial Standards	Criteria for Assessing Relevance & Alignment
Data Quality		
Accuracy		
Lineage		
Currency		Technical: accuracy, completeness, consistency, lineage
Coverage	ISO 19113 (Quality Principles) [12],	Procedural: metadata documentation
Adequacy	ISO 19157 (Data Quality) [26]	Policy: adherence to quality benchmarks
Reliability		
Completeness		
Consistency		
Software Utilization		
Software Functionality	Open Geospatial Consortium (OGC)	Technical: interoperability, functionality
Software Percentage Utilization	[9]. WMS, WFS, WCS [15]	Procedural: usability, integration workflows
		Policy: compliance
GIS Competency		
Technical Knowledge and Skills		
Experience Gained from Working within a GIS Environment		Technical: knowledge of tools and standards
Exposure to Equipment and Software	ISO/TR 19122 (Qualification and certification of personnel) [16]	Procedural: training programs, skill assessment
GIS Software Application Development		Policy: professional certification
System Administration Competency		
Quality Control and Quality Assurance Competency		
GIS System Governance Competency		
Operational Procedures		
System Data		
GIS System Technology		
GIS System Operations		
GIS System Standards, Operating Procedures and Legal Issues	ISO 19113 [12], ISO 19115 [41], ISO 19119 (Services) [42], ISO 19165 [43]	Technical: workflow consistency, system reliability
GIS System Resources	(Preservation of digital data)	Procedural: audit trails, data preservation
GIS System Privacy		Policy: governance and accountability
GIS System Security		
GIS System Stability		
GIS System Growth		
GIS System Funding		

3.3. Evaluation Criteria

This section provides an analysis of the relationship between geospatial standards and GIS audit parameters. The analysis systematically compares the identified standards with each audit parameter to determine the degree of correspondence and practical applicability. This process not only establishes where standards directly reinforce audit requirements but also identifies areas where coverage is limited or fragmented. To guide the analysis for each audit parameter, two dimensions are emphasized: the extent of alignment, where standards clearly support or fully correspond with the specific audit parameter, and the gaps, where existing standards provide limited or no guidance, requiring the use of supplementary frameworks or best practices. The analysis is carried out for each audit parameter as follows:

Data Quality: The extent of alignment between standards and this parameter is strong because audit parameters for data quality directly reflect the principles set out in ISO 19157 and ISO 19115. They comprehensively cover the fundamental dimensions of data quality, including accuracy, consistency, completeness, and lineage, thereby providing a solid reference point for geospatial data reliability assessments. The main gap, however, lies in the lack of domain-specific quality indicators. While the standards define general principles, they do not extend to the specialized measures required in fields such as cadastral mapping, health surveillance, or environmental monitoring among others. For instance, cadastral mapping may require topological consistency checks to ensure parcels close without overlaps or gaps, while public health surveillance data may demand temporal accuracy to track disease incidence trends over specific periods.

The implication of this limitation is that audits may successfully capture general data quality issues but risk overlooking critical sector-specific requirements, reducing the overall robustness of quality assurance in decision-making.

Software Utilization: The extent of alignment is also strong because the parameters directly reflect established benchmarks for interoperability standards. OGC standards such as WMS, WFS, and WCS, together with ISO 19163, provide a well-established framework for interoperability and standardized data exchange formats, ensuring cross-platform communication between geospatial systems. Nonetheless, there are notable gaps. Current standards do not adequately address usability, adoption, or integration into institutional workflows. As a result, audits may confirm that systems meet technical interoperability benchmarks while failing to determine whether the software is practical, user-friendly, and sustainable for organizational use. This limitation has significant implications, as it restricts audits from capturing the operational realities that influence system effectiveness and long-term adoption.

GIS Competency: In terms of alignment, ISO/TR 19122 provides broad guidelines on staff qualifications and professional roles, which offers a reference point for evaluating human resources in geospatial practice. However, a gap exists in the absence of a comprehensive global framework for assessing staff skills, train-

ing programs, or institutional capacity. While models such as the Geospatial Technology Competency Model exist [44], they are context-specific and not globally standardized. This means that, unlike ISO technical standards, there is still no universally recognized framework for auditing staff competency, training, and institutional capacity. The implication is that competency audits remain fragmented, leading to inconsistent assessments across organizations. This weakens accountability and comparability, making it more difficult to evaluate whether organizations possess the capacity to implement geospatial standards effectively.

Procedures: The extent of alignment is strong for this audit parameter because it uses existing benchmarks provided in service and workflow standards to evaluate process reliability and management. Standards such as ISO 19119 and ISO 19165 provide useful guidance on service architectures, workflow reliability, and the long-term preservation of digital geospatial resources. These cover important aspects of data and process management. However, there are gaps in the explicit treatment of audit trails, risk management, and information security, all of which are critical for ensuring accountability and compliance. The implication of these gaps is that organizations may demonstrate technically sound workflows but still fall short of meeting the broader audit requirements that safeguard transparency, governance, and institutional resilience. Although compliance and governance frameworks [45] appear across multiple standards and policies, their fragmented nature leaves a gap in providing a unified benchmark for audits.

The analytical gaps identified across parameters form the basis for the conceptual model presented in Section 3.4, which explains how geospatial standards theoretically influence GIS audit effectiveness.

3.4. Conceptual Model for Standard-Integrated GIS Audit

Figure 1 presents the conceptual foundation linking geospatial standards to audit parameters, serving as the basis for the mapping matrix presented in **Table 1**.

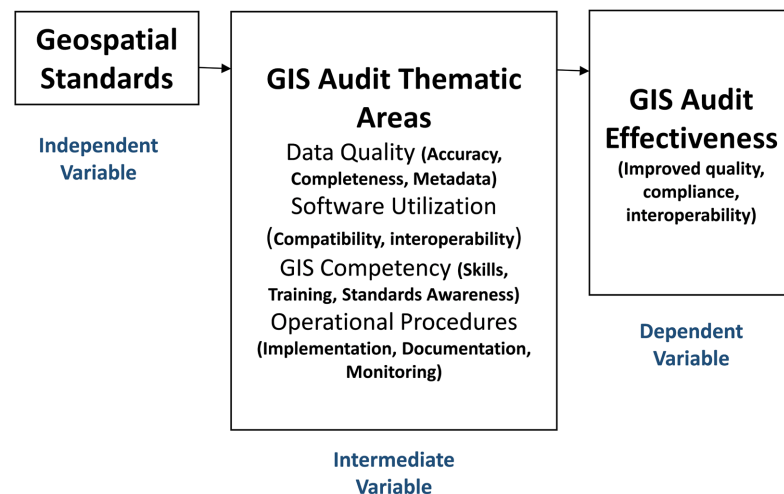


Figure 1. Conceptual model illustrating the theoretical relationship between geospatial standards and GIS audit effectiveness.

The conceptual model demonstrates how geospatial standards influence GIS audit thematic areas, which in turn enhance national and international geospatial governance.

The model illustrates how geospatial standards (independent variables) influence the effectiveness of GIS audits (dependent variables) through Major GIS audit thematic areas (intermediate variables). These thematic areas directly correspond to the four key audit dimensions introduced in the Abstract: data quality, software utilization, personnel competency and operational procedures, thereby maintaining conceptual consistency throughout the framework.

Geospatial Standards (Independent Variables): They represent the formal frameworks and technical specifications defined by international organizations like ISO (International Organization for Standardization) and OGC (Open Geospatial Consortium). They ensure consistency, quality, and interoperability in spatial data and systems.

GIS Audit Thematic Areas (Intermediate Variables): They explain how geospatial standards enhance GIS audit effectiveness. Data quality ensures spatial information is accurate, complete and compliant with relevant geospatial data quality standards. Software utilization reflects the efficient and interoperable use of GIS applications. Personnel competency represents the skills and awareness required to apply geospatial standards effectively, while procedures capture the workflows and governance practices that support consistent implementation. Together, these factors link the application of geospatial standards to improved audit outcomes.

Audit Effectiveness (Dependent Variable): When standards are well implemented across the audit parameters, the result is Improved Quality of spatial data and analysis, Enhanced Compliance with institutional and international norms and Better Interoperability between systems and organizations.

By bridging the gap between technical standards and audit implementation, the model contributes to international dialogue on spatial data governance and standardization. It supports the global move toward evidence-based geospatial policy, providing a replicable model that can be adapted by countries, institutions, and regional initiatives such as Spatial Data Infrastructure (SDI), seeking to improve spatial data quality and accountability.

Adopting geospatial standards in GIS audit not only improves audit effectiveness but also promotes international harmonization of geospatial practices, therefore advancing the goals of open data, interoperability and sustainable development monitoring worldwide.

4. Finding

The paper reveals that integrating geospatial standards within the GIS audit provides a robust foundation for improving geospatial governance at both institutional and national levels. By establishing clear linkages between standards, and the four thematic audit areas: data quality, software utilization, personnel compe-

tency and operational procedures, the paper offers a model that is both contextually adaptable and internationally applicable.

The integration guides the implementation of GIS policies, particularly in countries seeking to align with global best practices in data management and interoperability. It also supports the development of standardized GIS audit tools and methodologies that promote transparency and comparability of audit results across organizations.

The results indicate that the relationship between GIS audit parameters and existing international geospatial standards extends beyond a single organizational or regional setting. The analysis demonstrates that these relationships are transferable and applicable across diverse institutional and national contexts. By aligning the four GIS audit thematic areas with globally recognized geospatial standards, the study contributes to the broader discourse on spatial data governance, interoperability and quality assurance, particularly within the framework of National Spatial Data Infrastructures (NSDIs). This alignment underscores the potential of international standards to harmonize GIS audit practice, and strengthen the consistency of geospatial data management worldwide.

5. Conclusions

The paper contributes conceptually by articulating how geospatial standards serve as the structural foundation for defining and evaluating GIS audit parameters. It has clearly demonstrated the relationship between GIS audit parameters and geospatial standards, emphasizing how audit parameters play a vital role in ensuring compliance with established geospatial norms. This alignment is essential for the effective management of geospatial information. By providing measurable criteria, GIS audit parameters help assess how well a GIS adheres to defined standards, thereby contributing to the reliability, accuracy, and usability of spatial data across diverse applications. Moreover, the integration of standards promotes the adoption of GIS best practices, driving optimal outcomes while reinforcing the practical application of geospatial standards. Ultimately, this ensures that these standards are not merely theoretical constructs but are actively embedded in operational GIS environments.

Based on the analysis of standard alignment with GIS audit parameters, it is clear that existing geospatial standards, provide a strong foundation for GIS audits by supporting data quality, interoperability, and procedural reliability. However, alignment is uneven across audit parameters. While technical aspects such as data quality and interoperability are well covered, there are notable gaps in domain-specific quality indicators, usability and workflow integration, staff competency frameworks, and procedural elements such as audit trails and risk management. These gaps highlight that standards alone cannot guarantee comprehensive audit coverage. Without complementary measures, GIS audits risk being technically sound but incomplete in addressing organizational, human, and governance dimensions.

The study therefore advances a conceptual model that formalizes the linkage

between geospatial standards and GIS audit parameters. The linkages are adaptable across institutional and national contexts, providing a basis for consistent GIS auditing practices and contributing to global efforts in spatial data governance and interoperability.

The mapping matrix illustrating the relationship between GIS audit parameters and geospatial standards provides a globally adaptable basis for improving audit transparency and interoperability across institutional and national contexts. Ultimately, the approach demonstrates how geospatial standards can be operationalized within audit processes to support consistent, accountable, and high-quality spatial data governance worldwide. Future research could empirically assess how the identified geospatial standard versus GIS audit parameter relationships perform in real audit scenarios or within emerging National Spatial Data Infrastructure frameworks.

By formalizing the interface between geospatial standards and GIS audit parameters, the paper strengthens geospatial data governance by providing a transferable structure for evaluating compliance, interoperability and data quality across geospatial systems.

6. Recommendation

The findings of this paper underscore the importance of systematically aligning GIS audit frameworks with established geospatial standards to enhance data quality, interoperability and institutional accountability. While international standards provide robust technical foundations, their application in audit contexts remains uneven, particularly in areas involving usability, workflow integration, staff competency, and procedural governance. Strengthening GIS audits therefore requires not only adherence to existing standards but also targeted extensions and adaptations that reflect real-world operational contexts. The following recommendations outline strategic measures to bridge these gaps and advance the effectiveness, comparability, and sustainability of GIS audits across institutional and national settings:

GIS audits should be strengthened through a dual approach of extending standards and adapting audit practices. First, the development of domain-specific quality extensions is necessary to tailor ISO principles to specialized applications such as cadastral, environmental, and health data among others. Second, interoperability standards should be complemented by usability guidelines and workflow integration frameworks to ensure that systems are not only technically compliant but also operationally effective. Third, audits should incorporate capacity-building and certification programs to establish consistent benchmarks for GIS competency across institutions. Finally, procedural audits should be reinforced by harmonizing existing workflow standards into comprehensive audit checklists that explicitly cover risk management, audit trails, and information security.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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