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Review Article

A Critical Evaluation of Government Role in Spatial Data Infrastructures for Healthcare Decision-Making

Tosin Harold Akingbemisilu *

Department of Architecture, Computing and Engineering, University of East London, London, United Kingdom

Abstract

This study critically examines the government's pivotal role in promoting and regulating Spatial Data Infrastructures (SDIs), with a special focus on the healthcare sector. Through an in-depth analysis of global practices, our research highlights the indispensable value of SDIs in enhancing healthcare decision-making, emergency management, and public health monitoring by facilitating the integration and analysis of geospatial and healthcare data. Despite the evident benefits, the integration of diverse geospatial data sources poses significant challenges, including issues of data standardization, privacy, and interoperability across various stakeholders. Our findings underscore the balance governments must achieve in promoting SDI growth while ensuring data security, privacy, and open access. The study draws on a comprehensive review of literature and case studies to explore the effectiveness of current government strategies in advancing SDI capabilities, while also addressing the ethical considerations and potential barriers to innovation that stringent regulation might impose. By advocating for a collaborative ecosystem that supports data standardization alongside flexibility for innovation, this paper aims to provide insights into how governments can optimize the utility of spatially enabled data in healthcare and beyond. Our conclusion calls for strategic government action to promote a balanced approach to SDI governance, highlighting the importance of public-private partnerships, robust data security frameworks, and the fostering of an environment conducive to data sharing and innovation. This research contributes to the discourse on the critical intersection of technology, healthcare decision-making, and governance, offering valuable recommendations for policymakers, healthcare professionals, and stakeholders in the digital and geospatial domains.

Keywords

Spatial Data Infrastructure, Government, Promotion, Healthcare, Security, Challenges, Case Studies

1. Introduction

Spatial information has had increased importance over the years, and according to the study of Nebert, it has become indispensable for different aspects of rural and urban development, management, and planning within all tiers of government, the commercial sector, non-profit sector, and citizens in general [1]. Further emphasis has been made on how the current advancements in spatial data capture, such as satellite remote sensing, management of geographical information through geographic information systems (GIS) and database tools, development of high-resolution mappings with different analytical techniques, and access through web mapping growth, have led to this immense importance of geographically referenced information [2]. Holger's study also addressed how the monitoring of outcomes, evaluation of

*Corresponding author: tosinakingbemisilu@gmail.com (Tosin Harold Akingbemisilu)

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impacts, and adequate targeting of interventions make geographic information crucial [3].

Spatial Data Infrastructures play a crucial role in healthcare decision-making by enabling the integration and analysis of geospatial and healthcare data. They support a wide range of applications, from emergency management to monitoring health outcomes and resource allocation. GIS methods enhance the capability to identify areas of high disease incidence and explore spatial relationships between health outcomes and socio-economic conditions. Despite their potential, issues like data confidentiality and the difficulty of integrating various data sources frequently prevent the full use of GIS and SDIs in healthcare [4]. The incorporation of effective and efficient collection, access, use, and management of spatial data ultimately incited SDI concept. The people, technologies, and policies that facilitate the usage and generation of geographically referenced data in all facets of government, non-profit sectors, academia, and private sector are what makes up the whole spatial data infrastructure [5].

Globally, many countries, particularly at the national level, have adopted SDI, and the government has been the major beneficiary of spatial information, either as collectors or users, thereby making it more of a purely governmental system. Several use cases of geospatial information have been mentioned as a decision sustenance tool, where issues surrounding environmental, social, and economic importance are better sorted with readily available quality and timely spatial data in some parts of the world, such as United Kingdom, United States, Canada, etc [6]. However, this has been argued as not being the case in most developing countries like Nigeria, where there is difficulty in getting timely, accurate, and quality information due to a lack of adequate spatial data infrastructure, which has led to outcomes such as food insecurity, social insecurity, poor sanitation, environmental degradation, and many more [7]. Moreover, it has been shown that, since a vital part of the available knowledge in modern-day communication and information is formed by SDI, there are expectations that rules regulating access are critical in defining other programmes, policies, strategies, and projects within any nation [8].

The study of Rosen further argued that diverse data sources and their management across multiple organisations and agencies that are concentrated on a single obligation have led to some of the problems associated with SDI [9]. There was also a focus on these challenges being centred on current legal, administrative, and social cultures in a domain, which varies the arrangement on the choice of whether to continue with an existing agency in the leading of SDI development, utilise coordinating committees in a formal setting, or even use an agency that is specialised in SDI. As the number of participating organisations increases, it is now pertinent for SDIs to create an enabling platform for the support of those chains of services that are required across these organisations, since access to these information and services is far beyond the influence or domain of just a single organisation [10].

This research paper seeks to shed light on the evolving landscape of SDI in healthcare and its profound implications for healthcare stakeholders. Rather than offering an exhaustive evaluation of cutting-edge SDI, our study focuses on illuminating the concerns and perspectives of healthcare stakeholders regarding government promotion and regulation of SDI expansion both in the present and the foreseeable future. The unprecedented growth of spatial data in healthcare has ushered in an era of geographical interventions and collaborative technologies that have the potential to revolutionize healthcare services and decision-making processes.

This paper delves into the dual roles of government in promoting and regulating SDI and evaluates the effectiveness of current approaches. We aim to explore the benefits that SDI brings to the healthcare sector and scrutinize the government's response to these transformative technologies. Throughout our analysis, we will consider the gains, challenges, and ethical dimensions of government involvement in SDI advancement. By providing a comparative assessment, we endeavour to explain both the advantages and limitations of government intervention in this domain. This research, through its multifaceted exploration, serves to inform policymakers, healthcare professionals, and the public alike about the critical relationship between healthcare, technology, and governance, ultimately influencing the course of healthcare decision-making, regulatory frameworks, and the ethical landscape in an era of digital transformation.

2. Research Methodology

This study employs a comprehensive research methodology combining critical analysis and an experiential approach to investigate the government's role in SDIs for healthcare decision-making. To ensure the robustness of our findings, a wide range of credible sources, including case studies, books, articles, and scholarly journals, were meticulously curated from authoritative databases such as ProQuest and Google Scholar. The selection of these sources was guided by the strategic use of relevant keywords, ensuring alignment with the study's specific objectives while rigorously excluding materials that did not meet the report's thematic criteria or exhibited argumentative and conclusional deficiencies. In total, 51 carefully chosen resources were methodically categorized and employed to provide a well-rounded evaluation of the subject matter.

While this research method offers several advantages, it is essential to acknowledge its limitations. The heavy reliance on secondary data inherently confines our examination to previously documented information, potentially overlooking the latest developments or confidential insights not publicly disclosed. Secondary data sources may also introduce biases or inaccuracies that could inadvertently influence research outcomes. Additionally, the descriptive approach adopted in this study limits our capacity to establish causal relationships or engage in experimental or prospective analysis. Nonethe-

less, this methodological framework ensures a rigorous and evidence-based exploration of the government's role in SDIs for healthcare decision-making, offering valuable insights and critical perspectives within the existing knowledge landscape.

In this paper, we remained committed to ethical principles. While our study involves the analysis of existing research and literature, rather than primary data collection, we ensured the responsible use of previously published works and respecting the privacy and intellectual property rights of authors, with appropriate citing of relevant literatures. Additionally, we recognize the importance of ethical principles such as fairness, transparency, and accountability in evaluating the government's role in spatial data infrastructures for healthcare decision-making. Our aim is to contribute to the ethical discourse surrounding the utilization of existing knowledge while upholding the principles of responsible research and knowledge.

3. Review of Literatures

3.1. Definition and Components of Spatial Data Infrastructures (SDIs)

SDIs are foundational frameworks that enable the effective discovery, access, management, distribution, reuse, and preservation of digital geospatial resources. These resources encompass a wide array of data products such as topographic maps, land cover data, transportation networks, and hydrographic features [11]. The proliferation of GIS has facilitated the derivation of these diverse data products from collected data, enhancing location-based services and the contribution of volunteered geographic information (VGI) by the public through mobile devices and social media platforms [12]. The componentization of GIS has also introduced geospatial services that offer data processing and spatial analysis functions in the general web environment. Despite the abundance of geospatial data, services, and maps, the widespread distribution of these resources across different government agencies and websites presents significant challenges in terms of accessibility and data redundancy, leading to wasted resources in duplicated data collection and maintenance efforts [13].

The concept of SDI is broad, encapsulating a range of components essential for the effective use of spatial data. According to the World Bank's definition, SDI is a framework comprising policies, institutional arrangements, technologies, data, and people. This framework enables the sharing and effective use of geographic information by standardizing formats and protocols for access and interoperability. The objectives of developing an SDI include reducing duplication of efforts among various levels of government, lowering the costs associated with geographic information while enhancing accessibility, increasing the utility of existing spatial data, and fostering key partnerships among states, counties, cities, academia, and the private sector. As part of broader e-Government initiatives, SDIs are crucial for improving interoperability and information sharing across different levels of government, particularly in the context of the European Union's Infrastructure for Spatial Information in the European Community (INSPIRE) directive, which mandates the development of SDIs to facilitate standardized geographic information sharing over the internet [13].

In summary, SDIs represent a critical infrastructure like other essential services like electricity and water supply, underpinning the effective use and management of geospatial data across various sectors, including healthcare, urban planning, environmental management, and more. The successful implementation and utilization of SDIs hinges on the integration of technological solutions, policy frameworks, and collaborative efforts among a wide range of stakeholders.

3.2. Historical Context of SDIs and Relevance in Healthcare Practice

The historical context of SDIs in healthcare reveals a dynamic evolution shaped by technological advancements and the growing recognition of the importance of geospatial information in public health decision-making. One of the earliest and most notable examples of utilizing spatial analysis in healthcare can be traced back to Dr. John Snow's work in the 19th century [14]. His investigation into cholera outbreaks in London, combining the locations of cholera deaths and water pumps, marked a foundational moment for epidemiology and the use of spatial data in tracking disease spread.

Spatial Data Infrastructure initiatives are now beginning to play a shifting role generally in society and in the health sector, as this provides the universal language and reference system to set up linkages and stability between environmental, economic, and social capital for the improvement of the basis for societal response [15]. The ability of users to gain access to accurate and dynamic real-world object spatial information to aid the support of inter-agency decision-making in areas such as management of natural resources, emergencies, water rights, and disaster relief across different provinces is now highly required [16].

The development of Health SDIs, as detailed in recent initiatives, emphasizes a framework comprising data, technologies, policies, standards, and human resources necessary to facilitate the sharing and effective use of geographic information. This framework aims to support a variety of stakeholders, including solution providers, market participants, government and institutes, standards organizations, researchers, health systems, and insurers. The primary goal is to integrate health data with non-health and novel datasets for quick diagnosis, identification of new population health measures, and ultimately, cost reduction in healthcare.

The Coronavirus disease (COVID-19) pandemic has further underscored the critical role of Health SDIs in crisis response and preparedness. The pandemic highlighted the indispensable need for location-related information of people and resources, trusted information sharing across diverse

stakeholders, and the utilization of FAIR (Findable, Accessible, Interoperable, Reusable) location information. The Open Geospatial Consortium (OGC) has been at the forefront of advocating for a standards-based Health SDI that can serve as a Pandemic Early Warning, Response, and Recovery Platform, demonstrating the potential of SDIs to support a wide range of applications beyond pandemic management [17].

Through the implementation of SDI, it becomes easy to isolate where things are happening, what should be done immediately, and the implementation support of that process [18]. Practical applications of the importance of SDI have been mentioned in the areas of preparedness for disasters, mobilization, response, and recovery based on provision of situational awareness from data, which has been very vital to the success of the sector [19]. An example is the illustration of how the spread of diseases is generally classified as a spatial event due to how infectious diseases spread from one individual to another and from place to place [20]. Another example includes environmental health concerns through the dispersion of substances that are dangerous across inhabited locations [21]. Answering all health-related questions in the cases mentioned, most especially in containing and suppressing diseases, requires SDI support. Some of the applications of spatial data in the health sector, among others, include:

1) Identification of individuals tested positive for an infection after diagnostics [22].
2) Contract tracing information, which enables getting in touch with infected persons and those in contact with them [23].
3) Understanding disease infection patterns, most vulnerable population, census population, housing, and neighbourhood characteristics [24].
4) Medical supply chain: comprehensive depiction and tracking of all key supply chains involved in a health emergency in relation to sources and the aspect of medical supplies within a geopolitical area, and how they are all connected from one point to the other [19].

These historical and contemporary perspectives on SDIs in healthcare highlight the ongoing and essential role of geospatial data and technologies in enhancing public health outcomes, emergency response, and healthcare delivery. The development and implementation of Health SDIs based on open standards and interoperability principles represents a promising avenue for advancing healthcare analytics, improving patient care, and informing public health policies on a global scale.

3.3. Current State of Spatial Data Infrastructure on the Health Care System, Governance and Society

The current state of healthcare decision-making without SDIs highlights several critical challenges and areas needing improvement. Key issues include the need for modernizing healthcare delivery through digital technologies, addressing cybersecurity threats, and ensuring equitable access to care through broadband and telehealth services. Without a cohesive and modern SDI, healthcare systems face difficulties in efficiently tracking healthcare quality, safety, and public health, largely due to antiquated and inefficient key data systems. There's a recognized historic underinvestment in health data infrastructure, which is crucial for preparing for future emergencies and improving patient and community health outcomes [25].

Hospitals and health systems are central to addressing these challenges but cannot do so effectively without increased federal support and coordination. The American Hospital Association (AHA) emphasizes the importance of investing in broadband, telehealth, cybersecurity, and modernizing data systems to ensure all patients have secure and equitable access to care. These investments are critical for health systems to identify and respond to issues affecting health equity, racial and ethnic disparities, the quality of healthcare delivery, and public health responses [26]. Moreover, the infrastructure of hospitals encompasses not just their physical buildings but also a vast array of technological and human resources required to deliver care effectively. The COVID-19 pandemic has underscored the importance of modernizing hospital infrastructure to maintain access to high-quality, safe, and sustainable healthcare. Investments in hospital infrastructure are seen as direct investments in the physical, mental, and economic health of the country, essential for communities across the U.S. to thrive [27].

It cannot be overemphasized the high negative impact a disease outbreak can have on every part of society: education, economy, jobs, food supply, transportation, and government services. Location therefore remains the key feature because it is the only basis that would aid the relation of all other information to one another. According to Plunkett, when mentioning how interoperable SDIs are, he made it clear that combining these different types of data helps make sure that they can work with other models, applications, and spatial analysis tools to create intelligence that helps with public health operations and decisions [28].

Existing challenges related to the gathering, sharing, and utilization of spatial data towards responding to health emergencies globally and planning for monitoring were exposed by the COVID-19 pandemic [29]. Some data elements required the inclusion of spatial data that could help provide the proper information during COVID-19 that were not previously considered were later realized to be very important. Real-time data and the integration of data across several sources and platforms would help sustain local and global preparedness, forecasting, and response but pose additional challenges [24]. If actions are not taken, the ripple effect of many of these challenges, even though they were available in the past and now, would continue when health emergencies emanate in the future [21].

Unfortunately, due to the lack of or ineffective SDI, data

collected at some levels of government is frequently not integrated, interoperable, or standardized, therefore limiting support for critical functions and use cases. Establishing a blueprint that would better situate the community to get an early warning, respond to, and recover through a standardized health geospatial model would be essential for future health emergencies and the monitoring of critical supply chains, which would invariably improve efficiency and effectiveness of health outcomes, services, and fund utilization. Mika-petteri *et al.*, buttressed this by stating that a "virus-resilient economy requires knowing exactly where infected people are, living conditions, and access to medical services—all of which hinge on geospatial information" [30].

Without a comprehensive and modern SDI, healthcare decision-making is hampered by outdated systems, cybersecurity vulnerabilities, and inadequate access to digital health services. Addressing these gaps requires a concerted effort from both the government and healthcare organizations to ensure the healthcare system is robust, responsive, and equitable.

3.4. Government Role, Influence and Approach to Spatial Data Infrastructure

The government plays a crucial role in promoting and regulating SDIs, which are foundational for enhancing digital government transformation and facilitating effective data sharing across various sectors. According to the Federal Geographic Data Committee (FGDC), the National Spatial Data Infrastructure (NSDI) is defined by the Geospatial Data Act of 2018 as a combination of technology, policies, criteria, standards, and workforce necessary to promote geospatial data sharing across federal, state, tribal, and local governments, as well as the private sector, including nonprofit organizations and higher education institutions. This infrastructure ensures that geospatial data from multiple sources is available and easily integrated, enhancing the understanding of the physical and cultural world. The FGDC is tasked with preparing and maintaining a strategic plan for the development and implementation of the NSDI, advising both federal and non-federal users of geospatial data on their responsibilities relating to the implementation of the NSDI [31].

A lot of high-income countries today have established either a national, state, or organizational-based SDI, which includes base maps and layers from several agencies and organizations. On the other hand, low- and middle-income countries lack accuracy and exhaustiveness, even though the spatial data is available [19]. As part of the National Spatial Data Infrastructure, the US Federal Geographic Data Committee listed some of the goals of SDI [32]. These include improving the quality and lowering the cost of spatial information, reducing the amount of work that is done twice by different agencies, making spatial data easier for the public to access, increasing the benefits of using data that is already out there, and working together effectively with states and local governments. In setting up SDI, other countries like Canada, which instituted the Canadian Geospatial Data Infrastructure (CGDI), and the United Nations, with the establishment of the United Nations Spatial Data Infrastructure (UNSDI) [28].

The importance of spatial data infrastructure as a tool for economic development has led several Asian, American, and European countries to embrace the concept. Even in Africa, a lot of emphasis is being placed on the importance of establishing a National Spatial Data Infrastructure [33]. An instance is where, in 2004, Economic Community of West African Countries, with headquarters in Addis Ababa, implemented a unit that guarantees that all countries in Africa implement SDI programs [34]. However, some researchers explained how this development in Africa, which is primarily the result of government agencies, has been proceeding at an ostensibly slow pace, just like in other parts of the world [35].

The development of SDIs has offered valuable lessons to public authorities in terms of collaboration across sectors, focusing on users' needs, and the usefulness of platforms and Application Programming Interfaces (APIs). However, despite their recognized importance, there has been limited specific analysis on the role that SDIs play in Digital Government Transformation. A study by the Publications Office of the European Union highlights the strong relationship between SDIs and Digital Government Transformation, indicating the various ways countries have understood and cultivated this relationship. It also emphasizes that SDIs already significantly support Digital Government Transformation, and that this relationship is expected to strengthen in the future [36].

Nonetheless, Clarke in his study explained how lack of political will and little support in that aspect have made it impossible for formal SDI initiatives in Africa to materialize [10]. Evidently, the low awareness among the key governmental stakeholders and institutions, weak coordination and policy, inadequate resources, and complex nature of the economy, politics, and culture of the African countries must have led to this [16]. A study claimed that politicians and administrators would rather prioritize and utilize funds for projects with more visible performance that would have huge impact on their electoral wealth [37].

This information underscores the government's role not just in regulating and standardizing the collection, storage, and use of spatial data to protect privacy and security but also in leveraging SDIs to make more informed and effective decisions in policy and decision-making. Through strategic planning, collaboration, and adherence to standards, governments can ensure that SDIs contribute significantly to the digital transformation of public administrations, improving service delivery, policy making, and ultimately the well-being of the public.

3.5. Potential Impact of Government Responses and Promotion on the Spatial Data Ecosystem in Healthcare

Government promotion of SDIs has been recognized for its

potential to enhance healthcare decision-making by integrating and analyzing diverse health data sets. This integration facilitates a more comprehensive understanding of health determinants, enabling policymakers and healthcare providers to make informed decisions that can improve population health outcomes. The Rockefeller Foundation-Boston University Commission on Health Determinants, Data, and Decision-Making (the 3-D Commission) emphasizes the need for a transdisciplinary synthesis between social determinants of health and data science. This approach can guide opportunities for interventions designed to improve health, indicating a move towards more evidence-informed decisions that could significantly impact individual and population health through government policies and practices [38].

One case of government impact on spatial data ecosystem is the Malawi and Democratic Republic of Congo (DRC) data collaboratives for SDGs. Funded by the World Bank's Trust Fund for Statistical Capacity Building (TFSCB), these projects aimed to support Sustainable Development Goals (SDGs) on Health and Water, Sanitation, and Hygiene (WASH) in Malawi and DRC. An innovative aspect of the Malawi project was the use of drones to gather aerial imagery for water point detection, improving the quality of datasets by removing inconsistencies and enriching attribute information. These projects developed a framework to characterize a data ecosystem in its totality, addressing both sociological and technical aspects. They also enabled local communities to determine the transportation time needed to reach health centers in the DRC, with government and health care providers receiving training in GIS and open-source mapping tools [39].

Another case is the public works where Emerald Isle, NC used ArcGIS to create a real-time system for tracking yard waste pickup, enhancing service efficiency and transparency. Miami Beach, FL utilized GIS to prioritize mitigation projects against sea level rise, and Austin, TX spread the benefits of urban trees equitably across communities, addressing social inequities. Other examples include the use of drone imagery and AI by the San Francisco Estuary Institute for trash monitoring, and Dubuque, IA's use of GIS to support broadband funding efforts, showcasing the diverse applications of GIS in addressing public works and environmental challenges [40]. This system not only increased operational efficiency but also enhanced transparency with the public.

A report that gives evidence-based scientific support to the European policymaking process through an in-depth analysis of 29 countries, looked at different areas to find out how SDIs affected digital transformation while also looking at how the government responded. The study proved that, apart from paving the way for the sharing of more data in Europe through interoperable infrastructure, it has also helped with the better organization of digital government transformation [36]. A lot of geographical scholars have argued that countries where the government is fully involved in the implementation of SDIs have been able to unlock the potentials that are hidden in the data and have used this to stimulate economic activity. Furthermore, this interrelationship between the government and other stakeholders has helped to reduce duplication of efforts among agencies. It was earlier emphasized how partnerships that are well established with the states, cities, academia, and private sector have led to an increase in spatial data availability [41, 42].

Regarding healthcare services' accessibility and equity, case studies from Seoul, Korea, and the border regions of Thailand provide insightful examples. In Seoul, advancements in GIS methodologies, like the 2-Step Floating Catchment Area (2SFCA) and its enhancements, enhanced 2-Step Floating Catchment Area (E2SFCA) and Seoul Enhanced 2-Step Floating Catchment Area (SE2SFCA), have been pivotal in assessing healthcare accessibility. These methods consider spatial and non-spatial factors, including travel times and healthcare demand, to measure healthcare service accessibility more accurately in densely populated areas. This approach helps identify areas with inadequate healthcare services, guiding policy interventions to improve accessibility and equity [43]. Similarly, in Thailand's border regions, the implementation of mobile health clinics (MHCs) showcases a practical response to overcoming geographical barriers to healthcare access. GIS methodologies were employed to analyze spatial data, revealing significant disparities in healthcare access, with over 253,000 individuals living more than half an hour away from a hospital. This led to targeted interventions using MHCs to reach underserved populations, effectively bridging the gap in healthcare service delivery. These clinics not only address physical accessibility challenges but also provide a platform for overcoming various non-spatial barriers to healthcare, such as financial costs, linguistic and cultural barriers, and psychological intimidations, by fostering trusting provider-client relationships and enabling healthcare delivery in familiar community settings [44]. These case studies underline the importance of leveraging spatial data and GIS technologies in enhancing healthcare accessibility and equity. By utilizing sophisticated spatial analysis techniques and innovative service delivery models like MHCs and 2SFCA, these governments were able to make informed decisions to address healthcare disparities, ensuring more equitable healthcare access across different regions.

Additionally, the COVID-19 pandemic has underscored the importance of managing and safeguarding geospatial data. The integration of population and mobility data in COVID-19 forecasting and digital contact tracing efforts has revealed the delicate balance between leveraging geospatial technologies for public health benefits and safeguarding individual privacy [50]. Legal frameworks and practices currently present obstacles to widespread adoption of these technologies, highlighting the need for advancements in digital contact tracing applications and the development of ethical guidelines to address confidentiality and civil liberties concerns [45]. The experiences of the European Union and the United States, which have advanced SDI projects, show that SDIs are both

technical and political projects. These projects respond to incomparable political dynamics within specific administrative arrangements, influenced by ongoing technological changes in geographic information and its societal role [46]. These cases underscore the importance of a legal and political framework that can support the secure, private, and advanced development of SDIs. Such efforts will not only advance public initiatives but also maintain public trust in the spatial data ecosystems.

The evolving nature of SDIs and the role of adaptive governance have been examined, highlighting the complexities of managing such infrastructures in an environment with minimal governmental regulation. This adaptive governance is seen as essential for the effective development and management of SDIs, given their complex, multi-stakeholder, multi-level, and technical nature. The governance history of SDIs in The Netherlands and Flanders was used to illustrate how governance models have had to adapt over time to meet the goals of SDI development, often incorporating more hierarchical instruments to respond to changes and challenges effectively [47]. Luxon study also emphasized the significant economic benefits attached to the generation and availability of public spatial information, indicating that the value often manifests in terms of avoided costs [27]. However, the diversity in scope, assumptions, and methodologies across studies makes it difficult to directly compare results or fully understand the potential economic impacts of SDIs without consistent regulatory frameworks or promotion by governments [47].

The obligation to facilitate access and stimulate the strongest possible application of geospatial data lies fully in the hands of the government, and the promotion and regulation of spatial data infrastructure is the method through which this responsibility can be achieved. One of the key challenges identified was policy and coordination problems, which have led to weak coordination among ministries, organizations, and agencies as they neglect efforts towards ensuring spatial data is readily available to make promising decisions that would improve the health, economic, and social aspects of their nation [48]. It has been clarified that without government intervention in the promotion and implementation of SDI, this institutional coordination will remain absent, as can be seen in the comparison presented between places where SDI is working in Europe and where it is not working in most of the African countries [49].

However, in a study to identify the evolution of National SDI in Indonesia, it was realized that despite support from government leaders and the presence of legal instruments for NSDI application, stakeholders still experience problems. The article explained that the key obstacles are linked to the limitations in financial support, labor, technical resources, and low participation in the NSDI network. The lack of rules and strict government involvement in making sure that spatial data is integrated through a single infrastructure has caused government agencies and the private sector to work separately, with little to no interaction between them to help the country's spatial data infrastructure be put in place efficiently [51].

It is obvious that SDI forms the basis of policies and access mechanisms that allow data integration from several providers, systems, and services through the support of adjacent processes across organizations within a defined jurisdiction, and the government must be highly involved in its promotion and regulation. Rajabifard *et al.*, in their study, emphasized the need for the government to create an enabling platform, which would consistently be the primary domain of sub-national government, that would help create a large-scale dataset across jurisdictions that are linked [41]. The evidence collected in a paper in relation to institutional perspective reveals very clearly that implementation of SDIs is growing year after year within both the public and private sectors in Europe. The position of government collaboration with the private sector and in all these countries, other relevant institutions have helped with five main types of benefits: higher efficiency, better collaboration and exchange between stakeholders, smoother and better processes and services, and better policy results based on both quantitative and qualitative evidence [36].

4. Discussion

What Should the Government Be Doing for the Development of Spatial Data Infrastructure?

In examining the delicate balance between government promotion and regulation within the spatial data ecosystem, it is crucial to understand the dynamic interplay that exists between fostering innovation and ensuring privacy, security, and equitable access. Governments play a pivotal role in the development and utilization of SDIs through both promotional strategies and regulatory frameworks. The promotion of SDIs can drive significant advancements in public services, urban planning, environmental protection, and economic development. However, the regulation of spatial data is essential to address issues of privacy, security, and equitable access, and without thoughtful regulation, the large number of spatial data can raise concerns related to privacy, data autonomy, and the digital divide.

The balance between promotion and regulation requires governments to act with foresight and flexibility. Promotional activities must be designed to encourage innovation and the broad use of spatial data for societal benefit, while regulatory measures should ensure that such data use does not infringe upon privacy rights, lead to security vulnerabilities, or exacerbate social inequalities. This necessitates a collaborative approach involving government agencies, private sector stakeholders, civil society, and the academic community to develop standards, ethical guidelines, and policies that reflect the multifaceted implications of spatial data use. Additionally, governments must navigate the challenges of ensuring that the benefits of spatial data are equitably distributed, avoiding a

scenario where only certain regions or demographics have access to the advantages offered by advanced geospatial technologies.

Government promotion of SDIs often involves investing in technological infrastructure, supporting open data initiatives, and encouraging the development of geospatial technologies. This can lead to improved decision-making capabilities, enhanced efficiency in public service delivery, and the fostering of innovation within the private sector. For instance, initiatives like the European Union's INSPIRE Directive have aimed to create a European spatial data infrastructure that enhances environmental policies and supports public access to spatial information. Similarly, the United States' Geospatial Data Act of 2018 seeks to improve the governance and use of geospatial data across federal agencies and with the public [4]. To leverage the benefits of SDIs, governments should continue to invest in and prioritize the expansion of geospatial technologies and open data policies. Such efforts can significantly enhance public service delivery, decision-making processes, and stimulate innovation in the private sector.

Achieving a delicate balance between the promotion and regulation of spatial data ecosystems is essential for maximizing their societal benefits while minimizing potential harm. This balance is not static but requires ongoing evaluation and adjustment in response to technological advancements, societal changes, and emerging challenges and opportunities within the spatial data landscape. Governments, therefore, play a crucial role in steering this dynamic equilibrium through informed policymaking, stakeholder engagement, and the adoption of best practices in spatial data governance.

5. Conclusions

The findings revealed the delicate balance required from government bodies in fostering the growth and effectiveness of Spatial Data Infrastructures. Governments face the dual challenge of ensuring open access and interoperability of geospatial data for healthcare decision-making while imposing necessary measures to safeguard data security, privacy, and standardization across various sources and entities. Integration of diverse geospatial data sources into a cohesive SDI necessitates stringent standards and regulations to ensure data quality, compatibility, and privacy. However, overly strict measures can stifle innovation and hinder the timely sharing and utilization of data crucial for public health initiatives and emergency responses.

Thus, the government's role exceeds mere regulation and extends into devising a collaborative ecosystem where data standards and privacy measures coexist with flexibility for innovation and rapid data exchange. Effective governance of SDIs requires a strategic approach that encompasses the promotion of data standardization, fostering public-private partnerships for data sharing, and implementing robust data security and privacy frameworks. Additionally, the government must facilitate an environment that encourages coordination among all stakeholders, ensuring that geospatial data remains a potent tool for healthcare decision-making without compromising individuals' privacy or the integrity of the data infrastructure.

In conclusion, the government's role is pivotal in striking a balance between regulation and support for SDIs. By championing standards, privacy, and open access within a well-coordinated framework, governments can leverage the full potential of spatially enabled data to address healthcare challenges. This balanced approach will not only safeguard the privacy and security of spatial data but also ensure its effective utilization in advancing public health objectives and socio-economic development, thereby maximizing the benefits of SDIs in the digital age.

Abbreviations

2SFCA: 2-Step Floating Catchment Area
AHA: American Hospital Association
APIs: Application Programming Interfaces
CGDI: Canadian Geospatial Data Infrastructure
COVID-19: Coronavirus Disease
DRC: Democratic Republic of Congo
E2SFCA: Enhanced 2-Step Floating Catchment Area
FAIR: Findable, Accessible, Interoperable, Reusable
FGDC: Federal Geographic Data Committee
GIS: Geographic Information Systems
INSPIRE: Infrastructure for Spatial Information in the European Community
MHCs: Mobile Health Clinics
NSDI: National Spatial Data Infrastructure
OGC: Open Geospatial Consortium
SDGs: Sustainable Development Goals
SDI: Spatial Data Infrastructure
SE2SFCA: Seoul Enhanced 2-Step Floating Catchment Area
TFSCB: Trust Fund for Statistical Capacity Building
UNSDI: United Nations Spatial Data Infrastructure
VGI: Volunteered Geographic Information
WASH: Water, Sanitation, and Hygiene

Conflicts of Interest

The author declares no conflicts of interest.

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