(Reference: FIG Abstract #11709)

Innovation and Implementation of an Integrated Geospatial Infrastructure

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Key words: Geoinformation, Mapping, SDI, GSDI, Cartography

SUMMARY

National Mapping and Geospatial Authorities are striving to implement the United Nations Global Geospatial Information Management best practices. The fulfillment of their resolutions and the Integrated Geospatial Information Infrastructure requires a sound geospatial strategy and practical application of innovative technologies. Advances in remote sensing, computing, GeoAI and multi resolution geospatial production (multi scale mapping) have provided significant results on key performance indicators of these organizations. We will look at case studies of how they have done this and their remarkable returns on investment.

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Executive Summary

With an estimated fifty billion devices connected to the Internet, a trove of data is collected and stored every minute of every day. Yet, research shows that less than 1% of global data is used—at a significant lost opportunity cost. As with natural resources, governments can invest in infrastructure that converts these abundant data resources into valuable data assets. To turn data resources into data assets, governments need an integrated geospatial infrastructure to support the collection, management, production, analysis, and sharing of data. In past centuries, governments funded and built infrastructure to fuel economic growth. They understood, as we do now, that infrastructure is needed to link supply with demand. As the world plunges into the fourth industrial revolution, governments must invest in and sustain similar geospatial infrastructure for data.

Fortunately, governments have access to the resources and technology they need to build and benefit from their own geospatial infrastructure. The Integrated Geospatial Information Framework (IGIF), developed by the United Nations and World Bank, provides governments nine strategic pathways for creating an integrated geospatial infrastructure. (United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM), 2018) Geographic Information System (GIS) providers align with the IGIF by providing governments with the tools and resources they need to create and sustain their integrated geospatial infrastructure.

Specifically, providing governments with:

- **Integrated, interoperable geospatial technology**—With GIS software, governments can use maps and spatial reasoning to collect, manage, produce, analyze, and share data in new ways. Governments around the world use GIS to gain insights, solve real problems, and create positive change for their environment, economy, and society.
- **Focused programs and partnerships**—GIS providers like Esri offer users a robust selection of programs and partnerships that support stakeholders along their geospatial journey.

- **Resources to support user success**—Through trainings, consultations, and technical support, users receive the technical and professional guidance they need to build capacity and achieve their objectives.

Geospatial authorities around the world have used GIS; from implementing map automation and generalization in the Netherlands to modernization of the cadaster in Rwanda, demonstrating the opportunities governments can create with their data and the challenges they can overcome when it comes to producing timely, accurate, and trusted geospatial information.

Governments, as stewards of the public trust, are tasked with managing resources for the betterment of society at-large. To remain competitive in a digital age, they must invest now in geospatial infrastructure to realize the benefits of data for their national futures.

1. Unlocking the Value of Data

The plethora of digital devices—phones, computers, tablets, sensors, and many others—that are fixtures of modern life produce vast amounts of data. Because of this, the world is awash in digital information on a broad array of human activities and natural phenomena, including traffic patterns, consumer habits, and weather data. The Economist underscored this point in their article "The world's most valuable resource is no longer oil, but data" (The Economist, 2017).

Research shows governments can use this wealth of data to unlock value for their countries. In fact, a 2018 study from the United Kingdom (Cabinet Office United Kingdom, 2018) suggests the nation's location data, specifically, has potential economic benefits of up to £11 billion per year.

So, how do countries go about unlocking such benefits? To answer this question, governments are looking for best practices and guidance for how to strengthen their geospatial information management and related infrastructure. Whether a nation's economy will benefit from the data glut, or not, is chiefly a matter of governments developing the infrastructure—an integrated geospatial infrastructure—that allows them to collect, manage, produce, analyze, and share digital information.

2. Integrated Geospatial Infrastructure

Geospatial infrastructure is a concept Andy Coote first brought up to me in 2013 when we were collaborating at 2nd High Level Forum on UN-GGIM in Doha, Qatar, and later that year at the 3rd Session of UN-GGIM in Cambridge, UK (Coote, 2013). It is based on the earlier term National Spatial Data Infrastructure (SDI) that came from the United States Executive Order 12906 in 1994 that called for development of a National Spatial Data Infrastructure (NSDI).

The concept of a geospatial infrastructure is that many of the chief public works projects of the past century—road systems to bring products to markets, pipelines to deliver oil to refineries, and grid systems to bring electricity to homes—were government-initiated projects that efficiently linked market supply with consumer demand and fueled future economic growth. Today, governments must invest in and sustain similar infrastructure for data to stay

competitive into the 21st century. To turn data resources into data assets, governments need an Integrated Geospatial Infrastructure to support the collection, management, production, analysis, and sharing of data (Saligoe-Simmel, 2020), and the associated Geospatial Knowledge Infrastructure (Kumar, S., 2020).
Tools for creating this infrastructure already exist and are broadly referred to as geospatial technology. Using the location dimension of this data, geospatial technology provides an integrative platform that takes data from diverse sources, incorporates it into existing datasets, and makes it more accessible and ready to use. Additionally, when governments use geospatial technology, they can efficiently move data from production to consumption. This supports the creation of useful data assets that give governments insight into how they can compete in global markets and improve their societies.

2.1 Data for an Integrated Geospatial Infrastructure

Many governments already collect the data they need to benefit from an investment in an integrated geospatial infrastructure. The United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM)—an intergovernmental committee of experts that collaborate and advise on how to address global challenges using geospatial information—identifies a relatively small number of foundational geospatial datasets (United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM), 2020). Known as *fundamental data themes*, these underpin a wide range of applications—including parcel data, population data, and land cover data—data that are already collected by most national governments' geospatial authority agencies.

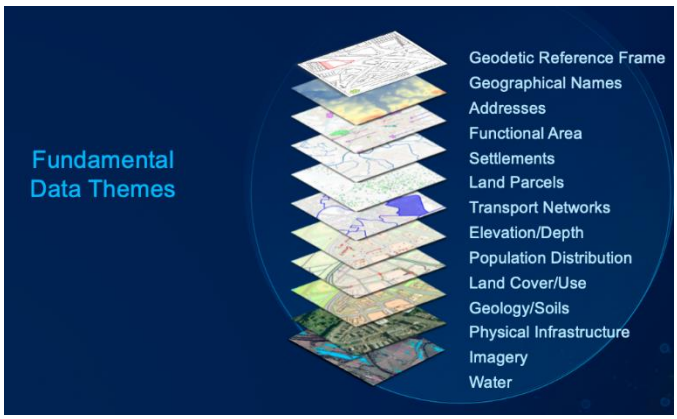

Figure 1. The list of fundamental data themes that underpin a wide range of applications.

Using this baseline, governments can add other datasets to their integrated geospatial infrastructure—whether related to agriculture, economic development, manufacturing, tourism, high-tech or other sectors—as deemed essential by their development priorities. When governments invest in their data and manage it as a critical asset, they lay the foundation for a digital transformation.

3. Digital Transformation Through Innovation

Nations that undergo digital transformations can integrate digital technology into all areas of business, which fundamentally changes how they operate and deliver value to stakeholders. When applied alongside location, digital transformations deliver improved services for citizens through self-service applications and maps, resulting in on-demand access and transparency. As governments undergo digital transformations, they also gain access to predictive analytics that deliver operational efficiencies and facilitate data-driven decision making. This integration of data, workflows, and systems leads to better information sharing, improved insights, and cost savings across the government.

As governments increasingly treat data as an enterprise-wide asset worth investing in, they can open new revenue streams and better provide for the security and prosperity of their citizens. For example, the Public Authority for Civil Information (PACI) in Kuwait uses AI and GIS, also known as GeoAI—machine learning and deep learning capabilities—to automate updates to their data in support of the Kuwait Vision 2035 and to serve citizens' authoritative country data (Majumdar, 2021). Similarly, the Ordnance Survey of Great Britain used automation tools (Cygan, 2019, Esri Blog) to capture data, map change and deliver a wide range of new information products and services (Cygan, 2020). These benefits are realized through innovation initiatives, like the Dutch Kadaster with their innovative processes and culture (Cygan, 2019 ArcNews).

4. Overcoming Challenges Through Using the IGIF

When developing and maintaining an integrated geospatial infrastructure, national governments face common challenges, including issues around capacity building, data governance, transparency, resources, and more. Because governments often struggle with these aspects of geospatial data infrastructure, the United Nations and World Bank developed the Integrated Geospatial Information Framework (IGIF) ((United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM), 2018). The IGIF provides guidance—applicable for all countries—for creating or modernizing geospatial data infrastructure for sustainable social, economic, and environmental development (United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM), 2020).

The IGIF provides guidance through nine strategic pathways: governance and institutions; policy and legal; financial; data; innovation; standards; partnerships; capacity and education; and communication and engagement. Each pathway falls into three primary themes—data governance, technology, and people—and defines how success is achieved for each pathway. As the criteria for each pathway is met, governments' data infrastructure becomes increasingly productive and valuable.

5. ALIGNMENT WITH IGIF & STRATEGIC PATHWAYS

GIS providers support the nine strategic pathways set forth by the IGIF. For example, Esri helps countries align with these pathways and implement the IGIF by applying technology, focused programs and partnerships, and support resources—such as training and professional consulting—to aid in their success. For over 50 years GIS providers have helped governments develop their people, processes, data, and technology to create and sustain their integrated geospatial infrastructure.

Specifically, GIS provides governments with:

- **Integrated, interoperable geospatial technology**—GIS is a mapping and analytics technology. It combines the science of geography with powerful GIS software to help governments make data-driven decisions. With GIS, organizations use maps and spatial reasoning to explore data in new ways and gain a deeper understanding of any problem or situation. They can then share these insights and collaborate with others through web maps and apps. National governments around the world are using GIS to solve real problems and create positive change for their environment, economy, and society.
- **Focused programs and partnerships**—Good GIS providers offer users a robust selection of special programs and partnerships that support stakeholders at different points along their geospatial journey.
- **Resources to support user success**—GIS providers support users with the information and guidance they need to achieve their objectives with GIS.

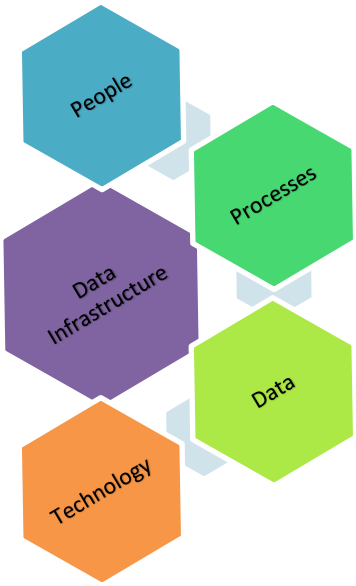

Figure 2. GIS supports each key area governments need to implement an integrated geospatial infrastructure.

For years, geospatial authorities have faced many kinds of challenges when it comes to producing timely, accurate, and trusted geospatial information—while pursuing digital transformation initiatives. This includes complying with local legislation and policy, doing more with less money, hiring and retaining high quality talent, and doing all this while contributing to economic growth and competitiveness.

5.1 Governance, Legislation & Business

The first three strategic pathways address representative governance models, public policy and legislation, and business. Beyond technology, geospatial authorities, in partnership with GIS providers, develop their geospatial strategy and roadmap, adapt to change, embrace new technology, define data sharing agreements, and stay abreast of best practices. They help ensure that location intelligence supports their organization's core mission and objectives. They are problem solvers, facilitators and trusted advisers to good governance and legal and policy reforms.

5.2 Data

The next strategic pathway, data, touches on geospatial authorities' core area of expertise: helping organizations develop and deploy data in their geospatial infrastructure. We do this through our geospatial subject matter expertise and applying a geographic approach using GIS. With GIS, users can organize and manage all aspects of their geospatial infrastructure. They can weave together apps, models, and notebooks, and manage and provide access to data and services through portal catalogs. Geospatial authorities can organize information products that people create and give the appropriate levels of access based on individual and group-based identities.
GIS integrates all types of spatially referenced data—tabular data, unstructured data, 3D data, BIM data, and many others—to help users employ one system for multiple data types. Users have access to many industry-specific templates, data models, and workflows, which allow users to quickly setup their geospatial infrastructure. Once established, nations can use geospatial infrastructure to collect, manage, produce, analyze, and share data.

5.3 Innovation

As a strategic pathway, innovation has the most significant potential for "stimulating and triggering rapid change, to leapfrog outdated technologies, and to bridge the geospatial digital divide. This allows geospatial authorities to advance the science of GIS and build geospatial infrastructure to help their stakeholders do their jobs better.
GIS enables geospatial authorities to stay abreast of new technological developments. GIS is rapidly changing and is advancing based on new forms of data (3D, drone, Lidar), new kinds of computing (cloud, AI/ML), new kinds of measurement, and many other innovation areas. At its core, GIS recognizes that not one tool or dataset is transformative, rather it is the union of many technologies woven together with authoritative data that supports digital infrastructure.
Because technology is only one side of the innovation coin, geospatial authorities support governments embrace innovation through change management, helping them adopt new technologies and establish geospatial centers of excellence. These advancements enable authoritative data providers to achieve efficiencies, deliver newer capabilities, and use new collaboration models.

The IGIF acknowledges, there is “a growing expectation” that governments use emerging technology. As government rise to this call to innovate, they will need to support enhanced service delivery and improve interactions with citizens, generating visible organization process efficiencies and savings. With GIS technology, innovative people, and a strong geospatial infrastructure, geospatial authorities help government innovate and use emerging technologies for the benefit of their citizens.

5.4 Standards

Geospatial authorities and GIS providers, like Esri, are committed to supporting international open standards and open specifications, because standards and specifications promote interoperability that generates value across stakeholder groups. As such, they actively contribute to setting standards, working with many U.S. and international geospatial groups and organizations including the Open Geospatial Consortium (OGC), Group on Earth Observations (GEO), International Organization for Standards (ISO), International Hydrographic Organization (IHO), and the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM).

Through active participation, they shape open specifications that have become *de facto* standards worldwide, such as Shapefiles and GeoServices. Some specifications go on to become international open standards, like Indexed 3D Scene Layers (I3S). Additionally, they align work with many industry-specific frameworks like the Land Administration Domain Model (LADM) and the Global Statistical Business Process Model (GSBPM).

GIS must be open and standards-compliant technology that help organizations produce and deliver their own authoritative data and content. This commitment to standards aligns with IGIF and allows support to geospatial authorities and other government organizations’ compliance obligations and facilitate interoperability between their and others’ systems and software. Open design architecture enables users to easily work within a heterogeneous IT environment—across many types of data sources and applications.
This includes:
Open Standards & Specifications—GIS must conform to established standards including data formats, metadata, and services. Standards support allows users to incorporate GIS into any application in a variety of web, mobile, and computing scenarios. This foster interoperability and cooperation.
Open Data—With GIS, users can pull data from any source. Then, they can publish their data in open formats and share findings using visualizations and analytics.
APIs & SDKs—Well-documented and easy to use APIs, in multiple languages, allow developers to apply GIS at different levels of their software stack. Organizations use SDKs to extend GIS to meet their needs.
Open Source—GIS open-source projects in GitHub, allow users to build on existing source code and contribute to foundational libraries (like LERC for imagery compression and JAVA

Geometry Engine), manage project connections (like Leaflet, R-bridge, KOOP, Geoportal), and create easy-to-use templates for web and mobile applications.
Open Science—GIS software enables scientists to derive spatial relationships, detect patterns, make predictions, and deploy intelligent apps. GIS also allows scientists and data producers to work across their communities in their native environments, tapping into the capabilities of Python, R, and other data-oriented programming languages.

5.5 Partnerships

The IGIF and the UN 2030 Agenda for Sustainable Development identifies partnerships as critical for the future, specifically identifying the importance of public, public-private, and civil society partnerships. Such joint efforts can maximize resources, minimize redundant investments, create efficiencies, and strengthen data infrastructure management.
Creating partnerships is a core part of UN-GGIM's DNA. Geospatial Authorities and the geospatial industry regularly create and facilitate different ways for our user community to engage and partner with each other. National geospatial authorities and Esri have partnered through our User Community for Geospatial Authorities (UCG). This collaborative forum gives geospatial authorities a channel to share their technology needs and solutions. GIS providers also work with international organizations and NGOs around the world who focus on conservation, humanitarian response, and education. These partnerships have opened new data sources, training resources, and solutions that unlock value to our broader user community.

5.6 Capacity and Education

People are central to the sustainability of an integrated geospatial infrastructure. Supporting users of all ages and stages of their GIS professional development and education is critically important to long-term capacity building programs and education systems needed to sustain geospatial information management. A wealth of learning resources are available to support building the capacity of this geospatial community.

GIS programs and curriculum for primary and secondary schools, which provides web and mobile apps, desktop licenses, and extensions for instructional use provide a strong foundation. At higher-level education institutions, easy availability for faculty, staff, and students for learning, research, and administration is vital to developing the geospatial professionals needed to sustain our geospatial infrastructure far into the future. Hands-on, self-paced GIS lessons and related resources, including MOOCs, webinars, self-help guides, and online open learn lessons accelerate this capacity building. Meet ups, conferences, facilitated discussions in online forums and young professional networks events help grow the geospatial community and help young professionals identify opportunities in the GIS sector.

Instructor-led and self-paced training that emphasizes GIS best practices and develops skills that users can immediately apply are very practical education and capacity building opportunities. Workforce development planning and change management help organizations be more successful with GIS. In very practical terms, training helps organizations' to:

- Increase productivity and operational efficiency in GIS operations, allowing staff to accomplish more with fewer resources
- Prevent costly mistakes in new GIS implementations and system updates
- Recognize opportunities for GIS to improve service, grow capacity, stay ahead of the competition, and increase revenue

5.7 Communication and Engagement

The real value in technology comes in empowering everyone in an organization with access to the best information and applications to do their job. Today, many organizations understand that they can meet their business goals by leveraging location intelligence and implementing a system of engagement. A good GIS is designed to enable everyone within an organization, with or without GIS experience, to access the information they need to carry out their daily tasks more effectively. This systematic approach complements an organization's investment in its larger business systems—systems of record and insight—by providing convenient access to relevant spatial data as well as easy-to-use applications that enable collaboration across the organization.

These apps can help organizations share or explain their data, solicit input from the public through surveys, and report progress against key performance indicators. A strong GIS is designed to facilitate communication and community engagement. It helps organizations engage community members on programs and initiatives through the use of open data, story maps, performance dashboards, online content, events and discussions, and feedback mechanisms such as surveys.

6. GIS IS CRUTIAL TO IMPLEMENTING THE IGIF

Integrated geospatial infrastructure combines the science of geography with powerful GIS mapping and spatial analytics technology to reveal deeper insights into your data and better decision support. Geospatial authorities enable national governments to establish their integrated geospatial infrastructure. Governments that embrace this infrastructure benefit from improved accuracy and currency of their data, more efficient data production, better data access and sharing, and ultimately better decision making capabilities and increased public trust. Integrated geospatial infrastructure delivers real outcomes and positions government leaders to unlock the most value from their modern spatial data infrastructure

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BIOGRAPHICAL NOTES

Mark has been working in GIS and mapping since 1984. He is Esri's Director of National Mapping Solutions and has been in Esri's Industry Solutions Group since 2005. Mark previously worked for nearly 10 years as a Senior Consultant and Project Manager in Esri's Professional Services starting in 1995. Prior to Esri, Mark was on the management team at NAVTEQ (now HERE), as they were pioneering digital mapping for in-vehicle, web and mobile uses. He was also the Manager of Rand McNally & Co, California Cartographic Services, the premier cartographic and travel publisher, as well as, the Automobile Club of Southern California, Cartography Section.

Mark is actively participating in the; United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM), UN-GGIM Geospatial Societies Board Member (and past Chair), User Community of Geospatial Authorities Executive Secretary and on the International Map Industry Association (IMIA) Board of Directors and chair of their Programs Committee (Events, Affiliation Partnerships and Awards).

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