USC Dornsife
Dana and David Dornsife College of Letters, Arts and Sciences

GEOSPATIAL WORLD
ADVANCING KNOWLEDGE FOR SUSTAINABILITY

Senior Executive Training Program on Geospatial Knowledge Infrastructure (GKI) at GEOSMART India 2025

Theme

Advancing India's Geospatial Future: Integrating National Priorities with State Capabilities

29 November - 4 December 2025 | New Delhi

GKI Program Partners

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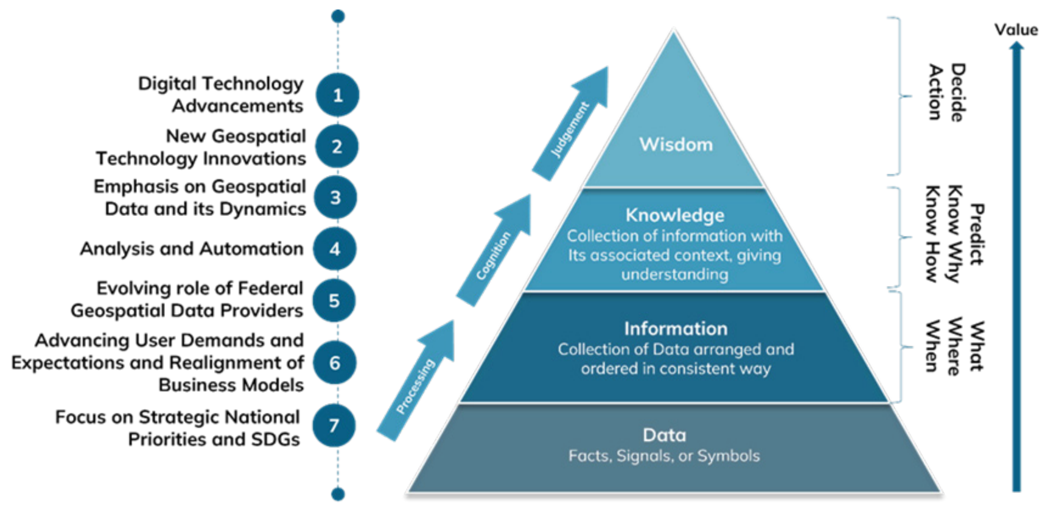
Introduction to Geospatial Knowledge Infrastructure (GKI)

The global geospatial landscape is undergoing a foundational shift—from legacy Spatial Data Infrastructures (SDIs) to a more advanced, integrated paradigm known as Geospatial Knowledge Infrastructure (GKI). This transformation is not merely technical; it marks a strategic evolution in how nations and institutions mobilize geospatial assets to derive actionable intelligence in an increasingly data-driven world.

GKI represents a next-generation framework that transcends the conventional mandates of data collection, storage, and dissemination. Anchored in the principles of the Fourth Industrial Revolution (4IR), it integrates geospatial technologies with AI, cloud computing, and IoT to enable real-time, predictive, and context-aware insights. In doing so, it moves the value chain decisively from data to decision—placing geospatial intelligence at the core of national digital infrastructure.

This evolution is propelled by the imperative to embed geospatial capabilities across public governance, industrial ecosystems, and the global digital economy. Whether enabling smart cities, climate resilience, or digital twin technologies, GKI offers a cohesive architecture for aligning policy, infrastructure, and innovation. It equips governments and enterprises alike to respond with agility to complex challenges—making decision-making not only smarter and faster but also more sustainable and systemically informed. In an era where digital competitiveness is increasingly geospatial in nature, GKI is not just a technological upgrade; it is a strategic enabler of national resilience, economic opportunity, and global leadership.

Figure 1: The Blueprint for the Future Geospatial Ecosystem



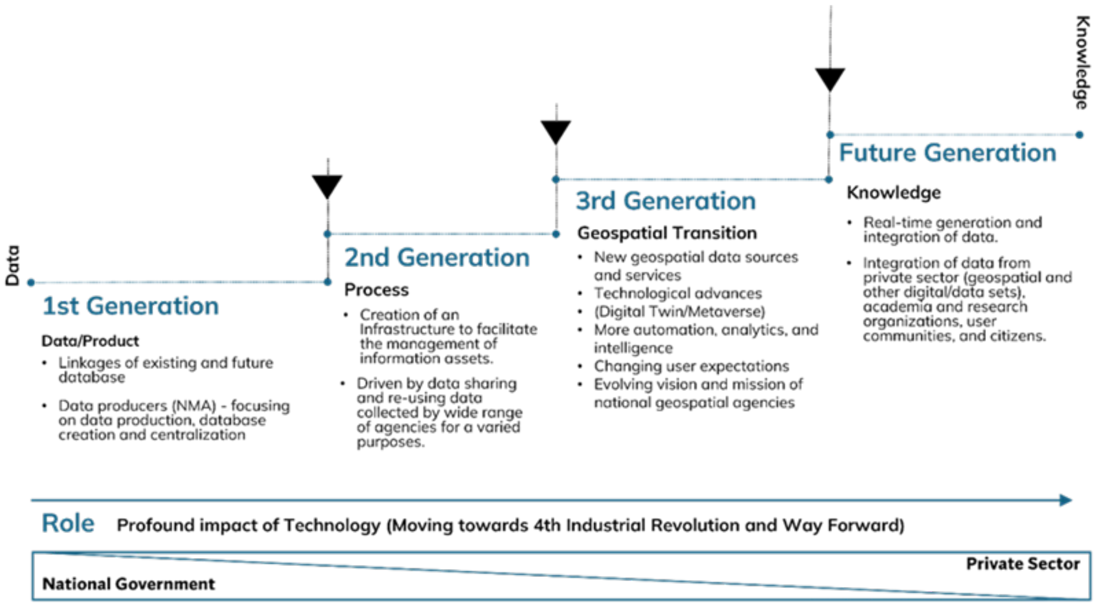
Source: Geospatial World Consulting

The transition to Geospatial Knowledge Infrastructure (GKI) signals the emergence of a third generation in the evolution of geospatial systems. The first generation was data-centric, focused on building the foundational capacity to collect, manage, and store spatial data. This was followed by the second generation, characterized by process-driven frameworks that integrated geospatial data into specific workflows, enhancing decision-making within siloed applications.

Today, the shift toward a knowledge-powered paradigm reflects a broader imperative: to generate actionable insights that inform real-time, system-level decisions. GKI embodies this transformation by leveraging advanced analytics, AI, and interoperability to convert data into strategic knowledge. It positions geospatial systems not merely as repositories or tools, but as critical infrastructure for national resilience, digital governance, and economic competitiveness.

A knowledge-powered geospatial paradigm enables the transition from merely observing patterns to actively shaping outcomes—through prescriptive analytics, adaptive systems, and autonomous decision-making. Yet, this shift requires more than technological innovation; it calls for the holistic integration of people, processes, policies, and platforms. Only by building such an ecosystem can geospatial knowledge be transformed into operational wisdom capable of addressing complex, interlinked global challenges.

Figure 2: GKI: Establishing the Geospatial Knowledge Infrastructure—Towards the Future Generation



Source: Geospatial World Consulting

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As the geospatial ecosystem advances and GKI reshapes the dynamics between data, algorithms, and human insight, national sovereignty and resilience are becoming critical pillars of this evolution. By linking geospatial intelligence with sovereign capabilities across the full technology stack—from satellites and GNSS to cloud and real-time analytics—GKI now serves not just as a value-creation roadmap but as a tactical readiness framework that empowers nations to operationalize geospatial and space infrastructure for autonomy, security, and future-ready growth.

Geospatial Knowledge Infrastructure for India

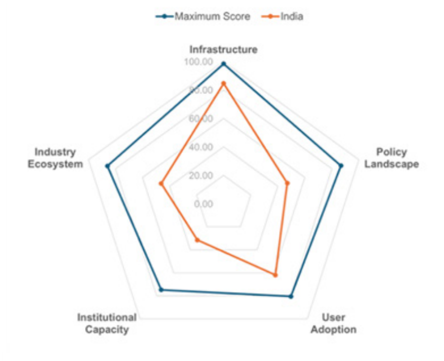
India is at a defining moment in its geospatial journey. With the National Geospatial Policy 2022, Indian Space Policy 2023, and guidelines for geospatial data, the country has laid down a progressive framework for liberalized data access and private sector participation. Foundational infrastructure is expanding rapidly through the Survey of India, ISRO, NRSC, and platforms such as Bhuvan and PM Gati Shakti, while flagship programs like SVAMITVA, NAKSHA, and Operation Dronagiri are driving innovation and ground-level adoption. Together, these initiatives highlight India's strategic intent to build a globally competitive geospatial economy with private sector engagement across drones, mapping, and earth observation.

At the same time, challenges remain. Data availability and quality are uneven across states and sectors, slowing down the creation of a seamless national ecosystem. The integration of real-time data systems and advanced analytics into mainstream public services is still limited. Moreover, geospatial literacy and institutional capacity vary widely across ministries, states, and municipalities, creating gaps between national ambitions and local implementation.

Figure 3: India's Ranking in the GKI Readiness Index 2025

Pillars	Score	Rank
Infrastructure	84.58	9
Policy Landscape	47.05	12
User Adoption	61.87	23
Industry Ecosystem	46.16	5
Institutional Capacity	31.50	18

GKI Readiness Index 2025: Relative Score India vs Top-ranked Country



Source: Geospatial World Consulting

This is where Geospatial Knowledge Infrastructure (GKI) provides a unifying pathway. GKI enables India to transition from siloed assets to an integrated, sovereign, and intelligence-driven ecosystem that supports real-time decision-making, sectoral innovation, and resilient governance. By aligning modernization efforts with broader national priorities—digital transformation, Atmanirbhar Bharat, sustainable development, and inclusive growth—GKI can ensure that investments translate into long-term societal and economic impact. Crucially, it helps bridge Central vision with State-level execution, creating a harmonized national geospatial fabric.

Why Are State Capabilities Important for GKI Success

India's geospatial progress depends on how effectively states can turn national policy into practical action. A strong GKI ecosystem at the state level allows departments to work with consistent, high-quality data, integrate geospatial tools into daily governance, and make faster, more informed decisions across sectoral workflows like infrastructure, resource management, and public services. When states build this capability, they improve service delivery, strengthen disaster readiness, support innovation with industry and academia, and ensure that investments are aligned with national priorities. Summing up, GKI gives states the capacity to deliver real development impact, transforming national vision into outcomes that citizens can see and experience.

The upcoming training Program on Geospatial Knowledge Infrastructure in New Delhi comes at a pivotal moment for India. It will serve as a platform to equip ministries, state departments, and national agencies like the Survey of India with the frameworks to operationalize GKI in line with national priorities. By fostering collaboration across government, industry, and academia, the program will strengthen data-driven governance, institutional capacity, and interoperability at both central and state levels. In doing so, the training will accelerate India's position as a global leader in applying geospatial knowledge for sustainable growth and digital transformation.

Training Outline

The Senior Executive Training Program on Geospatial Knowledge Infrastructure, a co-led program by USC Dornsife and Geospatial World along with its partners, Survey of India [SoI], Esri, Overture Maps Foundation, Foundation of Ecological Security [FES], Woolpert, SDG Data Alliance of PVBLIC Foundation, and United Nations Statistics Foundation, is scheduled to be held from the 29th November – 4th December 2025 in Crowne Plaza Hotel, New Delhi, India.

The program will be conducted in two phases –

- **Capability Building & Enablement Program for GKI:** The first three days (29 November – 1 December 2025) will begin with focused training programs on concept, framework, and processes of Geospatial Knowledge Infrastructure organized with an intent to enhance the participants' understanding of the Geospatial Knowledge Infrastructure (GKI) framework and its applications in India in alignment with the country's national and state' priorities. Designed for senior officials from national mapping agencies, government bodies, industry, and academia, the training will equip participants with practical tools to design, implement, and scale resilient, interoperable GKI ecosystems. Sessions will explore the GKI's ecosystem approach, socio-economic impact, India's geospatial knowledge infrastructure architecture need and requirements, interoperability and standards, foundational datasets and platforms, partnership models, and technology enablers such as AI, digital twins, drones, and IoT. Special focus will be given to GKI applications for architecture, engineering and construction, and ecological and resource management, and sustainable development, with interactive discussions, hands-on exercises, and collaborative forums enhancing learning outcomes.

- **Industry Engagement and Collaborative Ecosystem Building:** The next three days (2–4 December 2025) will focus on industry engagement at GEOSMART INDIA. This platform will convene government leaders, industry innovators, startups, academia, and multilateral organisations to showcase advanced solutions and foster partnerships for future-ready geospatial ecosystems. GeoSmart India provides participants with the opportunity to collaborate with peers and experts, engage in hands-on exercises, and contribute to sector-specific discussions that directly feed into India's Space and Geospatial ecosystem. With over 5,000–10,000 attendees expected at GeoSmart India, participants will gain exposure to global best practices, collaborative opportunities, and emerging innovations. The training program will conclude on 4th December 2025, where certificates will be awarded to participants, recognising their active involvement, reinforcing key learning outcomes, and celebrating their role in advancing national geospatial knowledge capacity.

Learning Outcomes

By the end of the training, participants will be equipped with the knowledge, skills, and strategies to advance geospatial innovation and integration through the following outcomes:

- **Strategic Foundational Awareness –** Understand GKI and its alignment with National Geospatial Policy 2022, Digital India initiatives, and Atmanirbhar Bharat objectives.
- **Standards & Best Practices Implementation –** Apply global and Indian standards (OGC, national guidelines) to India's governance framework and development.

- **Institutional and Multi-stakeholder Collaboration Enhancement–** Strengthen collaboration across central, state, and public–private–academic partners.
- **Governance and Interoperability Advancement –** Improve data governance and interoperability for inclusive, user-centric geospatial systems.
- **Technology Enablement –** Leverage AI, cloud, drones, digital twins, and big data analytics to scale GKI adoption in India.
- **Sectoral Opportunities –** Drive geospatial innovation in agriculture, land, disaster, water, transport, and infrastructure programs like PM Gati Shakti and Smart Cities.

Training Methodology

The training programme will consist of a variety of presentations, case study discussions, individual exercises, panel discussions and technology demonstrations. Participants will be able to interact with experts in the field, share experiences, and collaborate on practical solutions for increasing geospatial capacity in their respective organizations.

Training Agenda

DAY 1: 29th November 2025			
09:00 – 10:00 - Registration and Tea/Coffee			
10:00 – 10:15	**Welcome and Introduction by Sanjay Kumar, CEO, Geospatial World**		
10:15 – 11:30	**Lesson 1**	**Geospatial Knowledge Infrastructure – The Future Geospatial Ecosystem**	**Ananyaa Narain** Vice President – Consulting Geospatial World
11:30 – 12:00	**Coffee Break**		
12:00 – 13:00	**Lesson 2**	**Communicating the Value Proposition of Geospatial Knowledge Infrastructure**	**Ananyaa Narain** Vice President – Consulting Geospatial World
13:00 – 14:00	**Lunch Break**		
14:00 – 15:00	**Lesson 3**	**Building GKI and Prioritizing State-Level Development**	**Oaishik Bhattacharya** Associate Director, Geospatial World
15:00 – 15:30	**Coffee Break**		
15:30 – 17:30	**Lesson 4**	**Building the Future of GKI in India: Infrastructure, Innovation, and Integration**	**Prof. (Dr.) Zaffar Sadiq Mohamed-Ghouse** Vice President and Director-Advisory & Innovation, Woolpert
Day 2: 30th November 2025			
10:00 – 11:00	**Lesson 5**	**Information Technology as Critical Enabler of GKI Ecosystem: Role of AI, Big Data, Cloud Computing and IoT**	**Jitender Mehta** Director of Cloud Engineering, Oracle
11:00 – 11: 30	**Coffee Break**		
11:30 – 13:00	**Lesson 6**	**Integrated Platform Architecture for Governance and Service Delivery**	**Vijay Kumar,** Senior Vice President and CTO, Esri India
13:00 – 14:00	**Lunch Break**		
14:00 – 15:30	**Lesson 7**	**Fundamentals of Positioning, Navigation and Timing and its Relevance in the GKI Ecosystem**	**Major General (Dr.) B Nagarajan (Retd.)** Professor, Department of Civil Engineering, Indian Institute of Technology, Kanpur
15:30 – 16:00	**Coffee Break**		
16:00 – 17:00	**Lesson 8**	**Interoperability and Integration: Advancing Geospatial Data Infrastructure through Standards and Collaboration**	**Harsha Madiraju,** Associate Director, Open Geospatial Consortium (OGC)

Day 3: 1st December 2025			
09:30 – 11:00	**Lesson 9**	**Harnessing Earth Observation Data for National Mapping**	**Dr. Hrishikesh Samant,** Professor of Geology, St. Xavier's College, Mumbai
11:00 – 11:30	**Coffee Break**		
11:30 – 13:00	**Lesson 10**	**GKI Workflow Integration Across AEC/ Infrastructure Sector**	**Professor. John P. Wilson,** USC Professor and Founding Director of the Spatial Sciences Institute, University of Southern California
13:00 – 14:00	**Lunch Break**		
14:00 – 15:30	**Lesson 11**	**GKI Workflow Integration for Natural Resource Management and Ecological Restoration**	**Chiranjit Guha,** General Manager, Foundation for Ecological Security (FES)
15:30 – 16:00	**Coffee Break**		
16:00 – 17:30	**Lesson 12**	**GKI Workflow Integration for Disaster Management**	**Dr. Shirish Ravan,** Director, EarthSight Foundation
18:00 -19:00	**Networking Reception with the CXO Summit Delegates**		
19:00 – 20:30	**Honouring the Living Legends & GeoSmart India Leadership Awards 2025**		
20:30- 22:00	**Dinner Reception**		
Day 4: 2nd December 2025			

09:30 – 05:30	**GeoSmart India Conference Program**	• Participation in thought-leadership plenary sessions on:
		  ◦ State Geospatial Infrastructure and Industry Development Strategy
		  ◦ Sensors to Services: Advancing Turnkey Solutions through Collaborative Business Models
		• Explore strategies connecting technology with governance & gain insights on collaborative models.
		• Networking with policymakers, innovators, and industry leaders driving India's geospatial agenda.	

Day 5: 3rd December 2025			

11:00 – 13:00	**Technology Demonstrations as part of Senior Executive Training**	• 45-Minute-long immersive technology showcase:
		  ◦ Positioning, GNSS and Precision Infrastructure
		  ◦ High Resolution Aerial and 3D Imaging	

13:00 – 14:00	**Lunch Break**		
14:30 – 17:00	**ESRI Technology Track**	• ArcGIS Reality & Digital Twins: Showcasing advanced 3D reality capture and digital simulation capabilities. • Geospatial AI for Optical & SAR Imagery: Demonstrating AI-driven analysis and feature extraction across diverse imagery. • NISAR Data Processing in ArcGIS: Highlighting workflows to transform NISAR's global SAR data into meaningful insights.	
Day 6: 4th December 2025			
09:30 – 11:0	**Technical Sessions/ Seminars**	• Deep-Dive Sessions that bridge technical insight with strategic application: ◦ Expose participants to emerging technologies like GeoAI, HD Mapping and surveying, LIDAR, Scanning and spatial computing shaping India's geospatial transformation.	
11:00 – 12:30	**Assessment Workshop**	Key Takeaways and Outcomes	
12:30 – 13:00	**Closing Ceremony**	Presentation of Certificates and Group Photograp	

LESSON - 1

Geospatial Knowledge Infrastructure: The Future of Geospatial Ecosystem

Trainer' s Biodata: Ananyaa Narain, Vice President, GW Consulting at Geospatial World

This session is led by Ananyaa Narain, a globally recognised geospatial economist and senior consulting leader whose work spans policy design, socio-economic research, and geospatial market intelligence. With a background rooted in economics and a decade of consulting experience across governments, multilateral institutions, private industry, and academia, she brings a multidisciplinary perspective essential for understanding the evolution toward Geospatial Knowledge Infrastructure (GKI). Her professional engagements include analytical and advisory contributions to the European Commission's Joint Research Centre, the United Nations Global Geospatial Information Management network, and various international technology and engineering organisations. In these roles, she has examined how nations modernise their geospatial governance structures, how industry value shifts in response to technological disruption, and how knowledge ecosystems emerge at the intersection of data infrastructures, digital innovation, and societal needs.

Ananyaa's expertise extends across market forecasting, impact evaluation, ecosystem assessment, and strategic planning, with a strong emphasis on understanding how geospatial capabilities mature within public systems. She has advised national mapping agencies, digital economy agencies, and private sector leaders on policies, institutional reform, innovation pathways, and the design of geospatial platforms that enable knowledge-driven decision-making. Her work is marked by a forward-looking approach that integrates geospatial intelligence with emerging technologies such as AI, automation, real-time analytics, and cloud-native architectures. This perspective positions her as an authoritative voice on the transition from traditional data infrastructures to holistic knowledge infrastructures.

Her contributions to global discourse have earned her recognition as a 40 Under 40 Geospatial Professional and a Geospatial Rising Star, distinctions that reflect her leadership in shaping conversations around the future of geospatial ecosystems. As a trainer, she brings not only technical and policy expertise but also a nuanced understanding of how organisations can evolve, how capabilities can be scaled, and how geospatial knowledge can drive economic competitiveness, public sector modernisation, and societal resilience. This blend of strategic insight and applied experience forms the foundation for guiding participants through a deep exploration of GKI and its transformative potential.

1. Session Overview

This session introduces participants to the conceptual foundations and future-oriented logic of Geospatial Knowledge Infrastructure (GKI), a transformative paradigm that extends far beyond the traditional scope of Spatial Data Infrastructures. GKI represents a shift from viewing geospatial systems as collections of datasets or platforms to understanding them as dynamic, intelligence-driven ecosystems that generate continuous streams of actionable knowledge. As geospatial information becomes fundamental to global digital transformation, automation, sustainability, infrastructure governance, and economic strategy, GKI emerges as the architecture capable of supporting this expanded role.

The session situates GKI within the global technological and institutional transitions reshaping the geospatial domain. Participants will examine how rapid advances in cloud-native computation, real-time sensor integration, AI-enabled analytics, and immersive digital environments (such as digital twins) are redefining expectations from geospatial systems worldwide. While the thematic focus remains global, the discussion subtly recognises India's growing prominence as a digital economy and innovation hub—where national policy reforms, digital public infrastructure, and increased institutional readiness are creating fertile conditions for GKI-inspired models. This contextual framing allows participants to understand not only the global forces shaping the future of geospatial ecosystems but also why emerging economies like India are uniquely positioned to benefit from and contribute to this transformation.

To support conceptual depth, the session will guide participants to:

- Grasp the core principles of GKI, including its emphasis on interoperability, knowledge creation, user-centricity, and governance models that span sectors and institutions.
- Analyse the drivers of change affecting the global geospatial ecosystem—technological, institutional, economic, and societal.
- Understand how knowledge ecosystems function, and why they require new capabilities, partnerships, and digital architectures.

Why this session matters is rooted in the increasing centrality of geospatial intelligence to modern societies. The geospatial ecosystem is no longer defined by data collection or mapping activities; it is characterised by its ability to generate insights, anticipate risks, optimise systems, and support decision-making at multiple scales. GKI embodies this shift by integrating data, analytics, governance, and user experience into a coherent, knowledge-driven whole. For countries like India—where digital systems, public services, and economic growth are expanding rapidly—the momentum toward GKI carries strategic significance. The ability to transform geospatial resources into widely accessible, high-value knowledge assets will shape competitiveness, resilience, and innovation capacity in the years ahead.

The session therefore provides the foundational lens through which participants can interpret the broader transformation of the geospatial landscape. It prepares them to move beyond system-level thinking toward ecosystem-level understanding, bridging conceptual insights with the practical and institutional considerations that will be explored in subsequent modules.

2. Learning Objectives

This session is designed to strengthen participants' understanding of Geospatial Knowledge Infrastructure (GKI) as a globally emerging paradigm that is redefining how geospatial value is generated and applied. While the perspective is global, the session recognises that India—like many rapidly modernising economies—stands to benefit significantly from these transformations and is gradually positioning itself within this global shift.

By the end of the session, participants will be able to:

1. **Explain the Core Concepts and Principles of GKI:** Participants will understand GKI as an evolution from data-centric geospatial systems to knowledge-oriented ecosystems. They will learn to articulate why this transition is occurring worldwide, how GKI aligns with global technological and institutional trends, and how it transforms workflows, governance models, and value chains across the geospatial domain.
2. **Connect Global Drivers of Change to National and Regional Realities:** Participants will be able to interpret the global drivers pushing geospatial ecosystems toward GKI—advances in AI, cloud-native processing, multi-sensor integration, and rising user expectations. They will also reflect on how these global dynamics influence national contexts, including countries such as India that are undertaking broad digital transformation initiatives. The emphasis remains on global patterns, with India mentioned as one of many nations intersecting with these shifts.
3. **Identify Institutional and Governance Requirements for GKI Adoption:** Participants will develop an understanding of what organisations worldwide need to adapt: governance structures, standards, talent capabilities, and operational models that enable geospatial knowledge creation. While these requirements are universal, the session will note that countries with large, diverse governance systems—India included—may encounter unique implementation considerations.
4. **Assess the Maturity of Geospatial Ecosystems Through a GKI Lens:** Participants will be equipped to evaluate geospatial maturity using global benchmarks for GKI readiness. This includes analysing strengths, gaps, and capability levels across different national and subnational systems. India's context may be referenced as an illustrative example—one among several—of how large geospatial ecosystems navigate this evolution.
5. **Formulate High-Level Strategies for Advancing Toward GKI:** Participants will be able to conceptualise strategic pathways suitable for institutions transitioning toward GKI. These strategies are intentionally framed in a manner applicable across global geospatial ecosystems, with the flexibility to be adapted to country-specific contexts, including India's rapidly modernising digital and administrative landscape.
6. **Evaluate the Evolving Role of National Mapping Agencies and Geospatial Institutions:** Participants will explore how national mapping agencies worldwide are shifting from traditional custodianship to ecosystem stewardship. While using international case examples, the session will also acknowledge that India's institutions—like their counterparts globally—are navigating this change and redefining their mandates in line with GKI principles.

3. Key Concepts and Definitions

The foundation of this session rests on understanding a series of core concepts that collectively define the evolution of the global geospatial ecosystem. The presentation establishes a narrative arc that progresses from the changing nature of geospatial technologies and markets, through institutional transformation, to the emergence of Geospatial Knowledge Infrastructure (GKI) as the future geospatial ecosystem model –

Term	Explanation
Changing Geospatial Ecosystem	Rapid global shift driven by new technologies, expanding users, and rising demand for location-based intelligence.
Spatial Data Infrastructure (SDI)	Data-oriented frameworks enabling creation, organisation, and sharing of foundational geospatial datasets.
Geospatial Knowledge Infrastructure (GKI)	Geospatial Knowledge Infrastructure provides a blueprint to integrate digital economies, societies and citizens with geospatial approaches, data and technologies and in so doing deliver the location-based knowledge, services and automation expected in the 4IR age.
Evolving User Base	Increasing diversity of geospatial users—from finance to mobility to robotics—requiring intuitive, knowledge-ready solutions.
Geospatial Analytics Platforms	Tools and systems that process spatial data to support mapping, modelling, monitoring, and decision-making.
Digital Twins	Dynamic digital replicas of physical assets or environments that rely on integrated, real-time geospatial knowledge.
Global Risk Landscape	Rising climate, infrastructure, cyber, and socio-economic risks creating increased demand for predictive geospatial intelligence.
National Mapping Agencies (NMAs)	Public institutions evolving from map producers to stewards of national geospatial ecosystems and knowledge frameworks.
Data–Knowledge–Wisdom Progression	Maturity model describing the evolution from raw geospatial data toward higher-order knowledge and strategic insight.
AI (Artificial Intelligence)	Machine-based simulation of human cognitive abilities for tasks such as learning, reasoning, and decision-making.
ML (Machine Learning)	AI technique enabling systems to learn from data and improve performance without explicit programming.
Knowledge Graphs	Data structures capturing semantic relationships between entities to support contextual reasoning and advanced analytics.
IoT (Internet of Things)	Network of connected sensors and devices delivering continuous data streams for real-time geospatial intelligence.
API-first Design	Developing APIs before applications to ensure interoperability, scalability, and ecosystem-wide integration.
Geospatial Data Services	Cloud-based delivery of spatial datasets, analytical tools, or knowledge layers on demand.
Data as a Service (DaaS)	Cloud-based model providing data access without requiring users to manage underlying infrastructure.
Model as a Service (MaaS)	Cloud-delivered AI/ML models enabling rapid adoption of advanced analytical and predictive capabilities.
Data Spaces	Federated, secure data-sharing environments that maintain data sovereignty while enabling cross-sector collaboration.
Digital Infrastructure	Core technical systems—networks, cloud platforms, compute resources—that support digital and geospatial services.
Blockchain	Distributed ledger technology enabling secure, immutable transactions without central authority.
Privacy-by-Design Principles	Embedding privacy protection and responsible data governance from the earliest stages of system design.
Quantum Computing	Computing model using quantum mechanics to perform exponentially faster calculations for complex problems.
Innovation Hubs	Collaborative environments fostering research, experimentation, entrepreneurship, and co-creation.
United Nations Integrated Geospatial Information Framework (UN-IGIF)	Global framework guiding nations in building modern, integrated, and sustainable geospatial ecosystems.

4. Evolution Of National Mapping Agencies (Nmas): From Data Custodians To Knowledge Stewardship

4.1 From Map Makers To National Knowledge Stewards

National Mapping Agencies across the world are undergoing one of the most significant transformations in their institutional history. Traditionally designed to produce authoritative maps, maintain topographic databases, and manage national geodetic frameworks, these agencies once operated in an era where spatial information was stable, slow to change, and primarily used by specialised technical communities. Their core mandate revolved around accuracy, completeness, and custodianship—essential responsibilities when the pace of information production was measured in years or decades.

However, in the contemporary digital ecosystem, where data volumes multiply in minutes, not months, and where users expect immediate insight rather than static products, such traditional roles are insufficient. The global shift toward real-time monitoring, predictive modelling, and continuous intelligence requires agencies to move from the production of maps to the orchestration of knowledge. NMAs must increasingly serve as the institutional backbone of national geospatial ecosystems—setting standards, integrating multi-source data, enabling interoperability, and ensuring that location-based knowledge circulates widely across the economy. This represents a transformation not only in what NMAs deliver, but in how they conceive their purpose: no longer producers of data alone, but stewards of national spatial understanding.

4.2 Growing Demand For Integrated, Real-Time Geospatial Intelligence

The redefinition of NMA roles is driven by a rapidly expanding global demand for real-time, cross-sector intelligence. Modern governance, industry operations, and public services all rely on the seamless integration of spatial knowledge into daily decision-making. The expectations placed on spatial information today far exceed the capacity of traditional mapping workflows. Decision environments—whether in mobility, climate resilience, infrastructure management, resource allocation, or security—are dynamic, high-frequency, and interconnected. This requires geospatial systems that are continuously updated, analytically enriched, and interoperable across sectors.

The landscape of users has diversified far beyond cartographers and surveyors. Finance, insurance, energy, logistics, agriculture, environmental science, telecommunications, and consumer technologies all depend on spatial intelligence. This expansion in demand fundamentally alters the role of NMAs. They must now enable a national geospatial environment that supports:

- **Integrated, multi-layer knowledge ecosystems –** blending earth observation, administrative data, IoT sensors, mobility feeds, and environmental monitoring into coherent knowledge layers that respond to real-world needs.
- **Rapid-update cycles –** ensuring that geospatial information mirrors physical and socio-economic conditions, which shift rapidly due to construction, environmental change, migration, and economic dynamics.
- **Cross-domain interoperability –** providing the scaffolding for geospatial data and analytics to work seamlessly with financial systems, energy grids, supply-chain databases, health information systems, and national digital platforms.

This diversification creates a compelling need for NMAs to evolve beyond legacy modes of operation and adopt new roles that support continuous, scalable geospatial intelligence across entire national ecosystems.

4.3 Need For Ecosystem Leadership, Not Data Custodianship

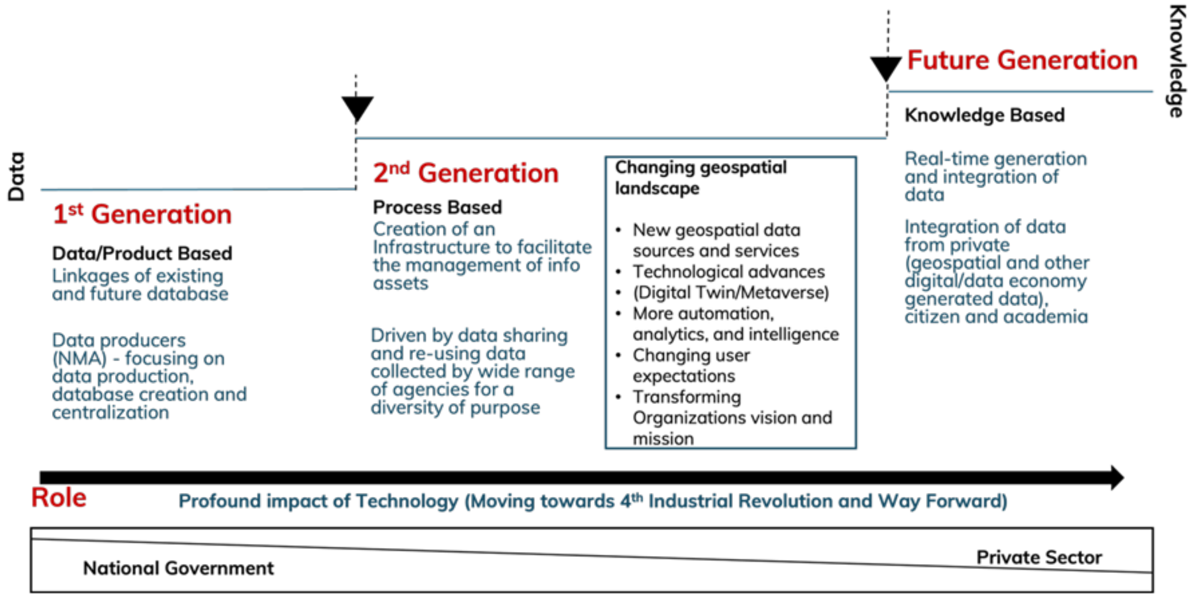
As geospatial intelligence becomes deeply embedded within national digital strategies, NMAs must take on roles that extend beyond traditional custodianship. Modern NMAs function as ecosystem orchestrators, responsible for setting the governance frameworks, technical standards, and institutional mechanisms that enable countries to maximise the value of location-based knowledge. Their role is no longer confined to producing authoritative datasets; it now includes shaping the digital infrastructure through which information flows.

Ecosystem leadership requires NMAs to support and coordinate a wide set of actors:

- **Public-sector ministries and agencies –** ensuring interoperability, avoiding duplication of effort, and enabling shared geospatial services across government.
- **Private-sector industries –** facilitating innovation by providing trusted reference layers, open standards, APIs, and predictable access policies.
- **Research and academia –** supporting R&D, pilot projects, experimental testbeds, and knowledge creation.
- **Startups and SMEs –** lowering barriers to entry through open data, sandbox environments, and accessible geospatial services.
- **Citizens and civic institutions –** enabling transparent access to spatial information that enhances public engagement, accountability, and service delivery.

Each of these responsibilities requires NMAs to adopt new institutional identities. Rather than operating as vertically structured production entities, they must become horizontally integrated enablers—organisations that facilitate collaboration, interoperability, and innovation across national ecosystems. The movement toward Geospatial Knowledge Infrastructure (GKI) reinforces this shift, positioning NMAs at the centre of national spatial governance but in a shared, distributed leadership model, rather than as solitary authoritative providers.

Figure 1: Changing Geospatial Ecosystem



India's Institutional Imperative: Transforming SoI into a Modern Knowledge Agency

For India, the evolution of NMAs is not only relevant but strategically urgent. The Survey of India (SoI)—India's oldest scientific organisation and the primary authority for national mapping—faces the same pressures as NMAs globally, but at a scale and complexity far greater. India's governance landscape is vast, multi-layered, and rapidly digitising. Urban expansion, infrastructure growth, climate challenges, mobility transitions, agricultural transformation, and expanding digital public platforms have created an unprecedented demand for trusted, real-time geospatial knowledge.

India's emerging digital programmes and national priorities illustrate the growing need for a modernised institutional role:

- **Land governance and property rights –** initiatives like SVAMITVA, NAKSHA, require drone-based mapping, precision boundary delineation, and scalable digital land information systems.
- **Infrastructure integration –** PM Gati Shakti demands unified, interoperable spatial layers integrating rail, road, ports, energy, telecom, and logistics networks.
- **Urban governance –** smart cities and AMRUT 2.0 require continuous monitoring, 3D/4D modelling, and urban digital twins.
- **Agricultural transformation –** precision agriculture depends on high-resolution datasets, soil maps, crop analytics, and farm-level advisories.
- **Climate and environmental resilience –** heat stress mapping, flood forecasting, coastal vulnerability assessments, and forest monitoring rely on integrated geospatial intelligence.

For India to realise these ambitions, SoI must transition from a production-centric agency into a national knowledge steward, working in close coordination with ISRO, NRSC, NIC, FSI, state RS/GIS centres, and diverse sectoral ministries. This requires modern workflows, open standards, AI-enabled production pipelines, API-driven platforms, and a governance model that supports cross-sector collaboration.

India's scale makes this institutional transformation not simply beneficial but essential. With more than a billion citizens interacting with digital systems daily, the nation needs geospatial knowledge infrastructures—anchored by modernised NMAs—to support future-ready governance, economic resilience, and sustainable development.

5. GKI a New Global Context Demands New Geospatial Capabilities

The future of the geospatial ecosystem is being shaped by powerful macro forces that fundamentally alter how nations manage information, govern societies, and optimise economic systems. The world now operates in a climate of rapid urbanisation, environmental stress, digital interconnectedness, and heightened uncertainty. Governments and industries confront disruptions that are increasingly spatial in nature—climate extremes, supply-chain vulnerabilities, public health crises, resource conflicts, infrastructure fragility, and demographic shifts. Traditional geospatial systems, designed for periodic updates and specialist interpretation, cannot support the scale, immediacy, and interconnected complexity of these challenges.

GKI emerges as the response to this tectonic shift. It provides a framework through which spatial knowledge is not merely stored or visualised but continuously interpreted, contextualised, and embedded into the core functions of modern governance. This makes GKI fundamentally future-oriented, enabling societies to anticipate rather than merely react to change. The ability to integrate historical trends, real-time indicators, and predictive analytics transforms geospatial capability from a descriptive tool into an instrument of foresight.

5.1 the intelligence economy requires knowledge, not data

As economies transition deeper into the digital and computational age, the value of geospatial information no longer lies in the data itself but in the knowledge ecosystems built around it. Datasets become powerful only when they are harmonised, enriched, and linked to decision systems. The intelligence economy—comprising AI-driven automation, autonomous mobility, climate-risk modelling, robotics, and digital twins—cannot operate effectively without spatial knowledge that is immediate, interpretable, and embedded into digital workflows.

This shift creates a structural transformation in demand: policymakers, city planners, infrastructure agencies, financial institutions, agritech companies, and public service providers no longer ask "WHERE IS IT?", but instead demand "WHAT DOES IT MEAN, AND WHAT SHOULD WE DO NEXT?" This operational need for actionable intelligence transforms geospatial into a strategic asset. GKI explicitly addresses this demand by establishing geospatial knowledge as a core layer of national intelligence systems—continuous, integrated, and decision-ready.

5.2 Expanding Markets And Sectors Depend On Spatial Knowledge

Geospatial intelligence is now indispensable across a wide spectrum of industries, each undergoing technology-driven transformation. Logistics and supply-chain networks require real-time spatial optimisation to manage disruptions and maintain service levels. Utilities rely on geospatial monitoring to manage distributed energy infrastructure, grid stability, and renewable integration. The insurance and finance sectors need granular climate-risk assessments and vulnerability modelling to make pricing, investment, and regulatory decisions in volatile environments.

Agriculture has been revolutionised by precision technologies that require high-resolution soil maps, crop monitoring, pest detection, and weather-informed advisory systems. Urban mobility, whether in conventional transport or emerging autonomous systems, depends on continuous spatial awareness and dynamic routing. Telecommunications companies rely on spatial models for network planning, fibre deployment, and 5G optimisation. In each of these cases, geospatial value is not unlocked through static data but through rich, context-aware knowledge systems—exactly what GKI is designed to enable.

As markets expand, geospatial capabilities fuse with a broader array of digital technologies—cloud, AI, IoT, blockchain, spatial computing, edge intelligence—resulting in integrated ecosystems that cannot be supported by legacy geospatial architectures. GKI becomes the natural evolution: an ecosystem that aligns spatial intelligence with modern digital markets.

5.3 The Acceleration Of Real-Time, High-Frequency Data Ecosystems

A defining feature of the future geospatial environment is the explosive growth of real-time data. Low-Earth orbit satellites provide near-continuous imaging. Drones capture hyper-local detail. Autonomous vehicles and robotics generate millions of spatial observations per second. IoT networks monitor infrastructure, environmental conditions, and human behaviour in real time. Mobile phones contribute geotagged interactions that reflect economic and social patterns with granular immediacy.

This environment demands systems capable of ingesting, harmonising, interpreting, and acting on data streams almost instantaneously. Conventional geospatial systems—built for batch updates and manual interpretation—were not designed for this new temporal reality. GKI provides the architecture for real-time intelligence by combining cloud-native computing, automated workflows, AI-based analytics, and scalable platform environments. It supports continuous learning, continuous modelling, and continuous decision support—capabilities indispensable for managing smart cities, climate shocks, energy systems, and automated mobility.

5.4 The Rise Of Digital Twins, Automation, And Simulation-Based Governance

Digital twins—dynamic virtual representations of physical systems—are rapidly becoming central to governance, infrastructure management, and industrial optimisation. These systems require multi-layered, continuously updated spatial foundations. They integrate spatial-temporal data with engineering models, sensor inputs, operational data, and predictive algorithms to simulate real-world behaviour. Without GKI, these digital twins cannot operate at national or sectoral scale.

Similarly, automation—in manufacturing, agriculture, logistics, and mobility—depends on precise, real-time geospatial knowledge. Simulation-based governance, where policymakers test interventions on virtual models before implementing them, requires continuous alignment between physical and spatial data. GKI provides the decision fabric that links all these technologies and operating models. It enables countries to move from reactive governance to anticipatory governance, from static planning to dynamic optimisation.

5.5 Societal Expectations Are Shifting Towards Location-Enabled Public Services

Citizens increasingly expect services that respond intelligently to their physical context. Whether in disaster alerts, public transport routing, emergency response, healthcare delivery, or service eligibility, modern governance must operate with spatial awareness embedded into public interfaces. Governments cannot meet these expectations with fragmented datasets or outdated spatial systems. GKI ensures that geospatial knowledge flows seamlessly into digital public services, enabling situational awareness, personalised delivery, and equitable access.

This shift fundamentally alters how governments design and run digital systems. Spatial intelligence becomes a backbone rather than an add-on. National digital platforms—identity, payments, logistics, procurement, health—can be significantly strengthened when integrated with real-time location knowledge. The future of citizen-centric governance rests on the ability to deliver spatially aware digital services at scale.

6. Geospatial Knowledge Infrastructure (GKI): Concepts, Architecture, And Strategic Value

6.1 GKI As A Transformative Concept In The Global Geospatial Landscape

Geospatial Knowledge Infrastructure represents a foundational transformation in how nations conceive and govern their spatial ecosystems. It moves beyond the traditional logic of assembling datasets or maintaining spatial repositories and instead articulates a holistic vision in which geospatial information functions as a KNOWLEDGE FABRIC connecting institutions, technologies, and sectors. In this conception, location is not merely a technical attribute of data but a cognitive lens that shapes how societies understand systems, behaviours, risks, and opportunities. The essence of GKI lies in its ability to convert vast, heterogeneous, and continuously evolving spatial inputs into dynamic knowledge flows that improve governance, competitiveness, resilience, and public value.

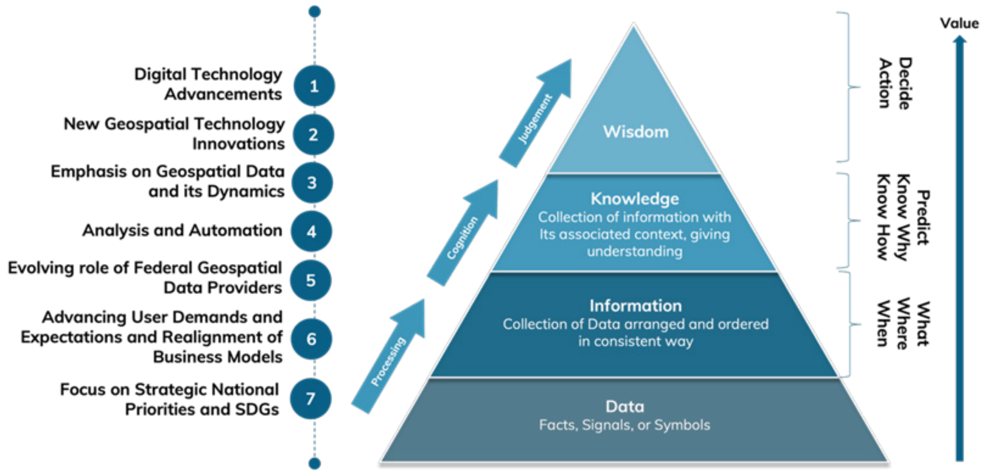
What differentiates GKI from earlier geospatial paradigms is its emphasis on intelligence. While Spatial Data Infrastructure established the mechanisms for data management, sharing, and standards, GKI introduces the conditions for CONTINUOUS INTERPRETATION, REAL-TIME SYNTHESIS, and CROSS-SECTORAL INTEGRATION. It mirrors the broader evolution of digital societies, where intelligence—not data—is the currency of impact. GKI aligns geospatial systems with this new reality by embedding analytics, modelling, automation, and governance into a unified ecosystem capable of supporting decisions at national, regional, and local levels.

6.2 The Shift From Data Infrastructure To Knowledge Infrastructure

The need for GKI emerges from the accelerating mismatch between what traditional data infrastructures were designed to deliver and what contemporary societies now require. Spatial Data Infrastructures were constructed with the primary objective of storing, organising, and standardising geospatial datasets. Their value was based on consistency, accessibility, and institutional coordination. However, SDIs were conceived in a period when spatial data was scarce, update cycles were long, and user groups were specialised.

In contrast, today's environment is defined by a proliferation of satellites, sensors, drones, smartphones, and machine-to-machine communication, generating spatial data at densities unimaginable two decades ago. The diversity of formats, frequencies, resolutions, and sources demands an architecture that can harmonise, interpret, and operationalise information at speed. Governments cannot rely on raw datasets when responding to extreme climate events, managing real-time mobility, assessing risk in financial markets, or modelling disruptions in supply chains. Industries cannot function on static maps when integrating robotics, autonomous vehicles, digital twins, or energy optimisation systems. Citizens expect services that respond instantly to geography—waste collection, transit routing, social welfare eligibility, emergency alerts—requiring spatial knowledge embedded directly within digital platforms.

Figure 2: Transition from Data to Knowledge: The Future of Geospatial Ecosystem



6.3 Architecture Of GKI: A Multi-Layered, Knowledge-Centric System

GKI is best understood as an architecture that weaves together multiple layers—each essential for transforming data into insight. These layers work as a continuum, not as discrete components, ensuring that knowledge can move fluidly from collection to comprehension to decision-making.

1. **Foundational Geospatial Assets:** Authoritative basemaps, cadastral frameworks, elevation models, geodetic networks, land cover datasets, and hydrographic layers form the stable geographic reference upon which all other knowledge is built. Their accuracy and coherence ensure national consistency.

1. **Digital and Computational Infrastructure:** Cloud environments, high-performance computing, containerised workflows, knowledge graphs, and API-driven architectures enable vast volumes of spatial data to be ingested, processed, and distributed efficiently. These infrastructures ensure scalability, reliability, and interoperability.

1. **Analytical and Intelligence Layer:** This is where GKI distinguishes itself from SDI. Advanced geospatial analytics, AI-driven classification, predictive modelling, simulation engines, and 3D/4D decision environments convert raw data into meaningful patterns and foresight. This layer supports early warning, scenario analysis, and automated insight generation.

1. **Governance, Policy, and Institutional Layer:** Standards, regulations, data sharing frameworks, licensing models, privacy safeguards, and ecosystem governance arrangements shape how geospatial knowledge is produced, trusted, and shared across public and private domains.This ensures ethical, secure, and responsible use of spatial intelligence.

1. **User and Service Ecosystem:** The final expression of GKI emerges in the applications, platforms, and services that deliver actionable knowledge to governments, businesses, civil society, and citizens. This includes urban management dashboards, climate-risk platforms, agritech advisories, logistics optimisation tools, and citizen-facing digital services.

Together, these layers create a system in which geospatial information becomes a living, dynamic asset—accessible, actionable, and embedded across societal functions.

6.4 Strategic Value Of GKI: Economic, Social, And Environmental Impact

The strategic value of GKI lies in its capacity to serve as a cross-cutting enabler of national development and global competitiveness. It underpins modern digital economies by improving resource allocation, reducing inefficiencies, enabling automation, and supporting innovation.

Economically, GKI strengthens productivity by enabling businesses to model consumer behaviour, optimise supply chains, manage assets, forecast demand, and integrate location into strategic planning. Companies in logistics, energy, retail, insurance, agriculture, real estate, and emerging technology sectors depend on spatial intelligence for operational efficiency and market expansion.

Socially, GKI enhances public service delivery by integrating geospatial knowledge into urban planning, social welfare targeting, health surveillance, education access, and disaster response. With real-time spatial awareness, governments can design interventions that are equitable, timely, and contextually grounded.

Environmentally, GKI provides the analytical foundation for climate resilience, biodiversity conservation, sustainable land management, water governance, emissions monitoring, and natural resource optimisation. Spatially explicit insight is indispensable for climate adaptation and long-term environmental stewardship. The overarching value of GKI is that it enables societies to manage complexity—with clarity, precision, and foresight.

India's Strategic Opportunity: Policy, Mission Architectures, Investment Pathways, And Ecosystem Maturity

India is uniquely positioned to advance GKI at national scale due to a combination of policy reforms, institutional maturity, digital governance experience, and a rapidly expanding geospatial market. The country's geospatial policy environment has undergone notable modernisation, with reforms aimed at enabling private-sector participation, democratising geospatial access, and accelerating innovation. India's National Geospatial Policy (NGP) 2022 provides a long-term vision for building a contemporary geospatial ecosystem centred on data accessibility, standards, and integration with digital systems. Complementing this is the emerging National Geospatial Mission, which seeks to unify national geospatial efforts, harmonise standards, expand foundational datasets, and promote ecosystem coordination.

India's institutional ecosystem—Survey of India, ISRO/NRSC, NIC, line ministries, state-level GIS centres, and numerous domain-specific agencies—provides a strong baseline for GKI adoption. Many of these institutions have modernised rapidly over the last decade, integrating drones, AI-based feature extraction, open data models, and advanced remote sensing workflows. Their readiness creates favourable institutional conditions for transition from data systems to knowledge infrastructures.

From an investment and market standpoint, India's geospatial economy is among the fastest growing globally, expanding through public-sector programmes (such as Smart Cities, SVAMITVA, PM Gati Shakti), private-sector innovation (agritech, logistics tech, fintech, mobility), and significant interest from global geospatial firms. Venture capital flows into location-enabled startups, combined with domestic advancements in satellite imaging, drone operations, and cloud-based spatial analytics, create a vibrant ecosystem primed for large-scale GKI adoption.

India's digital public infrastructure (DPI) success—Aadhaar, UPI, CoWIN, ONDC—demonstrates the nation's ability to build interoperable, citizen-scale digital systems. By extending this DPI logic to geospatial intelligence through GKI, India has the potential to establish one of the world's most integrated, inclusive, and future-ready geospatial knowledge ecosystems.

6.5 Understanding The Shift: From Spatial Data Infrastructure To Geospatial Knowledge Infrastructure

The evolution from Spatial Data Infrastructure (SDI) to Geospatial Knowledge Infrastructure (GKI) represents a structural transformation in how geospatial ecosystems operate. SDI emerged as an essential foundation for organising, standardising, and sharing spatial data among institutions. It emphasised metadata, standards, accessibility, and coordination—an important step in modernising national geospatial environments. However, SDI was inherently a data-centric construct: it focused on harmonising datasets rather than delivering integrated intelligence.

As digital economies matured, the limitations of SDI became evident. It could not support real-time data flows, multi-source integration, or large-scale analytical intelligence. Nor could it meet the demands of next-generation applications such as digital twins, climate modelling, autonomous mobility, or dynamic urban management. The requirements of modern governance now extend far beyond structured data repositories—they demand systems that can interpret, contextualise, and synthesise spatial information into decision-ready insights.

GKI emerges in response to this expanded need. It moves geospatial ecosystems into the realm of knowledge generation, value creation, and multi-sector intelligence flows. It enables governments and industries to operate with real-time situational awareness, predictive analysis, and continuous monitoring, all of which are becoming standard expectations in an increasingly complex and interconnected world.

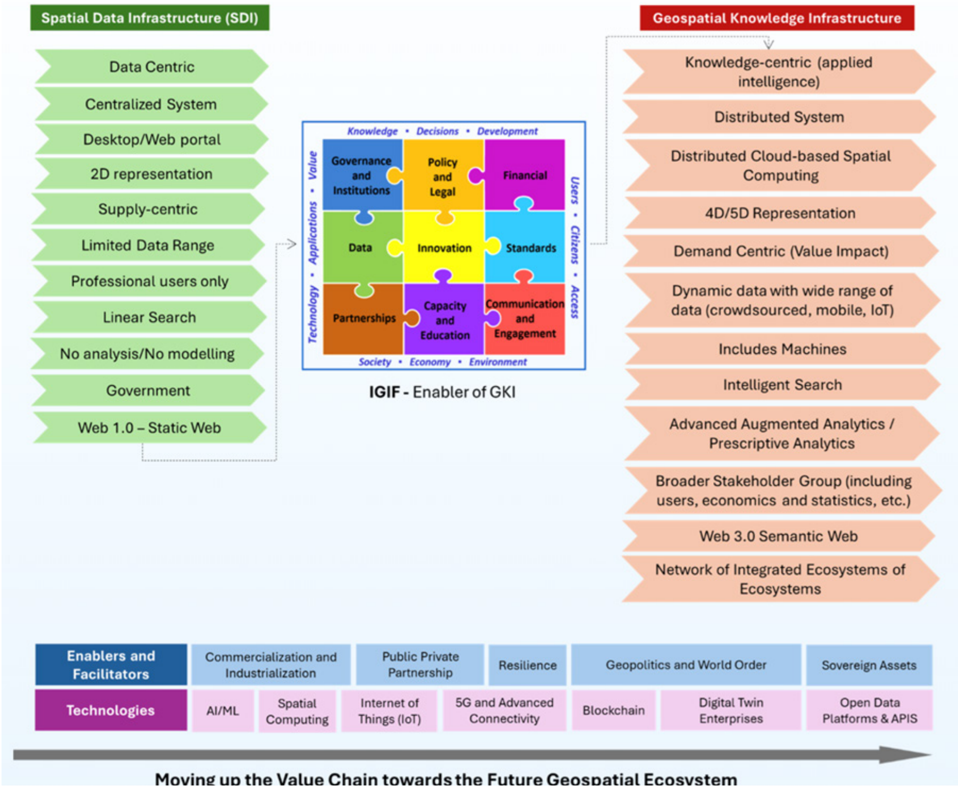
6.6 THE ROLE OF UN-IGIF IN ENABLING THE GLOBAL TRANSITION

The United Nations Integrated Geospatial Information Framework (UN-IGIF) serves as the enabling structure guiding countries through the transition from SDI to GKI. While SDI focused primarily on data pipelines, IGIF provides a holistic set of pathways that integrate governance, institutional arrangements, standards, financing, workforce development, partnerships, innovation, and user engagement into a unified approach for national geospatial development.

IGIF articulates geospatial ecosystems as strategic national assets—essential to economic growth, environmental sustainability, and social inclusion. It emphasises that modern geospatial systems must be interoperable, mission-oriented, user-driven, and capable of powering decision systems at all levels of government. This aligns directly with the GKI vision, making IGIF the bridge that helps nations move from a data infrastructure mindset to one centred on intelligence and outcomes.

Many countries use IGIF as a roadmap for reform, leveraging its nine pathways to build modernised governance structures, improve institutional coordination, develop foundational datasets, stimulate private-sector innovation, and establish sustainable financing mechanisms. This alignment between IGIF and GKI is not incidental—it reflects the shared recognition that future geospatial ecosystems must be coherent, scalable, and deeply integrated into national development strategies.

Figure 3: Evolving Geospatial Ecosystem: Transitioning from SDI to GKI Enabled by UNIGIF



7. Building a National Geospatial Ecosystem: Vision, Pillars, And Development Outcomes

Developing a national geospatial ecosystem requires a coherent vision that links long-term development outcomes with geospatial intelligence. The vision must articulate how geospatial knowledge will support economic competitiveness, social wellbeing, environmental sustainability, disaster resilience, digital governance, and public-service transformation.

At the heart of such ecosystems lies a continuous pathway from data → knowledge → wisdom, enabling increasingly sophisticated levels of insight and decision capability. Foundational datasets serve as the baseline, advanced analytics generate knowledge, and situational understanding empowers strategic planning and governance.

Development outcomes unfold across multiple dimensions:

- Economic value creation, including GDP uplift, job growth, and expansion of the commercial geospatial sector.
- Institutional strengthening, through enhanced governance, standards, and inter-agency coordination.
- Industry modernisation, as businesses integrate geospatial intelligence into strategy and operations.
- Environmental resilience, supported by real-time monitoring and predictive modelling.
- Citizen empowerment, through location-aware digital public services and participatory decision-making.

A national geospatial ecosystem grounded in GKI becomes an engine of development, resilience, and long-term competitiveness.

7.1 Pillars Of Geospatial Leadership: Translating Vision Into Practice

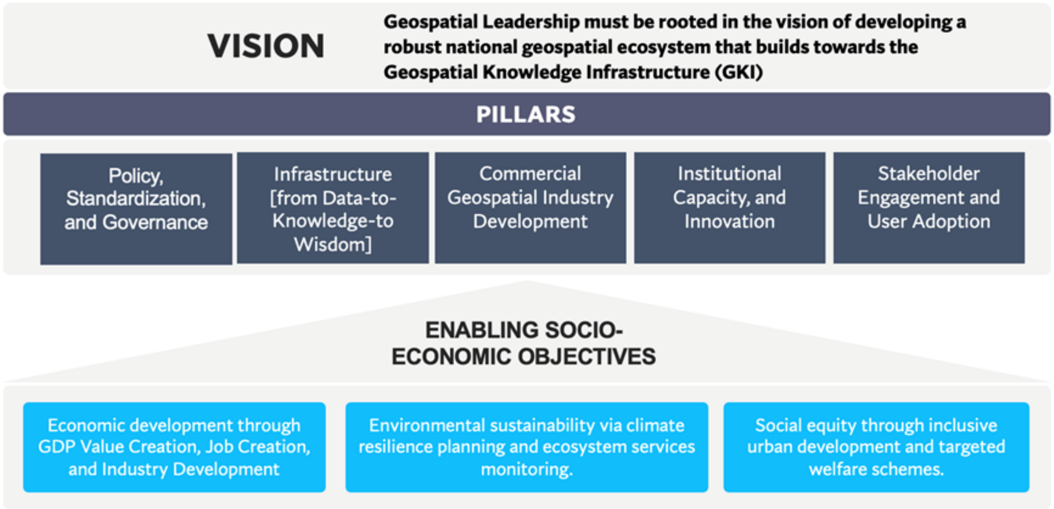
Across the world, leading nations demonstrate that geospatial leadership requires robust governance, strong foundational datasets, resilient industry capacity, and widespread geospatial literacy. These pillars create the structural conditions for GKI to thrive and for national geospatial ecosystems to deliver sustained value.

- **Policy Standardization and Governance:** Effective leadership begins with strong national policies, enabling regulations, inter-ministerial coordination mechanisms, and enforceable standards. Nations such as the UK, Saudi Arabia, Germany, and South Korea demonstrate the power of coherent governance architectures in accelerating geospatial modernisation.
- **Foundational Infrastructure and Digital Platforms:** High-quality base datasets, cloud-native platforms, 3D/4D modelling frameworks, and unified APIs establish the technical backbone for GKI. Countries investing in national geospatial platforms—digital twins, cadastral modernisation, national elevation models—are positioned to lead.

- **Commercial Geospatial Industry Development:** A strong commercial geospatial sector, startup ecosystem, and PPP frameworks stimulate innovation and ensure that national geospatial ecosystems evolve dynamically. Procurement reforms and sandbox environments play major roles in encouraging experimentation.
- **Institutional Capacity, and Innovation:** Capacity-building across government, universities, and industry ensures that geospatial knowledge becomes widely understood and adopted. Nations that invest in professional training, research collaboration, and innovation hubs create sustainable talent pipelines.
- **Stakeholder Engagement and User Adoption:** Geospatial leadership is realised only when knowledge serves users across government, industry, and society. User adoption depends on accessible platforms, participatory mechanisms, and feedback-driven system improvements.

These pillars collectively define the maturity and resilience of the global geospatial ecosystem and act as reference points for nations charting their own pathways toward GKI.

Figure 4: Building a National Geospatial Ecosystem



7.2 Development Outcomes of a Mature Geospatial Ecosystem

A mature geospatial ecosystem delivers structural, multi-dimensional, and long-lasting outcomes. Economically, it boosts productivity, reduces inefficiencies, and enhances national competitiveness by supporting intelligent infrastructure planning, resource optimisation, and risk management. It strengthens industrial capability and supports the growth of high-value markets such as climate analytics, mobility intelligence, and digital twin solutions.

Socially, a strong ecosystem improves welfare targeting, service delivery, and accessibility. Governments gain the ability to identify community needs accurately, deploy services equitably, and enhance citizen engagement. Geospatial knowledge also strengthens public transparency, accountability, and trust.

Environmentally, a mature ecosystem ensures sustainable management of land, water, forests, biodiversity, and energy systems. It enhances climate resilience by embedding spatial intelligence into long-term planning, disaster risk reduction, and environmental governance.

Institutionally, the ecosystem enables integrated governance, reducing duplication and aligning national strategies across ministries and levels of government. Digitally, it supports interoperability and strengthens the broader national digital infrastructure. Ultimately, a mature geospatial ecosystem forms the knowledge foundation upon which national development, resilience, and innovation rest.

8. GKI Workflow Integration Maturity Model And Collaboration Models

8.1 Understanding The GKI Workflow Integration Maturity Model

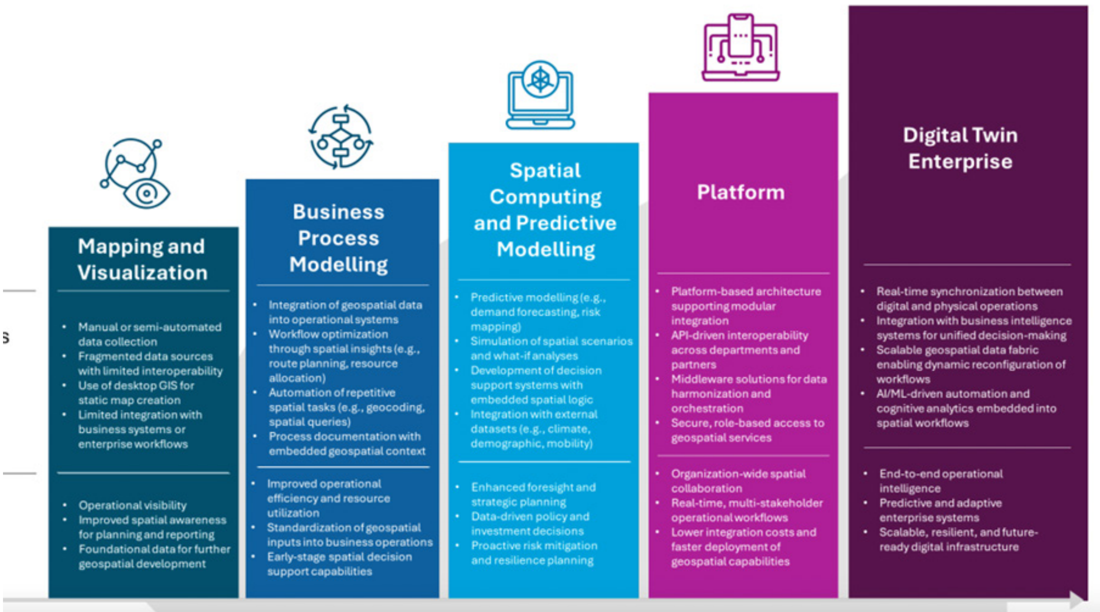
The GKI Workflow Integration Maturity Model provides a structured framework for understanding how organisations evolve from traditional geospatial operations to dynamic, knowledge-driven systems. At the lowest maturity levels, institutions operate with isolated datasets, manual processes, and technical workflows designed primarily for data production. These systems are functional but limited—they are not built to generate real-time knowledge or support large-scale coordination.

As organisations progress, they begin modernising workflows through automation, enterprise GIS platforms, cloud migration, and data standardisation. Institutions start to align their datasets, reduce redundancy, and develop shared analytical capabilities. Intermediate maturity levels involve cross-departmental data sharing, integration of AI and machine learning, and the development of digital twins or high-fidelity models that support planning and simulation.

At advanced maturity, geospatial knowledge becomes embedded into organisational decision-making systems. Automated data pipelines, semantic models, and interoperability frameworks allow institutions to generate continuous intelligence. Predictive analytics and simulation tools support anticipatory governance, enabling organisations to respond proactively to emerging challenges.

The highest level of maturity is achieved when national institutions operate within a unified knowledge ecosystem. In such systems, ministries, cities, infrastructure agencies, and private-sector entities share a common geospatial framework that enables seamless data integration, collaborative modelling, and coordinated action. This is the hallmark of a fully developed GKI environment—one that empowers governments to move from reactive decision-making to predictive, mission-oriented governance.

Figure 5: GKI Workflow Integration Model



Conclusion: Advancing Toward a Knowledge-Based Geospatial Future

GKI represents a fundamental reimagining of national geospatial ecosystems. It reframes spatial information as a strategic knowledge asset, essential for modern governance, economic productivity, societal equity, and environmental resilience. The progression from SDI to GKI signals a shift from data management to intelligence generation—aligning geospatial capability with the demands of a digital, interconnected, and rapidly changing world.

The topics covered in this module collectively demonstrate that geospatial ecosystems are no longer confined to mapping or data services. They form the cognitive foundation through which nations interpret complex systems, anticipate risks, and design future-ready solutions. The institutional, technological, and societal transitions described reflect a global movement toward knowledge-centric development.

India's Forward-Looking Imperative

India stands at a pivotal moment in its geospatial journey. With strong policy direction, expanding digital infrastructure, deepening institutional maturity, and a rapidly growing market, the country is well positioned to adopt GKI at scale. The National Geospatial Policy, emerging national missions such as the National Geospatial Mission, growing private-sector capability, and expanding investment interest collectively create favourable conditions for systemic transformation.

To realise this potential, India must strengthen governance, modernise foundational datasets, enable interoperability, develop a multidisciplinary workforce, and scale innovation across sectors. The transformation will require sustained leadership, cross-government collaboration, and a commitment to building systems that prioritise openness, intelligence, and long-term national value.

Thus, GKI is not a technological upgrade; it is a structural advancement in how nations organise knowledge, allocate resources, serve citizens, and plan for the future. It is the foundation upon which next-generation governance, resilient infrastructure, competitive industries, and sustainable societies will be built. As nations—India included—accelerate their journey toward digital modernisation, GKI will

Key Takeaways

- **The Geospatial Sector Is Undergoing A Structural Global Shift:** Nations are moving beyond map-centric systems and data repositories toward integrated knowledge ecosystems capable of supporting real-time decision-making, automation, and predictive governance. This shift is reshaping the geospatial economy and positioning GKI as the strategic foundation of modern national systems.
- **Geospatial Knowledge Infrastructure Represents The Next Evolutionl:** GKI transforms geospatial capabilities into a dynamic intelligence fabric. It integrates foundational data, digital infrastructure, analytics, governance, and services into a unified architecture that supports national development, economic competitiveness, and environmental sustainability.
- **Institutions Must Evolve From Production To Stewardship:** Agencies—especially National Mapping Agencies—must transition from data producers to knowledge orchestrators. Their value lies in coordination, standardisation, platform governance, and enabling cross-sector intelligence flows across public, private, and civil domains.
- **The Value Of GKI Extends Across Economic, Social, And Environmental Dimensions:** GKI generates significant value pathways:
  - Enhancing productivity and market growth
  - Improving service delivery and social equity
  - Strengthening climate resilience and environmental governance

  This makes GKI a nation-building asset rather than a technical upgrade.
- **Governance, Collaboration, And Standards Are Essential Enablers:** Successful geospatial ecosystems depend on strong governance frameworks, clear standards, open architectures, and structured collaboration among ministries, states, industry, academia, and international partners. Collaboration multiplies value far more than isolated institutional efforts.
- **India Has A Historic Opportunity To Lead In GKI:** With its policy momentum, digital public infrastructure successes, expanding market, and large-scale governance challenges, India is positioned to become a global model for GKI-driven transformation—provided it sustains investment, strengthens governance, modernises data foundations, and builds a multidisciplinary workforce.

Worksheet

- In what ways must your organisation shift from a data-production agency to a geospatial knowledge steward to remain relevant in the GKI era?
- How does GKI change the strategic value proposition of your organisation for national development, digital governance, and public-sector coordination?
- Which foundational datasets under your organisation's mandate (e.g., geodetic networks, base maps, elevation models) are most critical for enabling national GKI, and why?
- What steps can your organisation take to lead the development, adoption, and enforcement of India-wide geospatial standards and interoperability frameworks?
- How can your organisation bridge gaps between national geospatial policy (NGP 2022), emerging national missions, and the operational realities of data production and maintenance?
- Which ministries or agencies should your organisation prioritise for collaboration, and what governance mechanisms could strengthen inter-agency integration?
- What legacy workflows within your organisation hinder real-time data integration and knowledge generation, and how can these workflows be redesigned for GKI-aligned operations?
- How can your organisation accelerate adoption of cloud-native processing, automated feature extraction, AI/ML analytics, and API-driven dissemination within its operational framework?
- What infrastructure upgrades (digital, computational, organisational) are necessary for your organisation to support continuous-update national base layers?
- What skill gaps exist within your organisation—across surveying, data science, AI, cloud engineering, and product design—that must be addressed to enable GKI adoption?
- How can your organisation create and sustain multi-disciplinary teams that blend geospatial expertise with advanced analytics, modelling, and digital architecture skills?
- What cultural or institutional shifts are required within your organisation to move from production-centric to knowledge-centric organisational behaviour?
- How can your organisation build structured collaborations with the private sector, startups, and academia to accelerate innovation and expand national geospatial capabilities?
- What specific actions can your organisation take to catalyse India's commercial geospatial industry—through open data, procurement reforms, sandbox environments, or shared platforms?
- How can your organisation integrate community-generated, citizen-science, or crowdsourced data into national knowledge systems while ensuring quality and trust?
- How can your organisation embed geospatial knowledge into major national missions (smart cities, rural development, Gati Shakti, climate resilience) in a scalable and sustained manner?
- What types of real-time knowledge services could your organisation develop to support crisis response, environmental monitoring, or public safety?
- What indicators should your organisation use to measure progress toward becoming a GKI-aligned institution?
- If your organisation were to design India's first national Geospatial Knowledge Infrastructure blueprint, what core components should it prioritise?

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LESSON - 2

Communicating the Value Proposition of Geospatial Knowledge Infrastructure

Trainer' s Biodata: Ananyaa Narain, Vice President, GW Consulting at Geospatial World

2.1 Introduction

In an era marked by unprecedented technological advancement, Geospatial Knowledge Infrastructure (GKI) emerges as a pivotal catalyst reshaping the socio-economic landscape of any country, and it's economy. The Geospatial Knowledge Infrastructure (hereto referred to as GKI),is a multifaceted framework encompassing geospatial data, tools, and analytical capabilities, and is revolutionizing the manner in which societies and economies perceive, interact with, and harness spatial information. This transformative force transcends traditional boundaries, permeating industries, governance structures, and societal frameworks with its profound implications.

At its essence, geospatial knowledge infrastructure embodies the fusion of geospatial data with advanced technologies such as Geographic Information Systems (GIS), remote sensing, and spatial. This convergence empowers stakeholders across diverse sectors to derive actionable insights, make informed decisions, and drive innovation. Whether elucidating urban dynamics, optimizing supply chains, or mitigating environmental risks, GKI serves as a cornerstone for informed decision-making, underpinning sustainable development and fostering resilience in an increasingly complex world. Hence it is no surprise that the global geospatial industry is estimated to be USD 512 billion in 2023 and is forecasted to grow to USD 1.37 trillion in 2030.

The industry's growth is likely to result in a direct economic impact of approximately USD 30 trillion by 2030! Undoubtedly, geospatial knowledge is a critical socio-economic tool with its ubiquitous presence across all sectors and in all technology domains today. Several mainstream IT and engineering firms have already added geospatial portfolios through strategic partnerships and acquisitions, driven by the motivation to strengthen the geospatial dimension of their existing business portfolios to stay ahead of the innovation and competitive curves.

Thus, the socio-economic ramifications of GKI, reverberate across a spectrum of domains (societal, economical and environmental), catalysing transformative change and yielding tangible benefits for individuals, communities, and nations alike. From enhancing public service delivery to facilitating precision agriculture, GKI engenders efficiencies, fosters inclusivity, and nurtures economic growth. Moreover, by democratizing access to spatial information and fostering collaboration, GKI empowers stakeholders at all levels to participate in data-driven discourse, thereby fostering transparency, accountability, and participatory governance.

In light of these dynamics, it is imperative to explore the socio-economic impact of the Geospatial Knowledge Infrastructure, elucidating its transformative potential, discerning emerging trends, and delineating actionable insights for policymakers, industry leaders, and societal stakeholders. By interrogating the intersections of technology, policy, and society, a socio-economic impact assessment seeks to inform evidence-based decision-making, foster cross-sectoral collaboration, and pave the path towards a more resilient, inclusive, and sustainable future empowered by geospatial knowledge infrastructure.

2.2. Importance of Conducting a Socio-economic Impact Assessment

Assessing and conducting a comprehensive socio-economic impact assessment of GKI emerges as imperative for informed decision-making, risk management, accountability, and stakeholder engagement. By elucidating the transformative potential and nuanced implications of spatial interventions, impact assessments empower decision-makers to navigate complexity, optimize resource allocation, and realize the full socio-economic benefits of geospatial knowledge infrastructure.

1. Economic Perspective:

- **Resource Allocation:** Understanding the economic impact of GKI allows policymakers to allocate resources efficiently, directing investment towards areas with the highest potential for economic growth and development. By assessing the return on investment (ROI) of GKI initiatives, decision-makers can prioritize projects that yield the greatest socio-economic benefits.
- **Market Dynamics:** GKI influences market dynamics by providing businesses with spatial insights that inform market analysis, site selection, and supply chain optimization. Assessing the economic impact of GKI enables businesses to make strategic decisions, allocate resources effectively, and capitalize on emerging opportunities, thereby enhancing competitiveness and resilience in the global marketplace.
- **Job Creation:** GKI initiatives often stimulate job creation and economic growth by fostering innovation, entrepreneurship, and knowledge-intensive industries. Assessing the socio-economic impact of GKI allows policymakers to quantify the job creation potential of spatial interventions, identify skill gaps, and design targeted workforce development programs to enhance human capital and employment opportunities.

2. Policy Formulation Perspective:

- **Evidence-Based Decision-Making:** Conducting socio-economic impact assessments of GKI provides policymakers with empirical evidence to inform policy formulation, evaluation, and revision. By quantifying the socio-economic benefits and trade-offs associated with spatial interventions, decision-makers can make informed choices, anticipate unintended consequences, and develop policies that align with societal needs and aspirations.
- **Risk Management:** GKI impact assessments enable policymakers to identify and mitigate potential risks and vulnerabilities associated with spatial interventions. By conducting scenario analysis and sensitivity testing, decision-makers can assess the resilience of policy interventions to external shocks, anticipate future challenges, and develop adaptive strategies to enhance societal well-being and resilience.
- **Policy Integration:** GKI intersects with diverse policy domains, including urban planning, environmental management, transportation, and public health. Assessing the socio-economic impact of GKI facilitates policy integration and coherence by identifying synergies, trade-offs, and interdependencies across different sectors. By fostering cross-sectoral collaboration and coordination, impact assessments enhance the effectiveness and sustainability of policy interventions, ensuring holistic and integrated approaches to societal challenges.

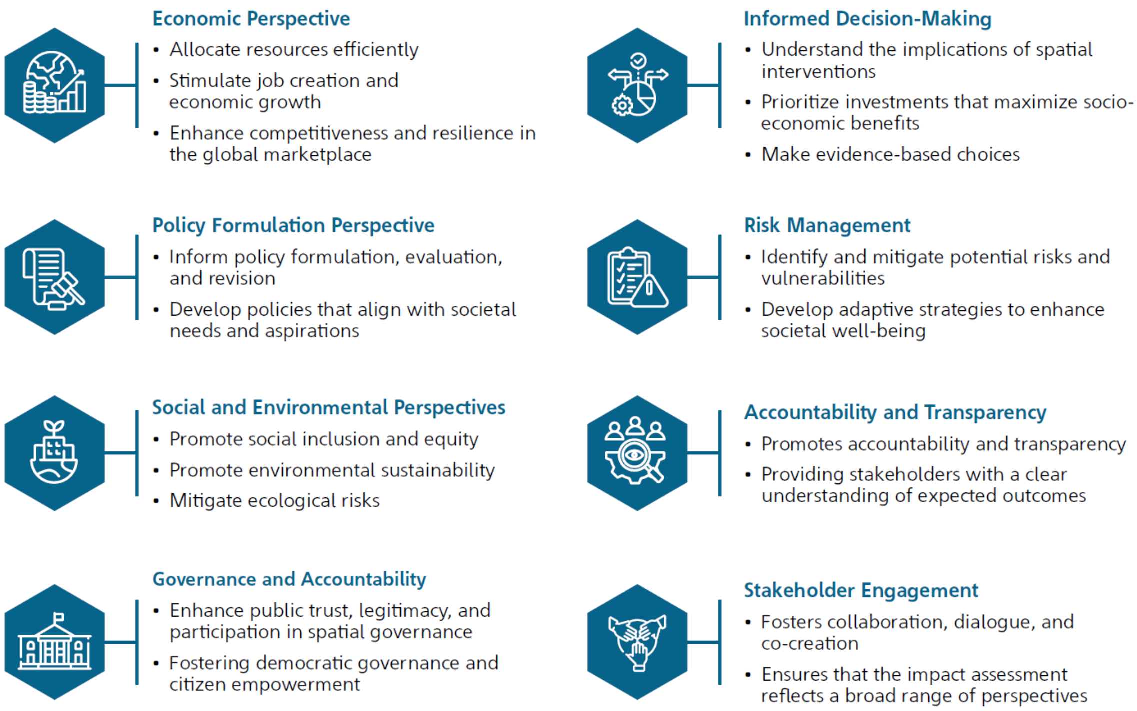
3. Social and Environmental Perspectives:

- **Social Inclusion:** Assessing the socio-economic impact of GKI helps identify disparities in access to spatial information and services, thereby promoting social inclusion and equity. By understanding the differential impacts of spatial interventions on marginalized communities, decision-makers can design targeted interventions to address inequities, enhance access to opportunities, and foster inclusive development.
- **Environmental Sustainability:** GKI impact assessments evaluate the environmental implications of spatial interventions, including their effects on natural resources, ecosystems, and biodiversity. By quantifying the environmental costs and benefits of GKI initiatives, decision-makers can adopt policies and strategies that promote environmental sustainability, mitigate ecological risks, and enhance resilience to climate change.

4. Governance and Accountability:

- Assessing the socio-economic impact of GKI promotes governance and accountability by providing stakeholders with transparency and accountability in decision-making processes. By engaging citizens, civil society organizations, and other stakeholders in the impact assessment process, decision-makers can enhance public trust, legitimacy, and participation in spatial governance, thereby fostering democratic governance and citizen empowerment.

Figure 1: Importance of Conducting a Socio-economic Impact Assessment



Source: GW Consulting

5. Informed Decision-Making:

- Conducting a socio-economic impact assessment of GKI enables stakeholders to understand the implications of spatial interventions, anticipate potential trade-offs, and prioritize investments that maximize socio-economic benefits while minimizing negative externalities.
- By quantifying the socio-economic impacts of GKI, decision-makers can make evidence-based choices, allocate resources efficiently, and optimize policy interventions to address societal needs and aspirations.

6. Risk Management:

- Assessing the socio-economic impact of GKI allows stakeholders to identify and mitigate potential risks and vulnerabilities associated with spatial interventions.
- By conducting scenario analysis and sensitivity testing, decision-makers can anticipate the socio-economic consequences of different policy choices, assess their resilience to external shocks, and develop adaptive strategies to enhance societal well-being and resilience.

7. Accountability and Transparency:

- Conducting a socio-economic impact assessment promotes accountability and transparency by providing stakeholders with a clear understanding of the expected outcomes and performance metrics associated with spatial interventions.
- By disseminating the findings of impact assessments to the public, decision-makers can foster greater trust, engagement, and accountability, thereby enhancing the legitimacy and effectiveness of spatial governance processes.

8. Stakeholder Engagement:

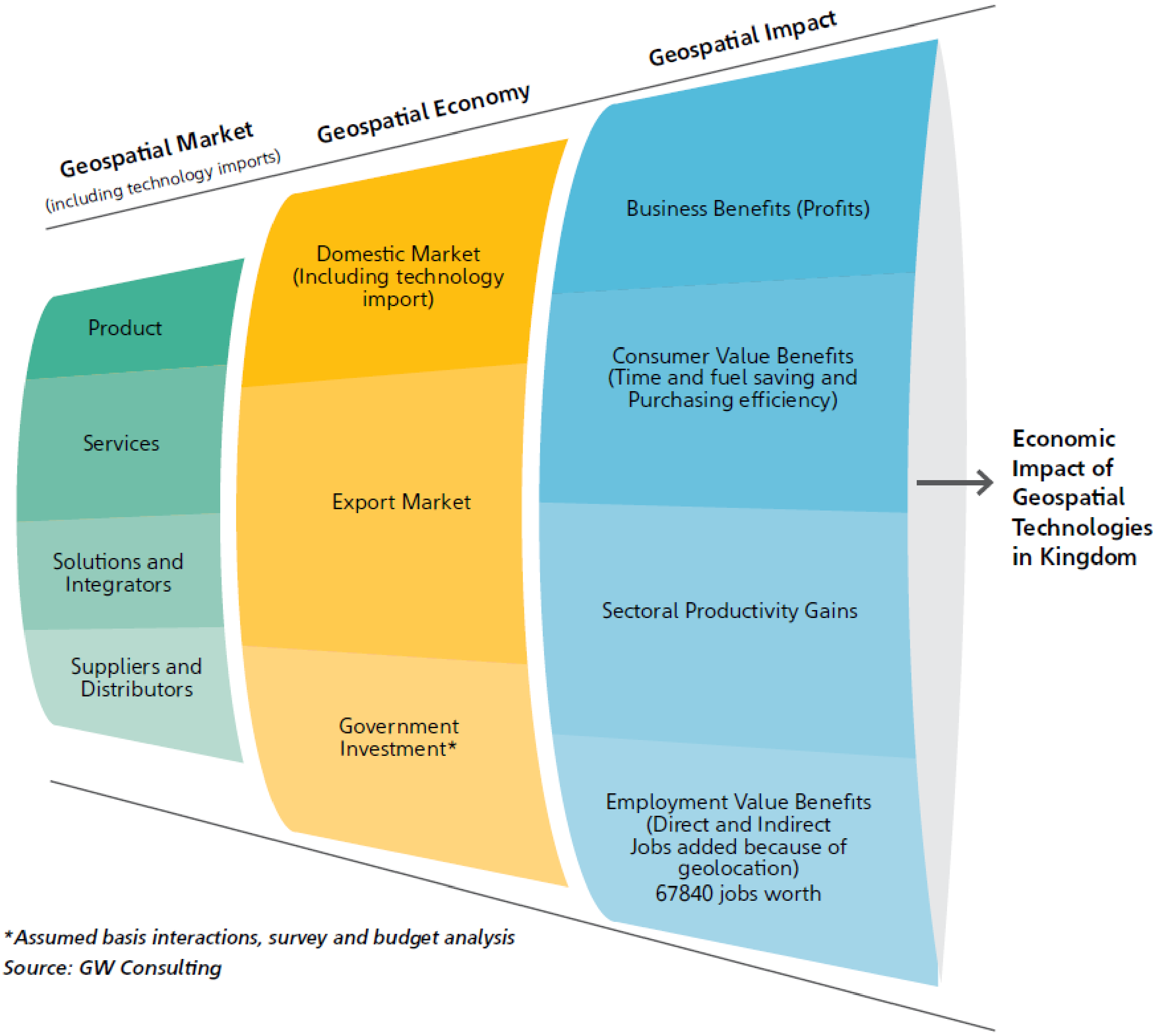
- Engaging stakeholders in the socio-economic impact assessment process fosters collaboration, dialogue, and co-creation, thereby enhancing the relevance, effectiveness, and sustainability of spatial interventions.
- By soliciting input from diverse stakeholders, including government agencies, civil society organizations, businesses, and local communities, decision-makers can ensure that the socio-economic impact assessment reflects a broad range of perspectives, priorities, and values, thereby enhancing its credibility, legitimacy, and relevance.

The integration of GKI as a concept into the socio-economic fabric of society offers a transformative potential that spans economic, governmental, and social spheres. By leveraging the power of geospatial data, societies can achieve more sustainable growth, enhanced public services, and a better quality of life for all citizens. The strategic use of GKI not only drives innovation and efficiency but also plays a crucial role in addressing some of the most pressing challenges of our time, including climate change, urbanization, and resource scarcity. As such, the development and enhancement of GKI should be a priority for policymakers, businesses, and community leaders aiming to harness the benefits of this pivotal technology.

2.3 Scope and Fundamentals of Socio-Economic Impact Assessment

Conducting a socio-economic impact assessment of geospatial technology and geospatial knowledge infrastructure on a nation's development is a multidimensional endeavour that requires a comprehensive understanding of both the technological landscape and the socio-economic dynamics at play. Quantifying the social and economic value that geospatial information contributes to modern society is a complex task. To construct reliable and consistent valuation measures, an understanding of the sequence of processes—from data acquisition to decision-makers' choices that impact society—is essential. Value is incrementally created along the chain, and pricing within a value chain is crucial for determining the distribution of this created value among the various participants (Krek, 2006). It is, therefore, important to evaluate the scope and fundamentals of socio-economic impact assessment while exploring each step of the geospatial value chain, from the technical aspects of surveying and mapping (data acquisition and management) to the delivery of services via applications, software, enterprise systems, and social media platforms, for the benefit of the global economy and society. The fundamentals of socio-economic impact assessment in the geospatial technology sector encompass the entire value chain. This assessment involves a thorough evaluation of the geospatial market, estimation of the geospatial economy, and an analysis of the overall impact of geospatial industry/technologies.

Figure 2: Importance of Conducting a Socio-economic Impact Assessment



**Assumed basis interactions, survey and budget analysis*

Source: GW Consulting

To accurately assess and communicate the economic impact of the geospatial industry, it is essential to conduct a comprehensive evaluation across multiple dimensions. This evaluation involves a detailed estimation of:

Geospatial Market Size and Assessment Across Categories: This involves quantifying the scale and scope of the market, which includes Original Equipment Manufacturers (OEMs), geospatial services, solutions, system integrators, and suppliers and distributors. By measuring these segments, we gain insights into the industry's composition and the roles various entities play.

Geospatial Economy: This component encompasses the Domestic Market, the export market of geospatial technologies, and total governmental investment in this sector. Understanding these areas helps quantify the direct financial contributions of the geospatial industry to the national economy, highlighting its significance in both domestic and international contexts.

Geospatial Impact: This analysis captures the broader benefits of the geospatial industry, such as:

- **Business Benefits:** Profits generated by companies operating within the geospatial sector.
- **Consumer Value Benefits:** Enhancements in consumer services and products due to geospatial technologies, leading to improved user experiences and satisfaction.
- **Sectoral Productivity Gains:** Increases in efficiency and effectiveness across various sectors that adopt geospatial solutions, contributing to overall economic productivity.
- **Employment Value Benefits:** Job creation and enhancement, including the development of high-skill jobs and the upskilling of existing roles through technology integration.

By systematically evaluating these components, stakeholders can understand the multifaceted contributions of the geospatial industry, facilitating strategic decision-making and policy development to foster further growth and integration of geospatial technologies within the broader economic framework.

In technical sense - Socio-economic impact assessments (SEIAs) of technology are comprehensive evaluations designed to understand the broader effects of technological innovations on society and the economy. From a geospatial perspective also, these assessments help policymakers, businesses, and other stakeholders make informed decisions by providing insights into the potential impacts of deploying or developing new technologies. Here are the key scope of such assessments:

The scope of such an assessment typically encompasses various facets, including but not limited to:

- **Technological Infrastructure:** Assessing the current state of geospatial technology infrastructure within the nation, including the availability of data, satellite imagery, geospatial tools, and communication networks. This involves evaluating the extent of coverage, resolution, and accessibility of geospatial data sources.
- **Applications and Use Cases:** Examining the diverse applications of geospatial technology across sectors such as agriculture, urban planning, natural resource management, disaster response, transportation, and public health. Understanding the specific use cases and how geospatial technology is being utilized to address societal challenges and drive economic growth.
- **Impact on Governance and Policy:** Analysing the role of geospatial technology in improving governance, transparency, and decision-making processes at various levels of government. Assessing how geospatial data is integrated into policy formulation, resource allocation, and monitoring of development initiatives.
- **Economic Contribution:** Estimating the economic value generated by the geospatial industry, including revenue from geospatial products and services, job creation, and contributions to GDP growth. Evaluating the cost savings, efficiency gains, and revenue generation enabled by geospatial technology adoption across different sectors.
- **Social and Environmental Impacts:** Investigating the social and environmental implications of geospatial technology deployment, such as its influence on community resilience, environmental conservation, and socio-economic equity. Understanding how geospatial tools can facilitate inclusive development and mitigate negative externalities.
- **Capacity Building and Human Capital Development:** Assessing the capacity of individuals, organizations, and institutions to effectively leverage geospatial technology for socio-economic development. Identifying gaps in skills, infrastructure, and institutional frameworks, and recommending strategies for capacity building and knowledge transfer.
- **Policy Recommendations and Strategic Interventions:** Formulating evidence-based policy recommendations and strategic interventions to maximize the positive socio-economic impacts of geospatial technology while minimizing potential risks and challenges. This may involve promoting interoperability, fostering public-private partnerships, and investing in research and development.

Figure 3: Scope of Work: Socio-Economic Impact Assessment Framework

Technological Infrastructure

- Data Availability: Availability of geospatial data types (satellite imagery, LiDAR, etc.).
- Coverage Extent: Geographic and thematic coverage of geospatial data.
- Data Resolution: Spatial, temporal, and spectral resolution of datasets.
- Accessibility: Ease of access to geospatial data for various user groups.
- Network Reliability: Reliability and uptime of data transmission networks.
- Integration Capability: Ease of integration with other data systems and platforms.
- Update Frequency: Frequency of data updates and refreshes.
- Technology Adoption: Rate of adoption of new geospatial tools and technologies.
- User Interface: User-friendliness of geospatial tools and platforms.
- Support Systems: Availability of technical support and user assistance.

Applications and Use Cases

- Sectoral Deployment: Usage of geospatial technologies across different sectors.
- Impact on Efficiency: Improvements in operational efficiency within sectors.
- Innovation Trigger: Role of geospatial tech in triggering sector-specific innovations.
- Problem Solving: Effectiveness in addressing specific societal challenges.
- Cost Reduction: Impact on reducing costs in critical operations.
- Decision Support: Contribution to decision-making processes.
- Public Service Enhancement: Enhancements in public services due to geospatial tech.
- Resource Management: Improvements in natural resource management.
- Emergency Response: Efficiency in disaster and emergency response.
- Health Outcomes: Contributions to public health surveillance and interventions

Impact on Governance and Policy

- Policy Formulation: Influence on the development of new public policies.
- Transparency Enhancement: Role in increasing transparency in governance.
- Public Participation: Facilitation of public involvement in governance.
- Regulatory Compliance: Assistance in monitoring regulatory compliance.
- Resource Allocation: Impact on the distribution and allocation of public resources.
- Development Monitoring: Usage in tracking development projects and initiatives.
- Data-Driven Decisions: Extent of adoption of data-driven decision-making processes.
- Cross-Agency Collaboration: Enhancement of inter-agency collaboration.
- Legislative Support: Support provided to legislative processes and law-making.
- International Cooperation: Role in fostering international governance cooperation.

Economic Contribution and Impact

- Industry Revenue: Total revenue generated by the geospatial sector.
- Job Creation: Number of jobs created directly and indirectly by the sector.
- GDP Contribution: Contribution to national GDP from geospatial activities.
- Investment Attraction: Ability to attract domestic and foreign investment.
- Innovation Rate: Rate of technological innovation driven by geospatial technologies.
- Export Capability: Impact on the export of geospatial products and services.
- Skill Development: Role in developing high-demand economic skills.
- Entrepreneurship: Stimulation of new business ventures in geospatial technologies.
- Cost Savings: Cost savings across industries due to geospatial solutions.
- Productivity Gains: Overall productivity improvements across sectors.

Social and Environmental Impact

- Community Resilience: Contributions to building resilient communities.
- Environmental Monitoring: Role in monitoring environmental changes and hazards.
- Socio-economic Equity: Impact on reducing socio-economic disparities.
- Urban Planning: Contributions to sustainable urban and regional planning.
- Cultural Heritage: Role in protecting and managing cultural heritage sites.
- Climate Action: Contributions to climate change mitigation and adaptation.
- Biodiversity Conservation: Impact on biodiversity conservation efforts.
- Water Resources Management: Improvements in managing water resources.
- Pollution Control: Role in pollution detection and control.
- Land Use Optimization: Enhancements in land use planning and management.

Thus in, conducting a socio-economic impact assessment, it is essential to employ a rigorous methodological framework that integrates quantitative and qualitative data analysis techniques. This may include surveys, interviews, case studies, economic modeling, spatial analysis, and stakeholder consultations. Additionally, collaboration between government agencies, academia, industry stakeholders, and civil society organizations is crucial to ensure the credibility, relevance, and legitimacy of the assessment findings and recommendations. When conducting a socio-economic impact assessment of geospatial technology on a nation's development, several key fundamentals should be considered to ensure a comprehensive and rigorous analysis.

2.4 Research Methodologies

Conducting a socio-economic impact assessment of geospatial technology on a nation's development requires employing a diverse array of research methodologies to capture the multifaceted nature of impacts. These methodologies encompass both quantitative and qualitative approaches, each offering unique insights into different aspects of the assessment. Below are several varied research methodologies commonly used in such assessments:

Case Study Analysis for Socio-Economic Impact Assessment [SEIA]

Using case study analysis in a socio-economic impact assessment (SEIA) provides a detailed and contextual approach to evaluate the effects of an intervention, such as the implementation of geospatial technology. Case studies can offer in-depth insights into complex phenomena by exploring how specific variables interact. Here's a structured approach to integrating case study analysis for socio-economic impact analysis -

1. Selection of Case Studies

Select case studies that are relevant to the technology and its application representing a variety of geographic locations, population groups, and economic contexts to capture diverse impacts including multiple case studies can provide a comparative analysis that highlights different outcomes and reasons behind those differences.

2. Assessment Framework Development

Define the specific socio-economic areas you want to assess, such as employment, productivity, access to services, inequality, and environmental sustainability. Establish clear indicators for each impact area which should be measurable and directly related to the goals of geospatial technology implementation.

3. Data Collection

Gather data on investment, operational costs, usage rates, and economic output linked to the technology in the case studies. This may include budgetary allocations, revenue generation, and cost-saving metrics. Simultaneously, conduct interviews, focus groups, and surveys with stakeholders such as local government officials, business owners, technology users, and community members. Document narratives and personal experiences that describe the perceived impacts.

4. Defining Patterns and Analysis Method

Compare findings across different case studies to identify patterns or variances in socio-economic impacts. This can help in understanding the conditions under which geospatial technology has the most beneficial impacts. Analyze how external factors such as economic conditions, policy environments, and cultural aspects influence the outcomes observed in the case studies.

5. Synthesis and Generalization

Draw together the data from various case studies to synthesize overarching insights. Highlight the key drivers of successful implementation and the barriers faced. Carefully generalize the findings to broader contexts, noting any limitations in applicability due to specific conditions in the case studies.

Selection of Case Studies → **Assessment Framework Development** → **Data Collection** → **Defining Patterns and Analysis Method** → **Synthesis and Generalization**

Incorporating case study analysis in socio-economic impact assessments not only provides detailed insights into individual and community-level impacts but also enhances the robustness of the findings by illustrating how various factors contribute to different outcomes. This approach is particularly effective in understanding new technologies like geospatial tools, where direct causal relationships may not be readily apparent.

Survey Research: Conduct surveys to gather quantitative data on the adoption, usage patterns, and perceived impacts of geospatial technology among various stakeholders, including government agencies, businesses, non-profit organizations, and individuals. Surveys can be designed to capture demographic information, technology adoption rates, user satisfaction, and behavioural changes resulting from geospatial technology interventions.

Case Studies: Undertaking in-depth case studies to explore specific geospatial technology initiatives and their socio-economic impacts in real-world contexts provides rich qualitative insights into the mechanisms, challenges, and outcomes of geospatial technology implementation across different sectors and geographical regions.

Econometric Analysis: Applying econometric techniques to analyze large-scale datasets and estimate the causal effects of geospatial technology adoption on various socio-economic indicators, such as economic growth, employment, productivity, and income distribution. Econometric models may include regression analysis, difference-in-differences estimation, propensity score matching, and instrumental variable methods to control for confounding factors and identify causal relationships.

Qualitative Interviews and Focus Groups: Conducting qualitative interviews and focus groups with key stakeholders to explore their perspectives, experiences, and perceptions regarding the socio-economic impacts of geospatial technology provide valuable insights into the contextual factors, social dynamics, and institutional arrangements that shape the adoption and diffusion of geospatial technology innovations.

Cost-Benefit Analysis (CBA): Performing cost-benefit analysis helps to assess the economic efficiency and societal welfare implications of geospatial technology investments. CBA involves quantifying the costs and benefits associated with geospatial technology projects, including both monetary and non-monetary factors, and comparing them to determine the net social value or rate of return on investment.

Cost-Benefit Analysis for Socio-Economic Impact Assessment [SEIA]

1. Define the Scope and Objectives

Define what is the aim to assess with the CBA, focusing on the economic impacts of geospatial technology. Determine the geographical and temporal scope of the analysis and whether to include all or which of direct, indirect, and induced impacts.

2. Identify Costs and Benefits

Include all costs associated with the implementation and maintenance of geospatial technologies. This includes initial capital investment, ongoing operational expenses, training costs, and any upgrades or expansions. Alternatively, measure direct benefits such as improvements in productivity, efficiency gains, reduction in costs due to optimized resource use, and increased revenue from enhanced services using case study analysis, and any information available. Account for broader economic benefits such as job creation, enhanced data accuracy for other sectors, improved environmental management, and better planning and development outcomes due to the availability of detailed spatial data.

3. Quantify Costs and Benefits

Assign monetary values to both costs and benefits using market prices where applicable. For benefits or costs where market prices are not available, use alternative valuation methods such as shadow pricing, willingness to pay, or cost of replacement. Estimate the expected life of the technology and the time over which the costs and benefits will accrue. This is crucial for calculating net present values.

4. Discount Costs and Benefits

Apply a discount rate to reflect the time value of money. Choosing an appropriate discount rate is critical and can be based on government economic guidelines or sector-specific standards. Alternatively, calculate the NPV of the project by discounting the benefits and costs to their present values. An NPV greater than zero indicates that the benefits outweigh the costs.

5. Sensitivity Analysis

Perform sensitivity analyses to understand how changes in key assumptions (such as discount rates, benefit estimates, or cost overruns) impact the CBA outcomes. Consider different scenarios (e.g., high adoption rates, technological advancements) to reflect varying future possibilities and their impact on costs and benefits.

Define the Scope and Objectives → **Identify Cost and Benefits** → **Quantify Cost and Benefits** → **Discount Cost and Benefits** → **Sensitivity Analysis**

Cost-Benefit Analysis provides a robust framework for decision-makers to evaluate the economic worthiness of investing in geospatial technologies, ensuring that the economic benefits derived from the technology justify the expenditures incurred.

Survey Research: Conduct surveys to gather quantitative data on the adoption, usage patterns, and perceived impacts of geospatial technology among various stakeholders, including government agencies, businesses, non-profit organizations, and individuals. Surveys can be designed to capture demographic information, technology adoption rates, user satisfaction, and behavioural changes resulting from geospatial technology interventions.

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By employing a combination of these varied research methodologies, agencies can conduct a robust and nuanced socio-economic impact assessment of geospatial technology on a nation's development, generating actionable insights to inform policy decisions, investment strategies, and technology interventions. In socio-economic impact assessment, it is import to consider and analyze the effects of interventions or technologies on society and the economy.

Communicating the Value of Geospatial Knowledge Infrastructure (GKI)

Effectively articulating the value of a Geospatial Knowledge Infrastructure requires a structured, repeatable framework that links stakeholder needs with the strategic, operational, and societal outcomes enabled by spatial intelligence. To support this objective, **a communication framework developed collaboratively by the U.S. Geological Survey (USGS) and the University of Pittsburgh and as showcased at GeoSmart India 2025** provides a foundational model for simplifying and conveying GKI's value across diverse audiences.

At its core, this framework positions GKI's value proposition as a function of five interconnected components—Audience, Pain, Solution, Gain, and Impact—forming a logical sequence that translates technical capability into strategic relevance.

Value Proposition Framework: f(A, P, S, G, I)

1. Audience (A): Clarifies who the value narrative is addressing—policymakers, regulators, private-sector innovators, local governments, or citizens. Understanding the audience ensures that the articulation of value is tailored, relevant, and aligned with their priorities and decision-making context.

2. Pain (P): Identifies the core challenges, inefficiencies, or risks that the audience currently faces.

These may include fragmented data ecosystems, planning uncertainty, rising climate vulnerabilities, or inefficient public service delivery.

3. Solution (S): Describes how GKI responds to the identified pain points through integrated geospatial governance, shared data infrastructure, and spatial intelligence capabilities. This step links functional attributes—interoperability, data quality, governance structures—to tangible problem-solving.

4. Gain (G): Articulates the benefits and improvements delivered by implementing or strengthening GKI.

These include improved economic efficiency, enhanced policy effectiveness, streamlined operations, greater transparency, and stronger multi-stakeholder collaboration.

5. Impact (I): Highlights the broader, long-term societal and economic outcomes generated—such as increased resilience, sustainable development, equitable service delivery, and improved national competitiveness. Impact moves beyond organizational benefits to demonstrate the systemic value of GKI at scale.

Strategic Relevance

The framework's strength lies in its ability to simplify complex geospatial ecosystems into a narrative that resonates with executive leadership and policy decision-makers—groups that often influence funding, adoption, and prioritization. By grounding the communication in audience needs and demonstrating clear pathways from challenges to outcomes, the framework ensures that GKI is viewed not merely as a data initiative but as a strategic national capability.

This approach enables governments and organizations to:

- Align GKI investments with national priorities and sectoral strategies
- Communicate the return on investment in terms of efficiency, resilience, and competitiveness
- Build cross-sector coalitions by demonstrating shared value
- Strengthen public understanding and stakeholder engagement in spatial governance

Example: Value Proposition for Geospatial Capabilities in a National Mapping Agency

"The governments, emergency services, industry innovators, and other national stakeholders who rely on authoritative geospatial intelligence [A] face persistent challenges from fragmented, inconsistent, and non-interoperable spatial data that hinder timely, evidence-based decision-making [P]. The National Mapping Agency addresses these challenges through a unified, authoritative, and continuously updated geospatial ecosystem powered by advanced mapping, Earth observation, and national data standards [S]. This enables faster, more reliable decisions, reduces duplication, improves operational efficiency, and accelerates innovation across sectors [G]. As a result, the nation benefits from stronger economic resilience, enhanced climate adaptation, optimised infrastructure planning, and reinforced digital sovereignty [I]."

Value Proposition of Geospatial Knowledge Infrastructure (GKI)

A robust Geospatial Knowledge Infrastructure (GKI) establishes the foundational data, governance, and institutional capabilities required for a modern, spatially enabled economy. By integrating geospatial intelligence across public, private, and civil-sector systems, GKI enhances national competitiveness, strengthens governance, and supports evidence-driven decision-making. Its value proposition spans economic performance, policy formulation, societal well-being, risk mitigation, and institutional effectiveness.

1. Economic Value Creation

GKI acts as a catalytic asset for national development by embedding spatial intelligence into economic planning and market operations.

- **Resource Optimization:** Governments and enterprises can allocate infrastructure, capital, and social investments with greater precision, minimizing inefficiencies and duplication.
- **Growth and Competitiveness:** Spatial data reduces transaction costs, improves logistics and supply chains, supports digital commerce, and strengthens participation in the global digital economy.
- **Innovation Enablement:** GKI underpins emerging sectors—including smart cities, autonomous mobility, precision agriculture, and climate-tech—driving job creation and entrepreneurial activity.

2. Policy Formulation and Public Sector Efficiency

A mature GKI enables administrations to design, evaluate, and refine policies anchored in objective, location-based insights.

- **Evidence-Driven Policy Cycles:** Spatial analytics enhance the ability to diagnose problems, monitor implementation, and assess policy effectiveness across sectors such as housing, health, transport, and land use.
- **Alignment with Societal Priorities:** The infrastructure ensures that policies reflect demographic, environmental, and socio-economic realities at local and national scales.
- **Regulatory Modernization:** GKI strengthens land administration, zoning, environmental regulations, and urban development frameworks through transparent and consistently updated geospatial information.

3. Social and Environmental Impact

By embedding geospatial knowledge into community and environmental systems, GKI supports more equitable and sustainable outcomes.

- **Social Inclusion:** Accurate spatial data reveals underserved communities, enabling targeted interventions in education, healthcare, and infrastructure.
- **Environmental Stewardship:** GKI enables the tracking of ecological change, supports conservation strategies, and promotes low-carbon development pathways.
- **Risk Reduction:** Spatial intelligence helps identify environmental stressors, anticipate ecological degradation, and guide mitigation strategies.

4. Governance, Accountability, and Institutional Trust

A well-designed GKI strengthens the foundations of transparent and equitable governance.

- **Enhanced Accountability:** Shared geospatial platforms allow citizens and stakeholders to understand public decisions, monitor delivery, and validate outcomes.
- **Citizen Empowerment:** Open geospatial data supports participatory planning, fosters democratic engagement, and reduces information asymmetries.
- **Improved Inter-Agency Coordination:** By standardizing spatial data governance, GKI reduces fragmentation and encourages coherent action across ministries, local authorities, and service providers.

5. Informed Decision-Making for Public and Private Sectors

GKI elevates strategic decision-making by providing a consistent, reliable, and interoperable geospatial intelligence layer.

- **Investment Prioritization:** Decision-makers can evaluate spatial trade-offs, allocate capital to high-impact areas, and design interventions that maximize socio-economic return.
- **Scenario Simulation:** Integrated datasets enable modelling of spatial interventions—such as new transport corridors, energy infrastructure, or urban expansions—before capital commitments are made.
- **Operational Efficiency:** Organizations benefit from streamlined workflows, reduced data redundancy, and improved situational awareness for daily operations.

6. National Risk Management and Resilience

A core value of GKI lies in its ability to strengthen national preparedness and resilience.

- **Proactive Risk Identification:** Spatially integrated risk models help identify vulnerabilities related to natural hazards, infrastructure failures, security risks, and climate impacts.
- **Adaptive Planning:** GKI supports the design of adaptive strategies that evolve with emerging threats and changing environments.
- **Rapid Response:** During crises, geospatial insight accelerates response coordination, resource deployment, and recovery planning.

7. Stakeholder Engagement and Collaborative Innovation

GKI functions as a unifying platform for cross-sector collaboration.

- **Co-Creation Ecosystems:** Public agencies, private enterprises, academia, and civil society can jointly leverage geospatial data to develop solutions and innovate.
- **Multi-Perspective Assessment**: Spatial information ensures policies and investments reflect diverse viewpoints and regional variations, strengthening legitimacy and adoption.
- **Market Development:** By lowering barriers to access, GKI nurtures a competitive ecosystem of data providers, technology firms, and service innovators.

Summary

The strategic value of GKI extends far beyond geospatial data management. It forms a national asset that enhances competitiveness, strengthens resilience, improves governance, and supports sustainable socio-economic development. For countries and organizations seeking to transition toward a knowledge-driven and spatially enabled future, GKI represents a critical enabling infrastructure with long-term systemic impact.

2.5 Value of economic impact and its relationship with GKI for National Development

Geospatial Knowledge Infrastructure (GKI) has become a strategic pillar of modern national development. By integrating spatial data and technologies across sectors, GKI enhances decision-making, optimises resource allocation, and strengthens national competitiveness. Countries that effectively harness geospatial capabilities are better positioned to achieve sustainable growth, operational efficiency, and economic resilience.

1. Strengthened Decision-Making and Governance

GKI provides precise, real-time insights that improve planning, governance, and sectoral coordination. Examples include the USGS's water-resource management systems, Singapore's land-use optimisation, Germany's renewable-energy grid management, and South Korea's integrated urban planning. These applications reduce risk, enhance service delivery, and produce measurable economic savings.

2. Improved Efficiency and Productivity Across Sectors

Geospatial data streamlines operations in logistics, transportation, agriculture, and public services. Route optimisation by UPS and FedEx, precision agriculture in Australia and Canada, and Japan's AI-enabled e-kakashi farming platform demonstrate how GKI reduces costs, increases yields, and drives operational efficiency. This translates directly into national productivity gains and improved competitiveness.

3. Catalyst for Innovation and New Market Creation

GKI stimulates innovation ecosystems, enabling new business models and market opportunities. India's Bhuvan platform, Africa's Zipline drone-delivery network, and Dutch water-management innovations illustrate how geospatial data fuels entrepreneurship, accelerates technological advancement, and supports emerging industries.

4. Foundation for Sustainable Development and Environmental Management

GKI is indispensable for climate resilience, conservation, and sustainable resource management. Brazil monitors the Amazon to combat deforestation, Canada manages forest-fire risk, and the Philippines uses geospatial tools for coastal protection and disaster mitigation. These initiatives safeguard ecosystems while supporting economic sectors such as agriculture, tourism, and forestry.

Strategic Value

Collectively, these examples show that GKI is far more than a mapping asset: it is foundational national infrastructure. It strengthens economic performance, enhances governance, accelerates innovation, and supports environmental sustainability. As nations confront complex socio-economic and climate challenges, GKI's role becomes central to maintaining global competitiveness and building long-term resilience. Strategically, well-governed investment in GKI will determine which countries thrive in the emerging knowledge economy—enabling more agile decision-making, improved resource stewardship, and sustainable prosperity for future generations.

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LESSON - 3

Building GKI and Prioritizing State-Level Development

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3.1 Session Overview

The future of India's digital governance and economic landscape hinges on the effectiveness with which states integrate geospatial intelligence into their fundamental administrative, planning, and service delivery frameworks. The Geospatial Knowledge Infrastructure (GKI) presents a forward-thinking framework that is rooted in real-time data, compatible platforms, and cohesive workflows, all aimed at enhancing governance effectiveness, boosting economic competitiveness, and ensuring public accountability. According to India's National Geospatial Policy 2022, foundational baselines are established by the country's national mapping and geospatial agencies; however, it is imperative for states to enhance their last-mile capacity by aligning policies, developing infrastructure, fostering partnerships, and implementing institutional reforms.

Essential transformation drivers encompass six interconnected pillars: a strong data infrastructure, empowered governmental institutions, and supportive policy and regulatory frameworks. Similarly, engagement with the user ecosystem, collaboration with the private sector and innovation, and ongoing investments in education and capacity development. As prominent states progress decisively, many others are still cultivating governmental frameworks that are hindered by a shortage of skilled employees, outdated infrastructure, and unclear data policies. The directive is unmistakable: states that excel in GKI advancement will reveal fiscal efficiencies, expedite developmental results, and influence India's digital growth path.

Learning Objectives

- **Define the concept of Geospatial Knowledge Infrastructure (GKI)** and explain its strategic importance.
- **Identify the evolving roles and institutional responsibilities of National Mapping Agencies (NMAs)** under the National Geospatial Policy 2022, particularly how they interface with state-level entities.
- **Evaluate key enablers at the state level**, including data infrastructure, industry and innovation ecosystems, and adoption of geospatial technologies across the user sector value chain.
- **Assess collaborative mechanisms at the state level**, such as public-private partnerships, academic linkages and international cooperation that can accelerate geospatial innovation and capacity-building.
- **Identify institutional and ecosystem-wide strategies to operationalise state-level geospatial transformation** by creating robust data infrastructure, institutional capacity, policy reform, user engagement, industry and innovation, and capacity development.

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3.2 India's National Mapping Ecosystem: Institutional Roles and Strategic Integration

India's national geospatial ecosystem is supported by a robust institutional ecosystem comprising core scientific and administrative bodies. Central to this structure is the Survey of India (SoI), the oldest scientific department in the country, which provides the authoritative geodetic and cadastral baselines. It is the national reference agency for spatial accuracy, boundary delineation, and geodetic control infrastructure (Survey of India, 2022).

Complementing SoI is the National Atlas and Thematic Mapping Organisation (NATMO), which plays a pivotal role in atlas compilation and thematic mapping (NATMO, 2025). They integrate thematic maps based on socio-economic and environmental data and also prepare school and state atlases. The Geological Survey of India (GSI) contributes foundational geoscientific data on the subsurface terrain, mineral resources, and seismicity, underpinning critical national infrastructure planning. The organisation is responsible for mapping the nation's geology, assessing mineral, water, and energy resources, and maintaining spatial data repositories. GSI's data feeds into resource exploration, land-use planning, and disaster risk mitigation (Geological Survey of India, 2025).

The ecosystem is further amplified by national policies and programmes. The National Geospatial Policy 2022 (NGP 2022) liberalised access to geospatial data and enabled public-private innovation. Initiatives such as Bharat Maps and the SVAMITVA Scheme institutionalise interoperable platforms for e-governance and land reform. These developments mark a strategic shift from siloed data production to integrated, multi-source, real-time geospatial intelligence that supports governance, public service delivery, and infrastructure development. The NGP 2022 establishes a framework of legal clarity and promotes the democratisation of data by facilitating open access to non-sensitive geospatial information.

The national mapping architecture of India has experienced a profound transformation, with the Survey of India (SoI) serving as the principal national mapping agency. With a rich history spanning more than two centuries, SoI is entrusted with the responsibility of providing high-precision geospatial data that serves as a foundation for planning, infrastructure, and governance systems. Central to this evolution is the implementation of sophisticated infrastructure and technologies. The establishment of the Continuously Operating Reference Stations (CORS) Network signifies a pivotal advancement in technology, facilitating centimetre-level precision (Department of Science and Technology, 2025). The integration of drone-based aerial surveys alongside Artificial Intelligence and Machine Learning (AI/ML) enabled analytics facilitates high-frequency, granular mapping.

The stakeholder constellation within this ecosystem is notably extensive. At present, the government acts as a driving force, facilitating the gradual integration of private geospatial companies, civil society organisations, academic entities, and end-users into the ecosystem. Platforms such as Bharat Maps, developed by the National Informatics, illustrate the effective amalgamation of various data sources designed to improve public services and e-governance, while also enabling timely decision-making assistance.

Figure 1: India's National Geospatial Agencies

3.3 Infrastructure and Data Foundations Accelerate India's Geospatial Maturity

India's geospatial maturity hinges on robust data and technology infrastructure. Foundational geospatial datasets are being centralised in a unified national platform. Survey of India is establishing a pan-India CORS network and geodetic reference frame to deliver high-accuracy positioning as the "national accuracy backbone". These standards underpin all mapping, visualization and analytics by ensuring every layer is georeferenced to the same datum. Concurrently, India's new National Geo Platform will "standardize, share and manage" authoritative datasets via web services and APIs (Ministry of Science and Technology, 2025).

- **Foundational Data & Positioning:** Survey of India (SoI) is consolidating core geospatial layers (orthoimagery, DEM, administrative boundaries, geodetic frame, etc.) into a unified repository. A nationwide CORS network ensures centimetre-level location accuracy for all stakeholders.
- **Unified Geospatial Platform:** The new National Geo Platform (SoI) will serve as a robust and scalable system for standardising, sharing, and managing foundational geospatial datasets through APIs, web portals and mobile apps. This "state-of-the-art digital infrastructure" will harmonise data formats and metadata (via a Spatial Data Registry) to promote cross-agency reuse (Ministry of Science and Technology, 2025).
- **Connectivity, Cloud and Artificial Intelligence:** High-speed connectivity (rural broadband, IoT networks and 5G) and cloud computing enable real-time geospatial workflows. For example, emerging Digital Twin projects fuse live IoT sensor feeds, AI/ML analytics and cloud services into city models. By leveraging AI, ML, IoT and cloud computing, digital twins can integrate diverse data streams into a single platform (Geospatial World, 2024).

3.4 National Geospatial Policy and Responsibilities

The National Geospatial Policy 2022 transitions India from a legacy, permission-based geospatial regime to an open, innovation-driven infrastructure model, positioning geospatial data as a foundational layer for national development and economic growth (Ministry of Science and Technology, 2022).

Six Core Pillars of Policy Reform

- Open Data Regime: Publicly funded datasets mandated for open access via self-certification.
- Unified Digital Infrastructure: Creation of National Geospatial Data Repository (NGDR) and Unified Geospatial Interface (UGI) for API-enabled access and inter-agency interoperability.
- Domestic Capability Development: Empowers Indian enterprises to generate and commercialise data under Atmanirbhar Bharat; reduces foreign dependence.
- Public-Private Innovation Framework: Institutionalises PPPs via the Geospatial Data Promotion and Development Committee (GDPDC); promotes full-stack private participation in data, analytics, and applications.
- Standards-Driven Interoperability: Mandatory compliance across systems, enabling scale, integration, and operational cohesion.
- Human Capital and Capacity Building: Targets skill gap with curriculum overhaul, training programmes, and academia-industry linkages.

Survey of India: Strategic Transformation

- Repositioned as Nodal Authority for foundational geospatial reference data (e.g., DEMs, orthoimagery, boundaries).
- Evolving from an exclusive producer to a national coordinator, enabling decentralised data generation while ensuring integration into a unified reference framework.
- Industry-responsive role, coordinating national frameworks while enabling private-sector innovation.

Impact: NGP 2022 frames geospatial intelligence as a vital public resource, fundamental to the tenets of sound governance, national strength, and the progression of India's $5 trillion economy (Ministry of Science and Technology, 2022).

3.5 National Mapping Agencies and State Responsibilities

At the state level, governments predominantly depend on the insights and knowledge offered by national agencies, especially the state-based Directorates of the Survey of India. State governments collaborate with local SOI Geo-spatial Directorates to address particular survey needs associated with state-level developmental initiatives. The Survey of India, as the foremost national mapping agency, spearheads the development of the country's geospatial framework. It sustains a network of specialised directorates and regional offices.

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Similarly, the National Remote Sensing Centre and the Regional Remote Sensing Centres (RRSCs) work with state government to deliver projects. They provide critical support for disaster management, geospatial services, and various applications across national, regional, and state levels.

State and Local Geospatial Bodies

- **State Remote Sensing Centres (SRSACs):** They function as independent entities within each state, frequently operating under the auspices of the State Department of Science and Technology or Planning, serving as the principal agency for geospatial initiatives.
- **Land Records/Survey Departments (DLRS):** The directorates responsible for state land records oversee the maintenance of cadastral maps and the automation of property records.
- **State Departments:** State departments utilise geospatial data for a diverse array of applications, encompassing infrastructure planning, disaster management, public safety, resource management, and e-governance.

NGP 2022 and Institutional Responsibilities at the State Level

As integral nodes within India's federated geospatial infrastructure, state-level organisations are entrusted with crucial responsibilities that advance national priorities through localised stewardship and domain-specific expertise. Under the National Geospatial Policy 2022, state-level agencies are designated as Lead Partnering Agencies for fundamental or sectoral data themes, with defined governance responsibilities (Ministry of Science and Technology, 2022). It requires that they establish Partnering Agency Data Nodes that are integrated with the National Geospatial Data Registry (NGDR) and the Unified Geospatial Interface (UGI), thereby guaranteeing open access to geospatial data generated by the state in accordance with national standards. States must uphold interoperability through adherence to common reference systems, eliminate duplication via integrated workflows with central agencies, and retain autonomy to disseminate data through their own platforms.

These provisions anchor cooperative federalism, enabling federated data stewardship, standardised service delivery, and spatial infrastructure harmonisation. These mandates operationalise cooperative federalism within the geospatial domain, ensuring state capacities are leveraged strategically while aligning with India's overarching vision of integrated spatial infrastructure (Ministry of Science and Technology, 2022).

In sum, this framework aligns the Survey of India and other agencies as institutional leads for core geospatial themes, operating as nodes in a federated data infrastructure. State remote sensing centres and line departments mirror this structure regionally. Together, under NGP 2022, they are empowered to modernise mapping, remove data silos, and share high-quality geospatial data openly for governance and development.

3.6 State-Level Collaborations and Partnerships

At the state level, collaborative models and partnerships are pivotal for scaling geospatial innovation and service delivery. Centre–state collaborations enable integrated governance, with national agencies and mapping authorities working with state departments on targeted initiatives through unified platforms like the Geospatial Data Interface (GDI) and National Geospatial Platform. Inter-departmental collaborations are institutionalised through State Spatial Data Infrastructure or State GIS Centres, promoting cross-sectoral coordination. States also engage the private sector via Public-Private Partnerships (PPPs), tapping into cutting-edge technologies and domain expertise for high-impact projects. International linkages allow states to align with global standards through initiatives like the UN-GGIM.

Operational models such as Andhra Pradesh's CORS integration (The Times of India, 2025), Haryana's full-state drone-based mapping (The Tribune, 2025), Maharashtra's municipal GIS collaborations (The Indian Express,2024), and Assam's satellite-based flood risk systems (Government of Assam, 2025) illustrate scalable templates for geospatial deployments. Additionally, academic partnerships underpin innovation. Government-academia collaborations advance R&D, while industry-academia partnerships support incubation, skill development, and tech transfer. International academic alliances build capacity through joint research and degree programmes.

These partnerships drive value through enhanced governance, data-driven decision-making, and improved transparency. They reduce operational inefficiencies by enabling shared infrastructure and eliminating duplication. States benefit from accelerated innovation cycles, reduced costs, and scalable service models. Overall, collaborative frameworks empower states to transition toward smarter, more resilient, and more accountable governance ecosystems by embedding geospatial intelligence into core developmental workflows.

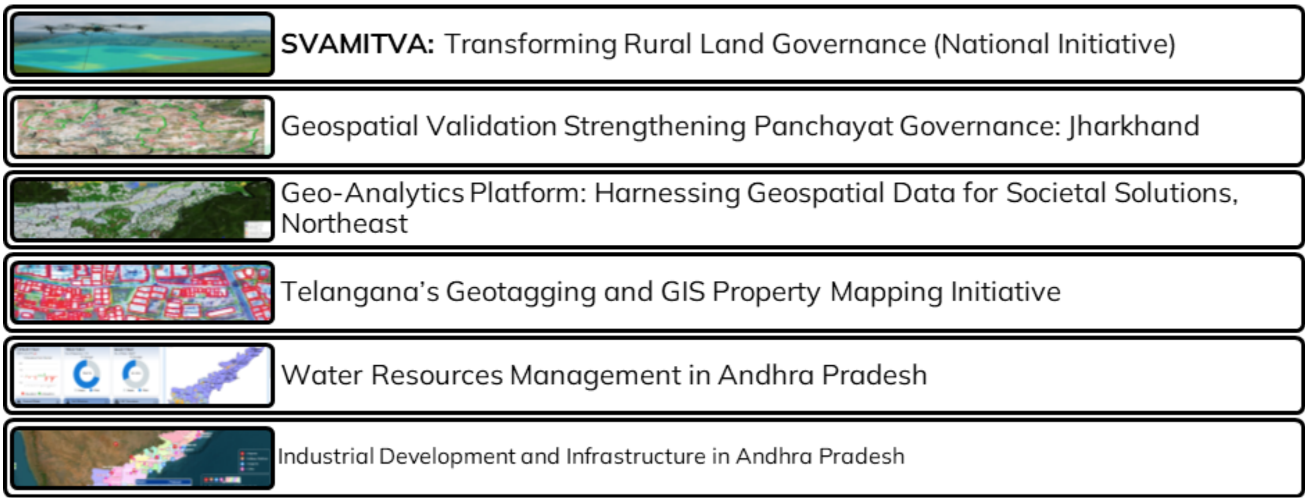
3.7 State-Level Realities and Ongoing Programs

The geospatial ecosystem in India is experiencing a significant transformation, with states assuming pivotal roles in advancing data-driven governance. The Survey of India is at the forefront of initiatives such as SVAMITVA and the validation of Panchayat boundaries, providing precise cadastral data and improving land rights, access to credit, and the processes of decentralised planning (Ministry of Panchayati Raj, 2021).

Simultaneously, the Northeastern Space Applications Centre (NESAC) has implemented a geo-analytics platform aimed at tackling significant challenges, including deforestation and food security, through the utilisation of extensive spatial data (NITI Aayog, 2025). The GIS-based property mapping in Telangana facilitates comprehensive urban planning through inter-agency collaboration (National Institute of Urban Affairs, 2025), whereas Andhra Pradesh's Andhra Pradesh Water Resources Information and Management Systems (APWRIMS) incorporate data on water resources to enhance management efficiency (NITI Aayog, 2024). The APIIC (Industrial) AGILE platform serves as a prime illustration of how Geographic Information Systems (GIS) can enhance the efficiency of land allotment processes, optimise infrastructure management, and expedite the approval mechanisms within the context of industrial development (Government of Andhra Pradesh, 2024).

These initiatives collectively exemplify scalable models that utilise geospatial data to enhance service delivery, optimise resource planning, and promote transparency. The recurring themes, like interoperability, institutional coordination, and domain-specific applications, illustrate the potential for geospatial infrastructure to be systematically integrated at scale. Such integration will foster resilient, data-driven state capabilities that are in harmony with national development objectives.

Figure 2: Ongoing Geospatial Programmes National/State level



Alignment with NGP 2022 & Need for State-level Policy

The NGP 2022 emphasises the need for a unified national geospatial data infrastructure, highlighting the necessity of state-level alignment to avert integration failures and escalating fiscal expenditures. States are assigned responsibilities that include acting as principal agencies for essential data themes and functioning as Partnering Agency Data Nodes. It is imperative that they guarantee open access to state data, maintain national standards for interoperability, and avert unnecessary duplication of efforts, all while preserving autonomy in the dissemination process. Aligning with NGP 2022 facilitates interoperability, dismantles data silos through the National Geospatial Data Registry (NGDR) and Unified Geospatial Interface (UGI), bolsters initiatives such as PM Gati Shakti, and enhances state-level governance by providing accessible, real-time geospatial data.

An established state geospatial policy is essential for tailoring the NGP 2022 to meet local requirements. It improves coordination, governance, and service delivery, while simultaneously fostering local innovation, enhancing data accessibility, and promoting skill development. The paramount conclusion is that, in the absence of state-level geospatial policies that are in harmony with NGP 2022, states face the potential of being marginalised from India's cohesive digital development framework.

Geospatial Knowledge Infrastructure at the State Level

The Geospatial Knowledge Infrastructure (GKI) is pivotal at the state level in facilitating India's evolution into the world's third-largest economy by the year 2027. Within the framework of Viksit Bharat 2047, GKI emerges as a fundamental economic catalyst, facilitating enhanced productivity, fostering innovation, and improving governance efficiency. The geospatial market in India is anticipated to attain a valuation of 106,000 crores by the year 2030, presenting significant avenues for investment in start-ups, geospatial clusters, and established anchor firms (Geospatial World, 2025). Nonetheless, the geospatial maturity at the state level exhibits considerable variability. While Andhra Pradesh, Gujarat, Karnataka, Telangana, and Maharashtra are advancing the institutionalisation of geospatial governance, other regions are still in the process of establishing foundational capabilities.

A cohesive knowledge ecosystem enhances integrated planning and facilitates data-informed decision-making, fosters collaboration within the private sector, and empowers more intelligent governance through the integration of workflows. It will help address unique developmental challenges faced by individual states, promote sustainable management of resources, and emphasise the importance of standardisation and interoperability. To maintain a competitive edge, it is imperative for states to enhance their institutional mechanisms, develop strategic capacities, and emphasise frameworks for knowledge sharing. This approach will facilitate the integration of geospatial intelligence into governance and developmental trajectories.

Conclusion

The conclusion is unequivocal: the forthcoming decade of governance efficiency and economic advancement in India is contingent upon the modernisation of geospatial foundations at the state level, in alignment with national policy. Although the Survey of India and national platforms provide essential support, it is imperative that states take the initiative in enhancing last-mile capability through the development of policy, establishment of standards, and commitment to institutional investment. Entities that engage proactively are poised to realise substantial financial advantages, enhanced strategic planning outcomes, and multifaceted effects across various sectors, underscoring the essential function of governmental leadership in a cohesive geospatial future.

Appendix: List of Abbreviations

GKI	Geospatial Knowledge Infrastructure
SoI	Survey of India
NATMO	National Atlas and Thematic Mapping Organisation
NRSC	National Remote Sensing Centre
ISRO	Indian Space Research Organisation
NIC	National Informatics Centre
CORS	Continuously Operating Reference Stations
GNSS	Global Navigation Satellite System
EO	Earth Observation
GIS	Geographic Information System
GPS	Global Positioning System
NGP	National Geospatial Policy 2022
NGDR	National Geospatial Data Registry
UGI	Unified Geospatial Interface
PPP	Public-Private Partnership
GDPDC	Geospatial Data Promotion and Development Committee
BIM	Building Information Modelling
ERP	Enterprise Resource Planning
CRM	Customer Relationship Management
API	Application Programming Interface
RTK	Real-Time Kinematic
DEM	Digital Elevation Model
OGC	Open Geospatial Consortium
BIS	Bureau of Indian Standards
PM Gati Shakti	Prime Minister Gati Shakti National Master Plan for Multi-modal Connectivity
GPDP	Gram Panchayat Development Plan
FSI	Forest Survey of India
GSI	Geological Survey of India
NHO	National Hydrographic Office
INCOIS	Indian National Centre for Ocean Information Services
NSIL	New Space India Limited
MoES	Ministry of Earth Sciences
UN-GGIM	United Nations Global Geospatial Information Management

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LESSON - 4

Building the Future of GKI in India: Infrastructure, Innovation, and Integration

Trainer' s Biodata: Prof. (Dr.) Zaffar Sadiq Mohamed-Ghouse, Vice President and Director-Advisory & Innovation, Woolpert

Prof. Dr Zaffar Sadiq Mohamed-Ghouse is an engineer and scientist, recognised as one of the global leaders in the Spatial and Space sector. He has held senior and executive roles in the Private Sector, government, and research sectors. He has over 25 years of experience, developing strategic plan for positioning networks including products; client management, strategic consulting studies, business development, project management, systems review and integration for the Utility Industry and Government, design, development and management of spatial databases, review data framework policies, develop spatial analyses techniques and technology including GIS applications development for major clients across the globe. Zaffar has published extensively in the field of Geomatics Engineering.

1. Session Overview

We live in an era of rising complexity and mounting risks from fragmented systems. From energy grids and global supply chains to emergency response and infrastructure development, the systems we depend on are increasingly interconnected. Yet, the data and decisions guiding them often remain siloed.

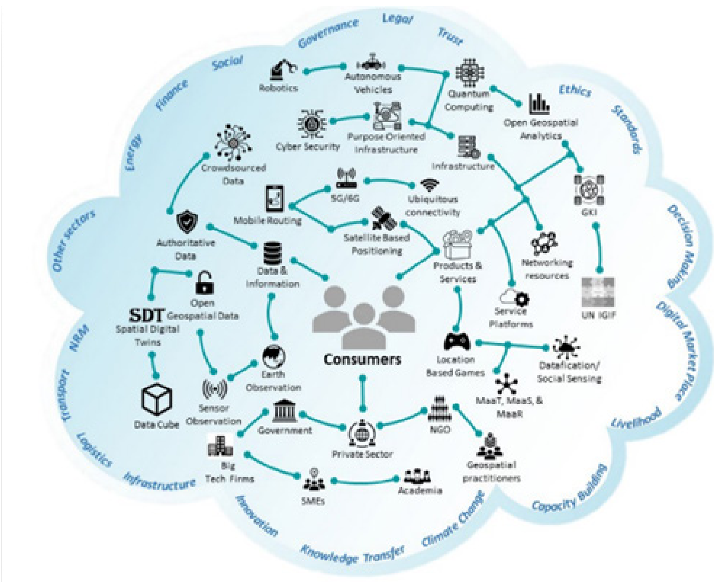
Geospatial information provides the foundation for managing this complexity. It tells us where things are, how they move, and how they relate to one another across time and space. From monitoring land use and tracking logistics to securing borders and planning for climate resilience, geospatial systems underpin some of society's most critical operations.

But today, it's not just about location. It's about shared semantics, common frames of reference, data rights, and trust. As systems become more complex and interdependent, knowing "where" is no longer enough. Decision-makers need to understand what it means, who controls it, how it can be used, and how it fits within a broader ecosystem.

This is the promise, and the challenge of the emerging interconnected geospatial ecosystem. According to Coetzee et al. (Towards a Sustainable Geospatial Ecosystem beyond SDIs, 2021):

"A geospatial ecosystem is where people from all over the world interact directly or indirectly, utilizing dependable and accurate location-based data and advanced geo-analytics conveyed through dynamic geomedia or open computing environments. Like a natural ecosystem, geospatial ecosystems are marked by strong interrelationships between actors and their surroundings, constant adaptation, and the potential for significant transformations resulting from certain events."

Figure 1: Geospatial Ecosystem



This section of the GKI training focuses on Building the Future of GKI in India: Infrastructure, Innovation, and Integration. Through this section of the training program, participants will:

- Understand how to design and implement strategic geospatial infrastructures that enable cross-sector data integration and foster state-level geospatial ecosystems.
- Explore advanced geospatial technologies and industry ecosystems that can drive economic diversification and sustainable growth, supported by strong capacity-building frameworks and skill development.
- Learn from the GEOSA–SLA collaboration case study, gaining practical insights into strengthening geospatial governance and building partnerships that advance the future of Geospatial Knowledge Infrastructure (GKI) at the state level in India.

2. Learning Objectives

By the end of this session, participants will be able to:

1. **Design strategic spatial infrastructure frameworks** that lay the foundation for state-level geospatial ecosystems, enabling integrated and future-ready solutions.
2. **Analyze emerging trends in the geospatial industry ecosystem** to identify opportunities for innovation, economic diversification, and sustainable growth.
3. **Apply advanced spatial data management approaches** to support cross-sector collaboration and unlock actionable insights for governance and planning.
4. **Develop strategies for capacity building and skill enhancement** that ensure long-term resilience and scalability of the Geospatial Knowledge Infrastructure (GKI).
5. **Relate their understanding through a case study example** of GEOSA and SLA.

3. Key Concepts and Definitions

Term	Explanation
AI (Artificial Intelligence)	Simulation of human intelligence by machines for tasks like reasoning, learning, and decision-making.
API-first design	Designing APIs before the application to ensure scalability, interoperability, and easy integration.
Blockchain	A decentralized ledger technology that securely records transactions without central authority.
Data as a Service (DaaS)	Cloud-based model delivering data on demand without managing infrastructure.

Data spaces	Federated environments enabling secure data sharing while maintaining sovereignty and compliance.
Digital infrastructure	Foundational technology systems like networks, cloud platforms, and computing resources supporting digital services.
Digital twins	Virtual replicas of physical objects or systems for real-time simulation and optimization.
Geospatial Analytics Platforms	Tools that analyze spatial data for mapping, planning, and decision-making.
Innovation hubs	Collaborative ecosystems fostering research, development, and entrepreneurship.
IoT (Internet of Things)	Network of interconnected devices exchanging data for automation and smart services.
Knowledge graphs	Structured data representations capturing relationships between entities for advanced reasoning.
ML (Machine Learning)	AI subset using algorithms to learn patterns from data and improve performance without explicit programming.
Model as a Service (MaaS)	Cloud-based offering providing ready-to-use AI/ML models for easy integration.
Privacy-by-design principles	Embedding privacy and data protection measures into systems from the outset.
Quantum computing	Computing paradigm using quantum mechanics for exponentially faster complex calculations.
United Nations Integrated Geospatial Information Framework (UN-IGIF)	Global framework guiding countries in developing integrated geospatial systems for sustainable development.

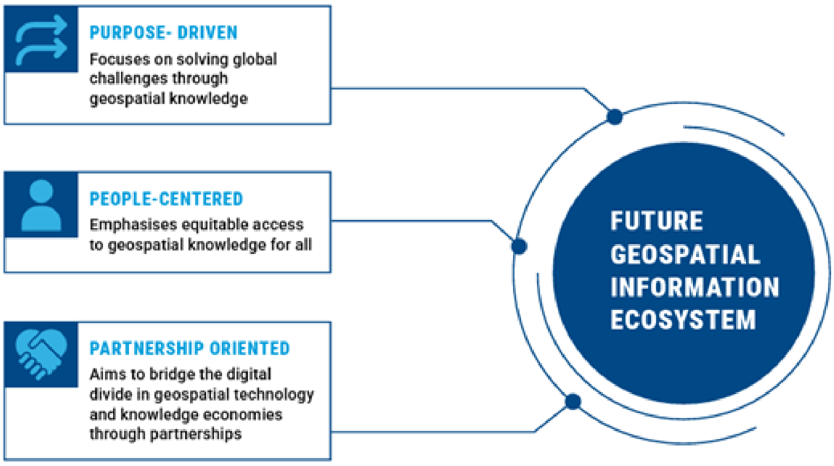
4. Core Content

4.1 Designing Strategic Spatial Infrastructure for State-level Geospatial Ecosystems

The United Nations paper, 'Positioning the Future of Geospatial Information Ecosystem' released in August 2025 highlights that Geospatial information plays a crucial role because of major changes in technology, governance, society, and the environment. These changes highlight the need for strategic planning and collective action.

- **Bridging the Geospatial Digital Divide:** Despite technological progress, significant disparities in geospatial capabilities persist between countries and regions. The future geospatial information ecosystem must prioritize inclusiveness, capacity development and equitable access to technologies and data, ensuring that all Member States, especially developing countries and small island developing States, can participate in and benefit from the evolving ecosystem.
- **Digital Transformation and Technological Convergence:** Rapid advancements in digital technologies, including AI, IoT, cloud computing, and advanced analytics, are transforming how data is created, managed and utilized. Geospatial information must evolve to remain an integral component of this wider digital transformation, enabling real-time decision-making, predictive modeling and dynamic service delivery.
- **Climate Change and Resilience Building:** Climate change presents an urgent global challenge requiring immediate, coordinated action. Location-based data is fundamental to understanding climate impacts, managing risks and building resilient societies. The future geospatial information ecosystem must empower decision-makers with integrated, geospatially enabled insights to drive mitigation, adaptation and resilience efforts.
- **Data as a Foundational Public Good:** Geospatial information increasingly underpins critical public services, from health and transportation to disaster response and resource management. Recognizing geospatial data as a foundational public good promotes equitable access, fosters ethical use, and advances broad societal benefit, strengthening the role of national and global data infrastructures.
- **Strengthening Governance and Trust in the Digital Era:** As data ecosystems become increasingly complex, maintaining public trust, upholding ethical governance and safeguarding data sovereignty are emerging as critical imperatives. The future geospatial information ecosystem must embed strong governance frameworks that prioritize transparency, accountability, inclusivity, and the protection of human rights, building and sustaining trust in the management and use of geospatial information.

Figure 2: Future Geospatial Information Ecosystem, Pillars of Change



The future of geospatial information rests on three key pillars:

1. **Purpose –** Using geospatial solutions to tackle global challenges like climate change, economic disruptions, and slow progress on the SDGs. Achieving the 2030 Agenda requires collaboration, data integration, and informed decision-making.
2. **People –** Ensuring equitable access to knowledge by empowering individuals, organizations, and governments through training and lifelong learning. This enables everyone to create and use data-driven insights for societal benefit.
3. **Partnerships –** Promoting digital cooperation across countries, sectors, and stakeholders to bridge the geospatial digital divide. Strong partnerships ensure no one is left behind and all nations benefit from geospatial technologies.

Together, these pillars aim to build an inclusive, resilient, and knowledge-driven ecosystem, where technology serves as a tool for collective progress—not an end in itself.

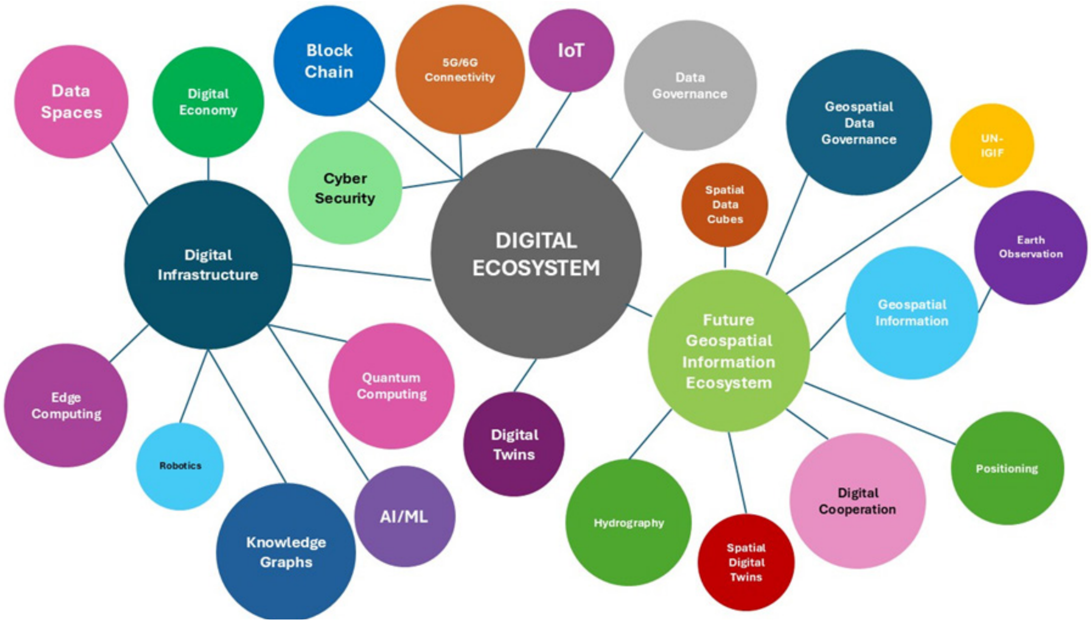
The Goals towards the future geospatial information ecosystem is to:

1. Promote Geospatial Information and knowledge as Public Good
2. Foster Digital Cooperation and Innovation
3. Bridge the Geospatial Digital Divide
4. Embed Adaptive and Anticipatory Governance
5. Uphold Trust, Human Rights, and Ethical Stewardship

The geospatial information ecosystem is a critical component of the wider digital ecosystem, working in synergy with emerging technologies and data frameworks to enable smarter decision-making and sustainable development. At its core, the digital ecosystem is powered by elements such as digital infrastructure, data spaces, AI/ML, blockchain, IoT, and advanced technologies like quantum computing and digital twins. These technologies create an environment where data flows seamlessly across sectors, driving innovation and efficiency.

Within this interconnected framework, the geospatial ecosystem adds unique value by providing location-based intelligence through components such as geospatial data governance, Earth observation, positioning, hydrography, and spatial data cubes. It emphasizes digital cooperation and global initiatives like UN-IGIF to ensure equitable access and bridge the geospatial digital divide. By integrating geospatial capabilities with broader digital technologies, this ecosystem supports resilience, inclusivity, and knowledge-driven growth where technology acts as an enabler for collective progress rather than an end in itself.

Figure 3: Geospatial Ecosystem in Wider Digital Ecosystem



The United Nations Integrated Geospatial Information Framework (UN-IGIF) provides a strategic blueprint for countries to develop and strengthen their national geospatial information management systems, enabling data-driven decision-making for sustainable development. The UN-IGIF framework, viewed through the lens of the geospatial ecosystem, emphasizes a holistic approach to building sustainable and inclusive geospatial infrastructures. It is structured around key domains that enable integration, innovation, and collaboration across sectors and countries.

Governance forms the foundation, promoting adaptive and dynamic ecosystems, cross-sector integration, and interoperable data networks. Policy and Legal frameworks ensure principles-based policies, cross-border cooperation, and anticipatory risk management, supported by financial mechanisms like public-private co-investment and decentralized finance. Standards play a critical role in enabling interoperability through evolving cross-domain standards and blockchain technologies.

The ecosystem also prioritizes Data—ensuring ethical, trusted, and real-time information—alongside Innovation, which drives continuous improvement through multi-stakeholder collaboration and technology co-development. Capacity and Education focus on inclusive participation and equitable learning opportunities, while Communication and Engagement foster global knowledge exchange and multi-stakeholder dialogue. Finally, Partnerships underpin the entire framework, creating value-driven collaborations at regional and global levels. Together, these elements define a resilient, inclusive, and innovation-driven geospatial ecosystem aligned with the UN-IGIF vision.

Figure 4: United Nations Integrated Geospatial Information Framework Strategic Pathways

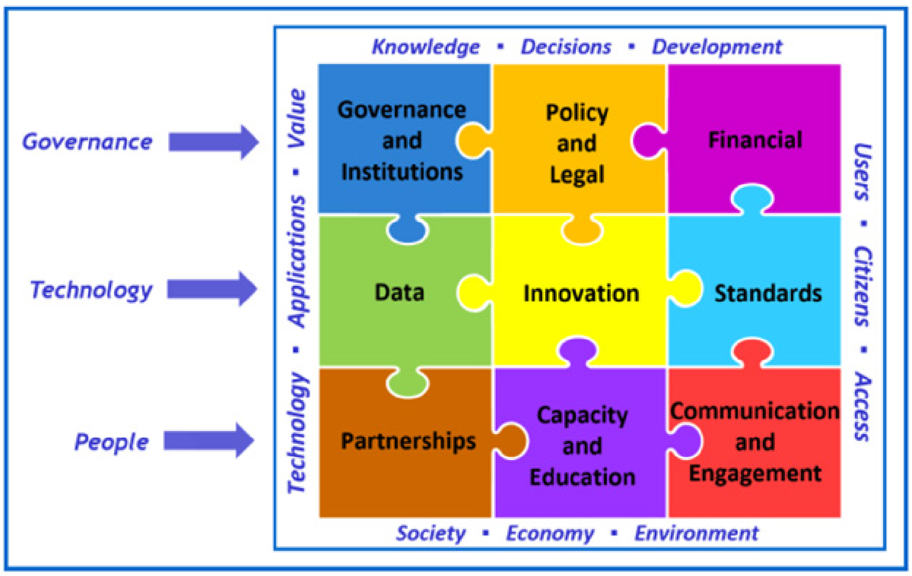
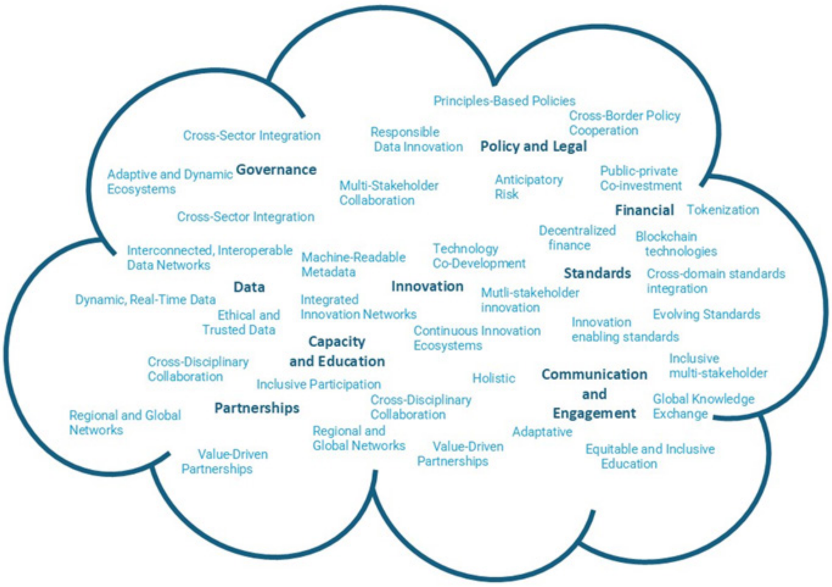


Figure 5: UN-IGIF Through the Lens of Geospatial Ecosystem



4.2 Future Geospatial Industry Ecosystem for Innovation and Economic Growth

India's development priorities spanning urban transformation, infrastructure modernization, climate resilience, and disaster preparedness require a geospatial ecosystem that is adaptive, interoperable, and innovation-driven. While traditional Spatial Data Infrastructures (SDIs) have provided a strong foundation, they often struggle to keep pace with the complexity and speed of emerging challenges. In response, a dynamic geospatial ecosystem is emerging, built on interconnected actors: people, systems, AI models, standards, governance frameworks, and shared vocabularies. These elements collaborate through trusted data spaces, forming agile networks that address state-level priorities and national missions.

In the paper, Destination Earth: Ecosystem Architecture Description, authors from the Joint Research Center of the EU, high-light key design imperatives as follows:

4.2.1 High Flexibility and Modularity

Future geospatial ecosystems must be modular, meaning core infrastructure (data storage, governance) should be separated from thematic applications (urban planning, agriculture, disaster management). If everything is tightly coupled, any change in one part (say, adding a new disaster management tool) could disrupt the entire system. By separating the core from applications, states can scale easily, add new services without breaking existing ones, and adapt quickly to new technologies or priorities. Let us understand this through a couple of examples.

1. Urban Planning vs Disaster Management

Core Infrastructure: A state-level geospatial data repository with governance rules, security protocols, and APIs.

Modular Applications:

- **Urban Planning Module:** Tools for zoning, land-use analysis, and infrastructure planning.
- **Disaster Management Module:** Flood risk maps, early warning dashboards, and evacuation route planning.

Benefit: Adding a disaster management module does not require redesigning the entire system, just plug it into the core.

1. **Agriculture vs Logistics**

Core Infrastructure: A centralized geospatial platform hosting satellite imagery and soil data.

Modular Applications:

- **Agriculture Module:** Crop health monitoring, irrigation planning, and yield prediction using AI.
- **Logistics Module:** Route optimization for farm-to-market transport and cold-chain tracking.

Benefit: Both modules share the same base data but serve different sectors without duplication.

2. **Smart Cities vs Climate Resilience**

Core Infrastructure: State geospatial cloud with APIs for real-time data access.

Modular Applications:

- **Smart City Module:** Traffic management, utility mapping, and citizen services.
- **Climate Resilience Module:** Heat maps, green cover analysis, and carbon footprint tracking.

Benefit: States can add climate resilience tools later without disrupting smart city services.

3. **Health vs Education**

Core Infrastructure: Geospatial data hub with demographic and location-based datasets.

Modular Applications:

- **Health Module:** Hospital location optimization, disease outbreak mapping.
- **Education Module:** School accessibility analysis, transport planning for students.

Benefit: Both modules use the same demographic data but apply it differently.

This approach allows incremental development wherein states can start with one priority (e.g., disaster management) and later add others (e.g., agriculture, smart cities) without rebuilding the entire system. This approach saves costs, accelerates deployment, and ensures flexibility for future technologies like AI and IoT.

4.2.2 Technology Independence

States should avoid being locked into a single vendor or proprietary technology because this limits flexibility and increases long-term costs. Instead, adopting open standards and interoperable platforms ensures systems remain competitive and future-proof.

For example, a state building land records modernization system should use open geospatial standards so that the same platform can later integrate with agriculture monitoring tools or urban planning dashboards without requiring complete overhaul. This approach also allows states to switch service providers or add new technologies like AI-based analytics without vendor restrictions.

4.2.3 Resilience and Co-evolution

A geospatial ecosystem must be resilient to disruptions, whether technological, economic, or environmental and capable of co-evolving with new technologies like AI, IoT, and Digital Twins. For example, Assam already uses satellite-based systems for near real-time flood mapping and damage assessment. The next step is to scale these capabilities by integrating IoT sensors for real-time water level monitoring and deploying AI-driven predictive models for early warnings across all flood-prone districts. This evolution would enable dynamic Digital Twins for river basins, improving disaster preparedness and response. Similarly, an agricultural state like Punjab could add Digital Twin models to simulate crop growth and optimize irrigation as technology matures.

4.2.4 Inclusive Access

Advanced geospatial systems should not be limited to large agencies. States must ensure affordable access for smaller organizations, local bodies, and SMEs, supported by low-code/no-code platforms and data literacy programs. This democratizes geospatial intelligence, enabling broader participation in planning and decision-making. For example,

- Bhuvan Panchayat portal, developed by ISRO provides Gram Panchayats with satellite imagery and geospatial data for planning and monitoring rural development activities. It supports waste management, water resource planning, and disaster preparedness through spatial analysis tools. Its features include a WebGIS platform, visualization, analysis, and integration of space-based data for decentralized planning.
- National Database for Emergency Management (NDEM), also developed by ISRO provides real-time geospatial data for disaster preparedness and emergency response, accessible to local bodies for planning and mitigation.
- Swachh Bharat Mission Dashboards are used by gram panchayats under SBM-G for solid and liquid waste management, which include geospatial mapping of assets like compost pits, soak pits, and waste collection points.

The next step is to scale adoption across all states, integrate real-time IoT data, and provide low-code **tools so even non-technical users can customize dashboards for local needs.**

4.2.5 Meta-Governance

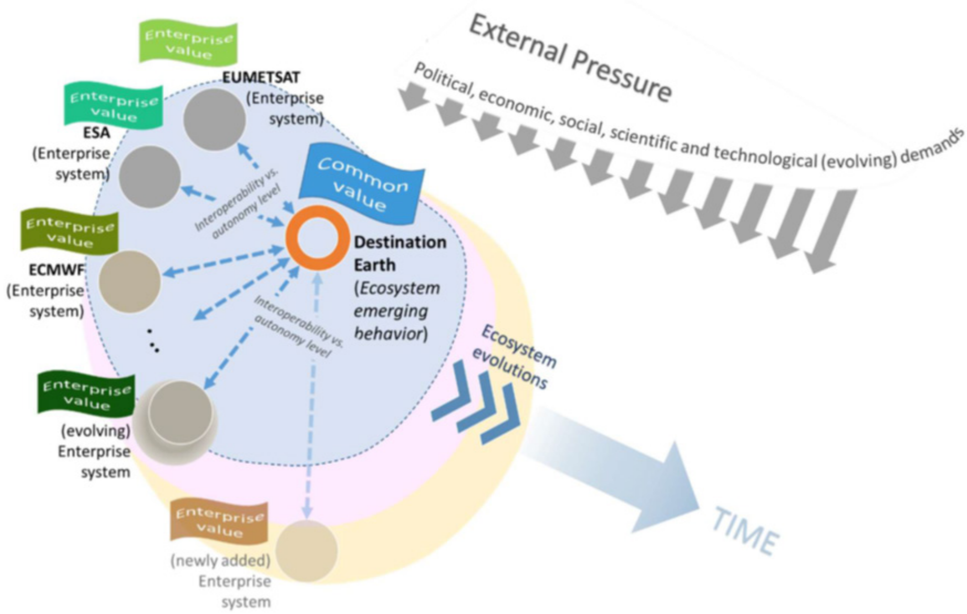
Meta-governance goes beyond technical standards. It is about creating a policy and oversight framework that ensures geospatial ecosystems remain secure, transparent, and aligned with national priorities as they grow and diversify. This includes data governance, cybersecurity, compliance, and ethical use of geospatial information.

What it means for Indian states:

- **Clear Roles and Responsibilities:** States need to define who owns and manages geospatial data. For example, in a smart city project, municipal bodies could act as data custodians, while state-level agencies oversee compliance and interoperability across cities.
- **Quality Assurance Mechanisms:** Implementing QA/QC protocols ensures data accuracy and reliability. For instance, a state disaster management authority could mandate periodic audits of flood risk maps to maintain trust in early warning systems.
- **Privacy and Ethical Guidelines:** As states adopt IoT sensors and AI for urban surveillance or traffic management, privacy policies must protect citizen data. For example, several Indian states and national dashboards already use anonymized and aggregated health and mobility data for pandemic response. The next step is to institutionalize privacy standards across all geospatial platforms, ensuring compliance with data protection laws and ethical guidelines. For example, states can adopt privacy-by-design principles for future health and disaster dashboards, including mandatory anonymization protocols and differential privacy techniques.
- **Cybersecurity Frameworks:** States should establish protocols to prevent data breaches and ensure resilience against cyberattacks. For instance, states advancing digital governance could integrate state-level cybersecurity audits for geospatial platforms.
- **Alignment with National and Global Standards:** States should align with UN-IGIF principles and OGC standards to ensure interoperability and global best practices.

For example, a state implementing smart city projects should define who owns the data collected from sensors, how it is shared across departments, and what safeguards exist to prevent misuse. States could establish a state-level geospatial governance board to oversee interoperability, security, and ethical guidelines for all municipal GIS systems.

Figure 6: Evolutionary nature of the Destination Earth DT ecosystem, its components, and the context in which they operate



This approach provides a roadmap for building future-ready geospatial ecosystems that support flagship programs like Digital India, Jal Jeevan Mission, Swachh Bharat Mission, Pradhan Mantri Awas Yojana, and climate resilience initiatives, while ensuring flexibility, security, and inclusivity. Without meta-governance, geospatial ecosystems risk fragmentation, data misuse, and security vulnerabilities. A strong governance layer ensures trust, accountability, and sustainability, enabling states to confidently scale their geospatial initiatives.

These principles align with India's vision for state-level geospatial ecosystems that are interoperable, AI-ready, and designed for sustainability. By embedding them, states can build platforms that integrate trusted data spaces, semantic standards, and scenario-driven solutions.

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As highlighted in the paper "Moving Forward Together: The Emergence of the Interconnected Geospatial Ecosystem," experts from OGC and GEOSA describe how the next-generation ecosystem is shaped by core capabilities:

- **Interoperability** – Seamless integration of diverse datasets and platforms using open standards.
- **Data Sovereignty** – Secure, governed sharing that respects ownership and national priorities.
- **Semantic Clarity** – Linked data and knowledge graphs for traceability and meaning.
- **Scenario-Driven Design** – Solutions tailored for urban planning, resource management, and emergency response.
- **Agility & Resilience** – Ability to adapt to technological, economic, and societal shifts.
- **Inclusion & Accessibility** – Low-code platforms, localized training, and equitable participation.
- **Sustainability** – Long-term social, economic, and environmental impact.
- **AI Readiness** – Systems designed for direct integration with AI-driven analytics and automation.

This transformation is not just about technology, it is about collaboration, trust, and capacity building. States must invest in skill development, modular architecture, and open standards to ensure scalability and resilience. Public-private partnerships and global best practices will play a critical role in accelerating this shift, strengthening coordination and enabling clarity across systems, sectors, and borders.

To support this evolution, Open Geospatial Consortium (OGC) - an international consortium driving open standards for geospatial data and services - is driving a new generation of services, tools, and partnerships by:

- **Modernizing standards to be modular, reusable, and community-driven**

OGC is moving away from rigid, one-size-fits-all standards toward modular frameworks that can be adapted for different use cases, like urban planning, disaster management, agriculture without reinventing the wheel. These standards are community-driven, meaning they evolve through global collaboration, ensuring they remain relevant and practical. For Indian states, this means they can adopt flexible standards that integrate easily with existing systems and scale as new technologies emerge.

- **Automating validation and compliance for real-time interoperability assurance**

Traditionally, checking whether data and services comply with standards has been manual and time-consuming. OGC is introducing automated compliance tools that validate data formats, APIs, and workflows in real time. This ensures interoperability across platforms instantly, reducing delays in deploying applications. For states, this means faster integration of datasets from multiple departments, like land records, transport, and disaster management without technical bottlenecks.

- **Enabling decentralized ecosystems where communities and governments manage their own vocabularies, registers, and services**

Instead of relying on a single centralized authority, OGC promotes decentralized governance models where states, local bodies, and even communities can manage their own data vocabularies, registries, and services while still adhering to global standards. For example, a state disaster management authority could maintain its own hazard classification system while remaining interoperable with national and international frameworks.

- **Accelerating innovation through agile development and open experimentation**

OGC encourages agile development cycles and open experimentation environments where new tools and services can be tested quickly. This approach reduces the time from concept to deployment and fosters innovation. For Indian states, this means they can pilot AI-based flood prediction tools or IoT-driven smart agriculture solutions without waiting for lengthy approval cycles, accelerating adoption of cutting-edge technologies.

- **Advancing semantic interoperability to power automation, integration, and responsible AI**

Beyond technical interoperability, OGC focuses on semantic interoperability, which ensures that data carries consistent meaning across systems. This is critical for AI and automation, where machines need to interpret data accurately. For states, semantic interoperability enables linked data ecosystems, for example, connecting land-use data with demographic and environmental datasets so that AI models can deliver reliable insights for planning and governance.

These initiatives make it easier for states to adopt global best practices, integrate diverse datasets, and deploy advanced technologies like AI and IoT without vendor lock-in or interoperability issues.

Saudi Arabia's National Geospatial Ecosystem (SANGE) offers a powerful example of this approach:

"We are building a geospatial ecosystem that is secure, scalable, and built for long-term value. By integrating international standards with national priorities, and investing in local capacity, we are equipping Saudi Arabia—and the wider region—to lead in geospatial innovation and respond to emerging challenges with confidence."

~ Dr. Eng. Mohammed Yahya Al Sayel, President of GEOSA

Building on these global lessons, Indian states can adopt a user-centric approach to ensure accessibility and impact:

- **User-Centric Design** – Interfaces and services designed around real user needs and workflows, supported by usability testing and iterative development.
- **Simplified Access** – Easy-to-use search and discovery tools, like a "Google for geospatial data."
- **Data Literacy Initiatives** – Programs that empower users to understand and apply geospatial information effectively.
- **Low-Code/No-Code Platforms** – Tools that allow non-technical users to build custom applications, lowering barriers to entry and enabling advanced spatial analytics without coding expertise.

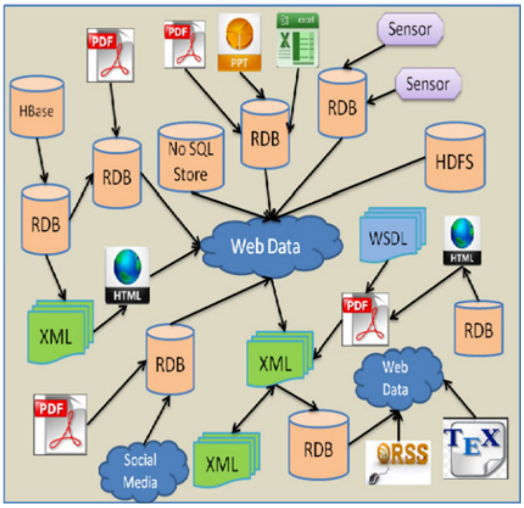
For Indian states, this model provides a clear roadmap: adopt open standards, strengthen governance, and invest in local capacity to create ecosystems that drive economic diversification, innovation, and sustainable growth. By embedding geospatial intelligence into flagship programs, India can position itself as a global leader in geospatial innovation.

4.3 Advanced Spatial Data Management for Cross-Sector Integration

Indian states have an opportunity to move beyond traditional Spatial Data Infrastructures (SDIs) toward next-generation geospatial ecosystems powered by trusted data spaces. This evolution is not just about storing data. It is about unlocking its full potential to create actionable insights and services that transform governance, planning, and citizen engagement. The future lies in shifting from static data repositories to dynamic, service-oriented ecosystems that enable real-time decision-making for urban development, disaster resilience, agriculture, and infrastructure modernization.

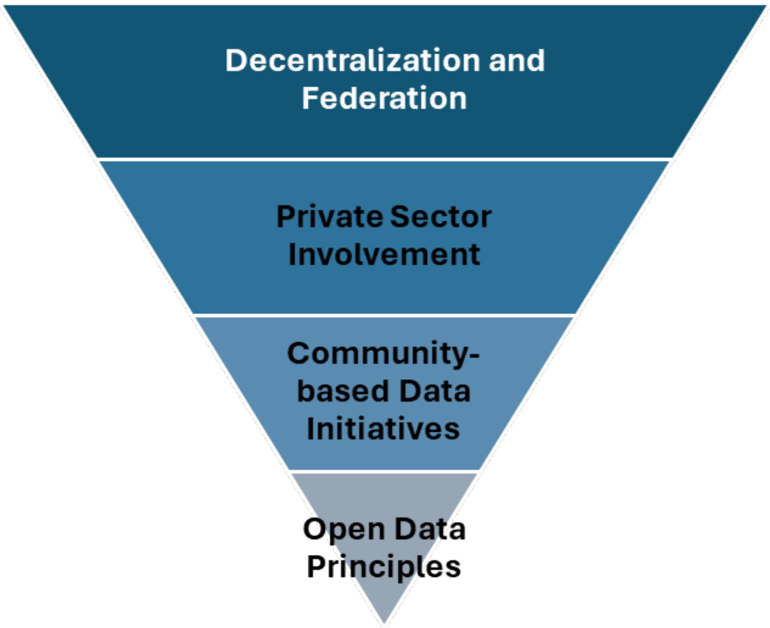
In this advanced model, data is no longer consumed as raw files but delivered through API-first design, allowing developers to build custom applications without interacting directly with underlying datasets. States could adopt Data as a Service (DaaS) and Model as a Service (MaaS) approach, where pre-processed data streams and pre-trained analytical models are available for predictive analytics, such as flood forecasting or traffic optimization. Cloud-based geospatial analytics platforms would provide ready-to-use insights without heavy infrastructure investments, while knowledge graphs could link geospatial data with demographics, economic indicators, and environmental factors to create richer, context-aware solutions for policy and planning

Figure 7: Participants in a Dataspace



Governance would also evolve from top-down, centralized systems to collaborative and federated networks, where state agencies, private enterprises, and communities share responsibility. This approach encourages innovation while ensuring public interest and equitable access. Private sector participation could accelerate the development of advanced geospatial services, while community-driven data initiatives, such as citizen science projects, expand coverage and relevance. At the same time, open data principles would democratize access and spur innovation in areas like smart cities and environmental monitoring, supported by strong governance frameworks to maintain trust and transparency.

Figure 8: New Approach - From Top-Down Government-Driven to Market-Driven & Collaborative



Emerging technologies will play a pivotal role in this transformation. Cloud computing offers scalability and cost-effectiveness, while big data analytics enable processing of massive datasets for real-time insights. Machine learning and AI can automate feature extraction from satellite imagery and support predictive modeling for urban planning and agriculture. IoT integration would bring real-time monitoring through sensors and drones, and blockchain could secure land registries and ensure data provenance. These advances must be paired with robust security and privacy measures, including encryption and privacy-preserving technologies, to maintain trust and compliance.

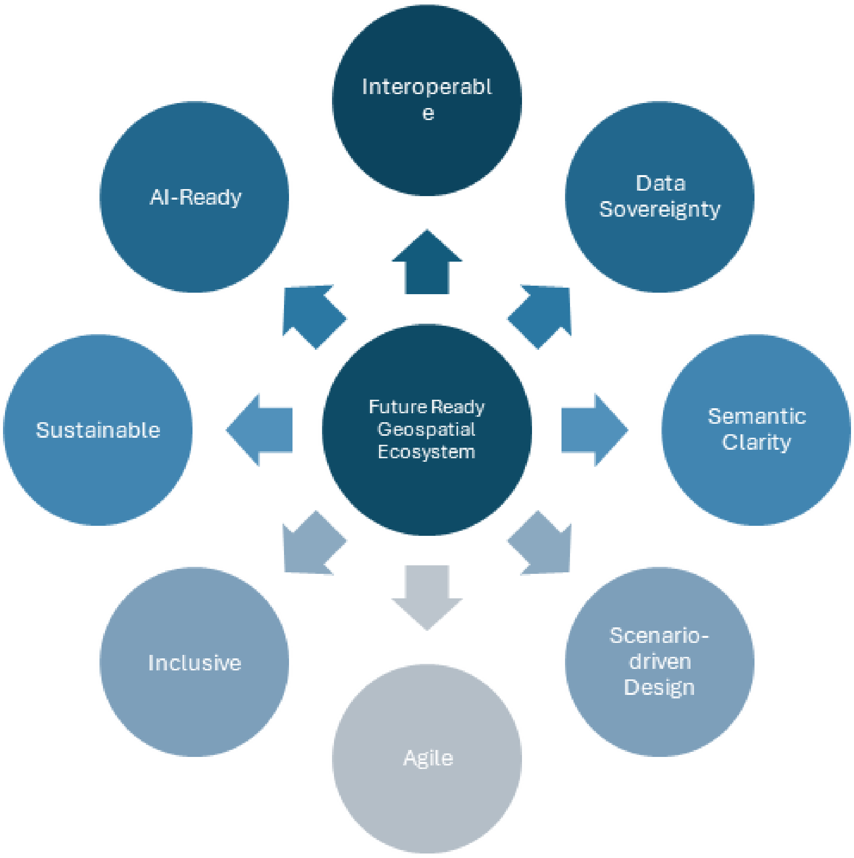
Of course, this transition comes with challenges.

- States will need to overcome institutional inertia,
- Establish clear data governance frameworks,
- Ensure interoperability across platforms,
- Ensure sustainable funding models and viable economic strategies, such as public-private partnerships,

- Invest in capacity building, requiring training programs and organizational change strategies to prepare stakeholders for this new paradigm, and
- Consider environmental impact, such as the carbon footprint of cloud and AI infrastructure, when planning for sustainable digital ecosystems.

A future-ready geospatial ecosystem is flexible, scalable, and inclusive, integrating people, technologies, data, standards, and governance models to enable dynamic aggregation and analysis of geospatial information. It is characterized by interoperability, data sovereignty, semantic clarity, scenario-driven design, agility, inclusivity, sustainability, and AI-readiness. For Indian states, this represents a clear aspiration: to build platforms that adapt quickly to new technologies, empower non-experts through low-code tools, and deliver actionable insights for real-world challenges.

Figure 9: Characteristics of Future-Ready Geospatial Ecosystem



4.4 Capacity Building and Skill Development for Sustainable GKI Growth

For Indian states to fully leverage the future geospatial ecosystem, capacity building must move beyond traditional training models. The old approach that focused on technical training, centralized learning, and periodic workshops will not suffice in an era where geospatial technologies intersect with AI, IoT, blockchain, and advanced analytics. Instead, states need to embrace distributed capacity ecosystems, lifelong learning, and cross-domain competencies that prepare professionals for a rapidly evolving digital landscape.

The future strategy emphasizes knowledge fluency over narrow technical skills. This means equipping individuals not only to use geospatial tools but to understand how these tools integrate with broader digital ecosystems. Learners should gain critical insight literacy, enabling them to interpret data ethically, assess automated decision systems, and apply geospatial intelligence to real-world challenges such as disaster resilience, urban planning, and climate adaptation.

Capacity building will increasingly happen through networks, open platforms, and collaborative environments rather than isolated classrooms. Indian states can create virtual labs where participants experiment with blockchain for secure land registries or semantic web technologies for interoperable governance systems. Open-source AI projects using geospatial data can foster innovation and hands-on learning. Participatory workshops should simulate real societal challenges, such as flood management or agricultural optimization, so that learning is practical and context-driven.

Private sector partnerships, innovation hubs, and civic tech communities will play a critical role in this transformation. By co-creating training programs, offering mentorship, and providing access to cutting-edge platforms, these actors can bring new skillsets and audiences into the geospatial domain. States should also invest in data literacy initiatives and low-code/no-code platforms, enabling non-technical users to build custom applications and democratize access to geospatial analytics.

Figure 10: Evolving Capacity and Education Needs

CHARACTERISTIC	OLD STRATEGY	NEW STRATEGY
SKILL FOCUS	Technical Training	Knowledge Fluency
COMPETENCIES	Geospatial-Only Skills	Cross-Domain Competencies
LEARNING STRUCTURE	Centralized Learning	Distributed Capacity Ecosystems
LEARNING CADENCE	Periodic Training	Lifelong Learning
USER SKILLS	Access to Tools	Critical Insight Literacy

Source: Positioning the Future of Geospatial Information, UN, 2025

Ultimately, capacity building for sustainable GKI growth is about creating an ecosystem where learning is continuous, inclusive, and future-ready. By shifting from geospatial-only skills to cross-domain competencies, and from access to tools to critical insight literacy, Indian states can ensure that their workforce is prepared to lead in the next generation of geospatial innovation.

4.5 Case Study- GEOSA-SLA Collaboration: Strengthening National Geospatial Infrastructure

The Kingdom of Saudi Arabia has adopted a Geospatial Ecosystem approach to manage its geospatial data and assets through the Saudi Arabian National Geospatial Ecosystem (SANGE) program. Backed by a three-year roadmap, SANGE encompasses critical functions such as Geospatial Data, Geospatial Intelligence, National Geospatial Platforms, Geospatial Governance, and Geospatial Security.

To accelerate implementation, GEOSA signed an MoU with the Singapore Land Authority (SLA), leveraging SLA's expertise to strengthen SANGE across five strategic pillars:

A. Geospatial Standards

- Developed a QA/QC framework to ensure data reliability, standardization, and compliance with national policies.
- Recommended aligning SLA's governance model with GEOSA's framework and OGC standards.
- Introduced regular compliance checks with data custodians and automated quality monitoring using tools like FME Flow.

B. Geospatial Platform

- Defined the architecture for the National Geospatial Platform (NGP), including data exchange and sharing mechanisms.
- SLA provided guidance on API management, data catalog design, and visualization platform requirements.
- Shared best practices from GeoSpace, SLA's government-wide data-sharing platform.

C. Geospatial Data

- Collaborated on standardizing workflows and pipelines for geospatial data integration across authorities.
- SLA demonstrated GeoSpace, its intranet platform for secure 2D data sharing, built on ArcGIS Enterprise.
- Highlighted the importance of data catalogs and streamlined upload/download workflows for efficient data access.

D. Geospatial AI

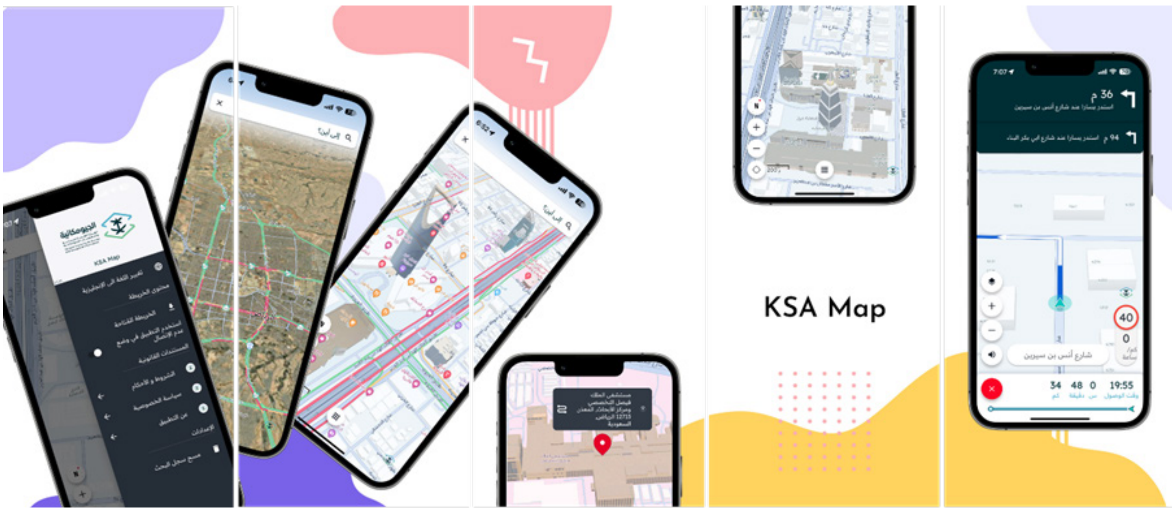
- Explored AI/ML capabilities for Digital Twins, IoT integration, and semantic interoperability.
- SLA proposed MapGPT, a framework for leveraging LLMs to automate processes and enhance end-user solutions.
- Recommended strengthening M2M communication interfaces for real-time data exchange.

E. Geospatial Excellence

- Focused on delivering geospatial products, visualization tools, and analytical services to enhance decision-making.
- SLA shared insights on its visualization platforms, analytical workflows, and QA/QC processes for clean, accurate data.
- Encouraged adoption of COTS GIS applications and specialized analytics for advanced use cases.

Singapore showcased its National Geospatial Platform architecture — GeoSpace and OneMap —highlighting mobile applications that enable seamless map browsing and interaction. Inspired by this, GEOSA initiated development of KSA Map, a similar user-centric solution.

Figure 12: KSA Map



Key Outcomes of the Collaboration:

- **Capacity Building** – Enhanced GEOSA workforce skills through knowledge transfer.
- **Technology Exchange** – Shared best practices in platform architecture and AI integration.
- **Data Governance Expertise** – Strengthened compliance and interoperability frameworks.
- **Regional Collaboration** – Extended partnerships to UN-GGIM AP-AS initiatives.

5. Knowledge Assessment

Menti-Meter an online tool will be used to assess the concepts and case studies discussed.

6. Summary and Key Takeaways

India's states stand at a pivotal moment. Rapid urbanization, climate extremes, infrastructure stress, fragmented data systems, and increasing demands for efficient public service delivery have placed unprecedented pressure on state governments. Many states continue to struggle with siloed datasets, inconsistent data standards, limited technical capacity, vendor lock-in, outdated Spatial Data Infrastructures (SDIs), and the absence of integrated systems that can support real-time decision-making. As states undertake ambitious missions, like Jal Jeevan Mission, Smart Cities, Swachh Bharat, Digital India, agricultural modernization, and climate resilience, the gap between what is required and what current systems can support is widening.

A future-oriented geospatial information ecosystem offers a powerful pathway to overcome these challenges. By integrating geospatial data with advanced technologies, like AI, IoT, cloud computing, digital twins, big data analytics, Indian states can transition from fragmented, reactive governance to predictive, integrated, and citizen-centric governance. The future ecosystem envisions a unified layer of location intelligence that permeates every sector: urban planning, infrastructure, agriculture, environment, health, and disaster management. With strong governance, open standards, ethical data stewardship, and inclusive access, states can build resilient digital ecosystems that deliver high-impact insights, drive innovation, and enable rapid, coordinated action.

Global shifts in technology, governance, and climate have reshaped the role of geospatial information. The United Nations' 2025 paper Positioning the Future of Geospatial Information Ecosystem, highlights five imperatives — bridging digital divides, digital transformation, resilience building, data as a public good, and governance for trust, which collectively underscore the need for strategic spatial infrastructures at state and national levels.

The UN-IGIF framework is a strategic blueprint for nations looking to modernize their geospatial systems. It emphasizes governance, policy, data stewardship, financial models, standards, innovation, capacity building, communication, and partnerships elements essential for building integrated, interoperable, and resilient geospatial ecosystems.

The future geospatial industry ecosystem draws on global examples such as the EU's Destination Earth initiative and the emerging "interconnected geospatial ecosystem" promoted by OGC and GEOSA. Key design principles, such as modularity, technology independence, resilience, inclusive access, and meta-governance, are critical pieces for the Indian states to apply to its geospatial information governance and management modules.

The next-generation ecosystem moves beyond traditional SDIs to trusted data spaces and service-oriented architectures (Data-as-a-Service, Model-as-a-Service). This enables real-time analytics for climate resilience, urban development, logistics, agriculture, and emergency response. Core capabilities such as interoperability, semantic clarity, scenario-driven design, sustainability, and AI-readiness become foundational.

To sustain this transformation, capacity building must evolve into distributed, lifelong learning ecosystems that integrate digital literacy, critical insight skills, and hands-on experimentation with emerging geospatial-AI tools. Public-private partnerships, open platforms, and civic-tech communities are essential in expanding the talent pipeline.

This section of the GKI training is particularly transformative because it translates global frameworks into concrete, state-level strategies that address India's unique governance challenges and development priorities, including:

- fragmented and duplicated datasets
- inconsistent standards across departments
- legacy infrastructure not designed for AI or IoT
- vendor lock-in and lack of technology independence
- slow, siloed decision-making
- insufficient data governance
- limited technical capacity in line departments

Modularity, interoperability, and open standards, can provide Indian states a clear, actionable blueprint to modernize systems without high transition costs.

6.2. Key Takeaways for Indian States

A. Strategic Takeaways

- Build modular, flexible geospatial ecosystems that evolve with future technologies.
- Strengthen governance, policy, and ethical frameworks to ensure trust and accountability.
- Treat geospatial data as a foundational public good to support cross-sector integration.

B. Technological Takeaways

- Adopt open standards, API-first design, cloud-native platforms, and semantic vocabularies.
- Use trusted data spaces, knowledge graphs, and digital twins to support real-time decision-making.
- Ensure AI-ready infrastructure through interoperable data formats and automated compliance tools.

C. Governance Takeaways

- Establish state-level geospatial governance boards to harmonize systems across departments.
- Implement QA/QC, cybersecurity, privacy-by-design, and compliance mechanisms.
- Align with UN-IGIF and OGC global best practices to future-proof state systems.

D. Inclusion & Capacity Takeaways

- Empower local bodies, SMEs, and non-technical departments through low-code/no-code tools.
- Invest in data literacy, cross-domain competencies, and lifelong learning ecosystems.
- Build collaborative innovation networks with private sector, academia, and civil society.

E. Economic & Development Takeaways

- Drive innovation and economic diversification by enabling startups and PPPs in geospatial services.
- Enhance efficiency and transparency in flagship missions such as Jal Jeevan Mission, SBM-G, smart cities, climate action, and rural development.

7. Other Resources

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LESSON - 5

Information Technology as a Critical Enabler of the GKI Ecosystem: Role of AI, Big Data, Cloud Computing & IoT

Trainer' s Biodata: Jitender Mehta [Director – Cloud Eng], Amit Kaushik Principal Cloud Architect

With over 21 years of experience in the IT and ITeS industry, have been focused in driving digital transformation for the Government and India PSU sectors. Career has been centered around leveraging cutting-edge technologies—particularly Cloud and AI solutions—to solve complex business challenges and accelerate modernization initiatives. Successfully led a wide range of implementations, ensuring that organizations remain agile, secure, and competitive in a rapidly evolving technological landscape. My passion lies in enabling strategic growth and efficiency through innovation, collaboration, and a deep understanding of the unique needs of the public sector.

Amit Kaushik, a Principal Cloud Architect at Oracle, has over 22 years of experience in designing and delivering complex, enterprise-scale IT solutions across telecom, banking, defense, and public sector domains. He has worked on scalable systems and High-Performance Computing solutions within these sectors. His expertise also includes supporting major public sector undertakings in energy and manufacturing domains. Currently, he focuses on cloud-based transformation for public sector initiatives using Oracle Cloud Infrastructure, driving digital innovation. Amit holds a Ph.D. in Management, an MBA in Marketing and IT, and a B.E. in Computer Science & Technology. His diverse educational background complements his extensive industry experience, enabling him to deliver impactful solutions.

5.1 Session Overview and Learning Objectives

5.1.1 What This Session Covers

This training session provides senior executives with a comprehensive understanding of how information technology serves as the backbone of modern geospatial knowledge infrastructure. We examine the transformative impact of 4IR technologies on national mapping agencies and explore strategic pathways for integrating these capabilities into India's geospatial ecosystem. the session emphasizes practical implementation considerations, policy implications, and real-world applications that directly support national development priorities.

Participants will explore the critical intersection of geospatial data and emerging technologies, understanding how cloud platforms enable scalability, how AI drives automation and insight generation, how big data analytics processes massive spatial datasets, and how IoT devices provide real-time data streams. The content bridges technical concepts with strategic decision-making requirements for government leadership

5.1.2 Why It Matters

As India accelerates its digital transformation and geospatial democratization initiatives, understanding the role of IT technologies becomes essential for effective policymaking and resource allocation. The convergence of geospatial capabilities with 4IR technologies represents a strategic opportunity to enhance service delivery, improve decision-making, and drive innovation across multiple government sectors.

National mapping agencies worldwide are transitioning from traditional data providers to sophisticated knowledge infrastructure platforms. This transformation requires senior leadership to understand technological possibilities, implementation challenges, and strategic investment priorities. The session equips executives with the knowledge needed to champion these initiatives and make informed decisions about India's geospatial future

Recognize IT's Strategic Role

Understand how cloud computing, AI, big data, and IoT function as critical enablers rather than mere tools, fundamentally transforming how geospatial knowledge is created, managed, and utilized

Apply Practical Understanding

Identify specific use cases andimplementation pathways for integrating 4IR technologies within state geospatial infrastructure, addressing challenges while maximizing strategic value

Grasp Integrated Technology Impact

Comprehend how these technologies work synergistically to enhance data accessibility, enable predictive analytics, support real-time decision-making, and create scalable geospatial platforms

Champion Innovation

Develop capability to foster technology adoption, support digital transformation initiatives, and position geospatial infrastructure as a catalyst for broader government modernization efforts

5.2 Core Technologies Enabling GKI: Detailed Examination

Cloud Computing: Foundation for Scalable Geospatial Services

Cloud computing fundamentally transforms how organizations approach geospatial infrastructure by shifting from capital-intensive hardware investments to flexible, consumption-based service models. Rather than purchasing and maintaining expensive servers, storage systems, and networking equipment, government agencies can access computing resources on demand over the internet, paying only for what they actually use. This shift has profound implications for geospatial knowledge infrastructure deployment and evolution

5.2.1 Public Cloud Benefits

- Massive scalability supporting millions of concurrent users
- Cost efficiency through shared infrastructure and metered billing
- Global reach with 50+ data center locations worldwide
- Rapid deployment of new services and capabilities
- Access to cutting-edge technologies without infrastructure investment

5.2.2 Hybrid Cloud Advantages

- Data sovereignty compliance keeping sensitiveinformation within national boundaries
- Balanced approach using public cloud for appropriateworkloads
- Integration with existing on-premises systems
- Flexibility to optimize costs and performance
- Compliance with MeitY guidelines and regulations

5.2.3 Multi-Cloud Strategy

- Vendor neutrality avoiding dependence on singleprovider
- Enhanced security through diversification
- Optimization by using best capabilities from eachplatform
- Risk mitigation against service disruptions
- Compliance with varied regulatory requirements

5.2.4 Internet of Things: Real-Time Geospatial Data Collection

IoT technologies enable unprecedented collection of location-specific data from connected devices including sensors, GPS trackers, mobile devices, and embedded systems. This createscontinuous streams of spatial information that provide real-time context for decision-making. In the context of GKI, IoT devices serve as distributed data collection infrastructure,dramatically reducing the cost and complexity of maintaining current geospatial information while enabling entirely new classes of applications and services.

5.2.5 Agriculture Applications

IoT sensors monitor soil moisture, temperature, and nutrient levels, enablingfarmers to optimize irrigation and cropmanagement. GPS-enabled tractors provide precise location data for variable rateapplication of inputs.

5.2.6 Logistics Optimization

IoT- equipped vehicles provide preciselocation and status data, helping companiesreduce delivery times, optimize fuelconsumption, and improve route efficiencythrough real-time traffic and condition monitoring.

5.2.7 Urban Planning

Connected sensors throughout cities collect data on traffic flow, air quality, noise levels,and infrastructure utilization. Thisinformation supports data-driven urbanplanning and real-time management of city services.

5.2.8 Environmental Monitoring

IoT devices track climate variables, wildlifemovements, water quality, and ecosystemhealth. Scientists use this data tounderstand environmental changes andpredict future impacts of climate change.

5.2.9 Big Data Analytics: Processing Massive Geospatial

Spatial Big Data refers to massive volumes of complex, variable geospatial information from satellites, aerial sensors, mobile devices, social media, and other sources. These datasets,typically measured in terabytes or petabytes, require specialized platforms and analytical approaches. Big data technologies enable organizations to extract meaningful insights from information volumes that were previously impossible to process, creating new opportunities for evidence-based policymaking and service delivery optimization.

5.3 Understanding the Fourth Industrial Revolution Context

The Fourth Industrial Revolution represents a fundamental shift in how we leverage technology to solve complex problems. Building upon the digital revolution's foundation of computers electronics, and internet connectivity from the 1950s through early 2000s, 4IR introduces unprecedented convergence across four critical technology domains. This convergence creates exponentially greater value than individual technologies operating in isolation.

For geospatial infrastructure specifically, 4IR technologies eliminate traditional constraints that limited data collection, processing, and distribution. Cloud computing provides virtuallyunlimited scalable resources accessible from anywhere. Artificial intelligence automates complex analytical tasks previously requiring extensive human expertise. Big data platforms process volumes of spatial information that were simply impossible to manage a decade ago. IoT sensors create continuous streams of location-based data from countless connecteddevices.

5.3.1 Connectivity, Data & Computational Power

Cloud technology platforms provide on-demand computing resources, internet infrastructure enables global collaboration, blockchain ensures data integrity and transparency, and ubiquitous sensors collect real-time information from physical environments

5.3.2 Analytics and Intelligence

Advanced analytics techniques extract meaningful patterns from complex datasets, machine learning algorithms improve through experience without explicit programming, and artificial intelligence systems perform tasks requiring human-like reasoning and decision-making capabilities

5.3.3 Human-Machine Interaction

Virtual reality creates immersive digital environments for visualization and planning, augmented reality overlays digital information onto physical spaces, robotics andautomation handle repetitive tasks with precision, and autonomous vehicles navigate without human intervention

5.3.4 Advanced Engineering

Additive manufacturing enables rapid prototyping and customized production, renewable energy technologies support sustainable operations, nanoparticles create materialswith novel properties, and advanced sensors capture previously unmeasurable phenomena

The integration of these 4IR domains with geospatial technologies creates powerful new capabilities for national mapping agencies and government organizations. Users are no longerconstrained by computing limitations or data accessibility barriers. Geospatial ecosystems organized around cloud platforms and virtualization enable data access from anywhere throughstandard web interfaces. This democratization of geospatial capabilities accelerates innovation and expands the community of users who can derive value from spatial information.

5.4 Artificial Intelligence and Machine Learning in Geospatial Context

Artificial intelligence and machine learning represent perhaps the most transformative technologies for geospatial infrastructure, enabling automation of complex analytical tasks,extraction of insights from massive datasets, and prediction of future conditions based on historical patterns. AI systems can perform image classification, object detection, change detection, and predictive modeling at scales and speeds impossible for human analysts. This capability fundamentally changesb what's possible with geospatial information.

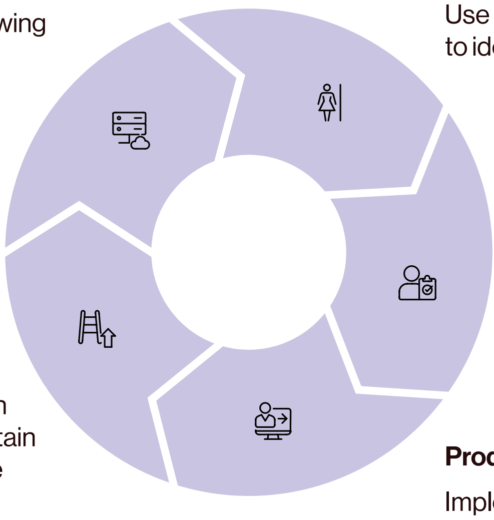
Traditional geospatial analysis required skilled professionals to manually interpret imagery, delineate features, and extract information. Machine learning algorithms can now be trained toperform these tasks automatically, processing thousands of images in the time a human analyst might examine one. Deep learning models can detect subtle patterns invisible to human observers, identifying early indicators of crop stress, urban encroachment, infrastructure deterioration, or environmental change.

Training Data Collection

Gather labeled examples showing AI systems what patterns to recognize in geospatial data

Model Development

Use training data to build algorithms that learn to identify features and patterns automatically



Validation and Testing

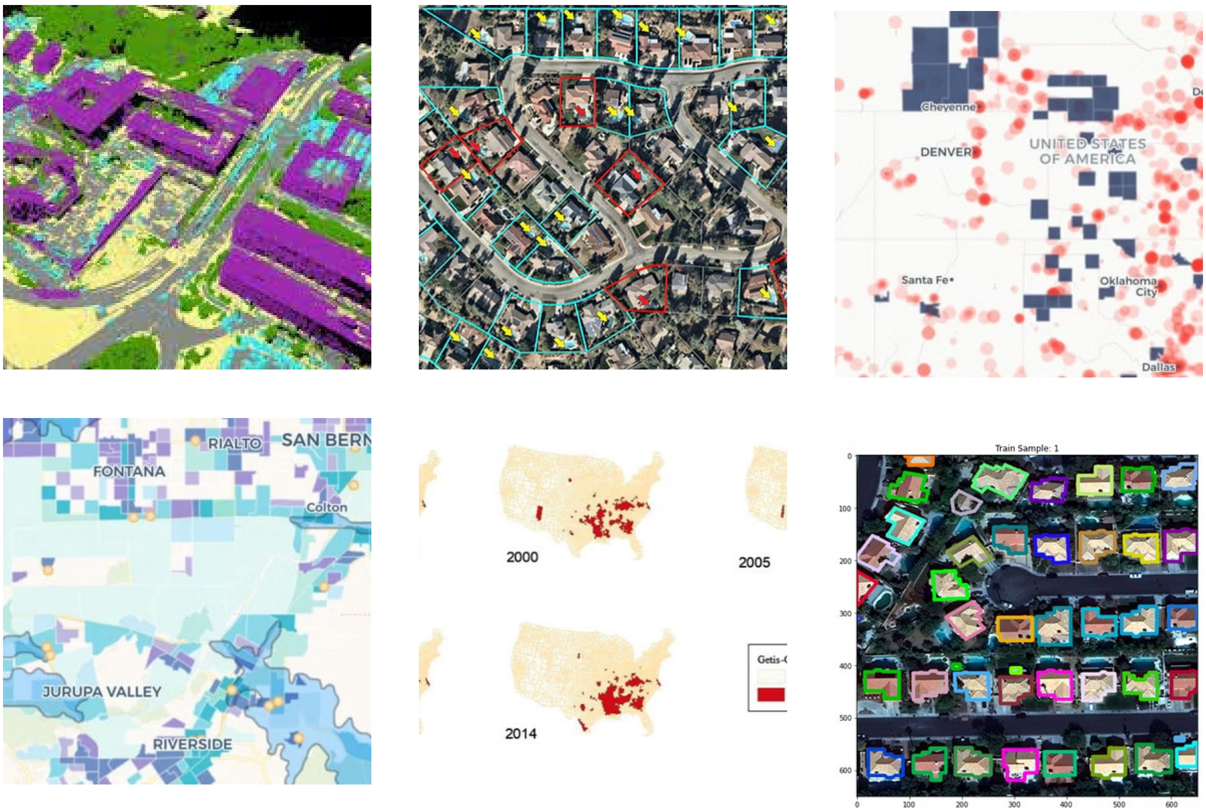
Evaluate model accuracy on new data to ensure reliable performance across diverse conditions

Monitoring and Refinement

Track performance and retrain models with new data to maintain accuracy as conditions evolve

Production Deployment

Implement validated models in operational systems processing real geospatial data at scale



AI/ML Application Areas in Geospatial Infrastructure

5.4.1 Urban Growth Detection

Machine learning algorithms automatically identify new construction, infrastructure expansion, and land use changes by analyzing time-series satellite imagery. This enables governments to monitor urban development patterns, enforce zoning regulations, and plan infrastructure investments based on actual growth trajectories.

5.4.2 Site Selection Optimization

AI-powered spatial analysis evaluates multiple criteria simultaneously4accessibility,demographics, competition, infrastructure availability, environmental constraints4toidentify optimal locations for facilities, services, or development projects. This acceleratesplanning processes and improves decision quality.

5.4.3 Solar Potential Scoring

AI models analyze building geometry, roof orientation, shading patterns, and climate datato calculate solar energy generation potential for every structure. This information supportsrenewable energy planning and helps property owners make informed decisions about solar installation investments.

5.4.4 Portfolio Risk Analysis

Machine learning models assess geographic risk factors including natural hazards, climateexposure, market volatility, and infrastructure dependencies across asset portfolios.Financial institutions and insurance companies use these insights for risk management and pricing decisions.

5.4.5 Tree Cover Analysis

Point cloud data from LiDAR sensors combined with machine learning enables precisemeasurement of tree canopy coverage, biomass estimation, and vegetation healthassessment. Urban forestry programs use this information to track environmental goals and optimize tree planting strat.

5.4.6 Predictive Hotspot Identification

AI algorithms analyze historical patterns and real-time data streams to predict whereincidents, demands, or events are likely to occur. Police departments, emergency services,and public health agencies use these predictions for proactive resource allocation.

5.5 Digital Twins and Simulation Technologies

A digital twin represents far more than a static 3D model or simulation. It is a dynamic, continuously updated virtual replica of a physical object, process, or system that uses real-time datafrom sensors and observations to mirror the actual state and behavior of its physical counterpart. This technology enablesunprecedented capabilities for monitoring, analysis, prediction, and optimization across geospatial infrastructure applications.

Digital twins create a bridge between the physical and digital worlds, allowing decision-makers to test scenarios, predict outcomes, and optimize operations without risking disruption to actual systems. For geospatial knowledge infrastructure, digital twins integrate diverse data sources4IoT sensors, satellite imagery, maintenance records, weather data, user feedback4 into cohesive virtual representations that support sophisticated analysis and planning.

Infrastructure Monitoring

Digital twins of buildings, bridges, roads, and utilitynetworks integrate structural sensors, maintenancehistory, and environmental conditions. Engineers monitorasset health in real-time, predict maintenance needsbefore failures occur, and optimize lifecyclemanagement strategies. This proactive approachreduces costs while improving infrastructure reliability and safety.

Environmental Management

Virtual replicas of rivers, forests, watersheds, andecosystems combine satellite observations, fieldsensors, and scientific models. Environmental managerssimulate impacts of development proposals, climate scenarios, or management interventions beforeimplementation. This supports evidence-based conservation and sustainable resource management decisions.

Urban Planning

City-scale digital twins integrate building data,infrastructure systems, traffic patterns, demographicinformation, and environmental conditions. Plannersvisualize proposed developments in context, analyzeimpacts on traffic flow and services, and engagestakeholders through immersive visualization. This improves planning quality and public participation.

The power of digital twins lies in their ability to answer "what if" questions without real-world experimentation. Transportation agencies can test traffic management strategies beforeimplementation. Emergency managers can simulate disaster response scenarios to identify gaps and improve preparedness. Utility companies can optimize network operations to reduce costs and improve reliability. These capabilities transform how government organizations approach complex planning and operational challenges.

Implementing digital twin capabilities requires robust geospatial knowledge infrastructure providing foundational data, real-time data streams from IoT devices, cloud computing platforms for processing and storage, AI/ML models for prediction and optimization, and visualization tools for human interaction. The convergence of these 4IR technologies makes digital twins increasingly practical and valuable for government applications.

5.6 Strategic Implementation: Building GKI on 4IR Foundation

Transforming national geospatial capabilities requires strategic integration of 4IR technologies with clear understanding of implementation priorities, dependencies, and success factors.Senior executives must champion initiatives that build modern infrastructure platforms, establish interoperable ecosystems, promote standards adoption, foster innovation, develop skilled workforce, and communicate value across government and society

Foundational Data Excellence

Establish comprehensive, authoritative geospatial datasets as the bedrock of GKI. Priority national datasets including parcels, addresses, buildings, hydrography, imagery, utilities,elevation, land use, transportation networks, and boundaries must be readily available to all users through modern web services. Take advantage of advances in IT for efficientdata acquisition, development, management, maintenance, and distribution. This foundation enables consistent, equitable, quality decision-making across all sectors.

Modern Infrastructure Platforms

Build GKI on contemporary cloud-based infrastructure that evolves with IT industry advances. Create interoperable geospatial ecosystems connecting users with data, tools,models, solutions, and emerging capabilities through standard web services. Enable users to extract knowledge at the source rather than copying massive datasets. Providemarketplace for new data products and services, fostering innovation ecosystem that extends beyond government.

Standards and Interoperability

Actively participate in national and international standards development forums. Standards-based GKI development enables knowledge sharing and promotes "build once,use many times" philosophy. Maintain and promote open standards, specifications, and best practices facilitating rapid technology adoption and data integration. Standards ensure reusability across sectors and applications, enabling local to global interoperability while supporting data accuracy and sharing.

Innovation and Research Leadership

Foster, support, and encourage investment in cutting-edge geospatial research and development. Evaluate and enable technology advancements while promoting responsible adoption. Lead innovation in data collection, autonomous mapping, self-updating maps, intelligent search and discovery, immersive visualization, and AIdriven analysis. Improve access to geospatial capabilities in everyday applications including digital assistants, large language models, browsers, and mobile platforms.

Skilled Workforce Development

Nurture skilled geospatial workforce through continuous learning and professional development. Cultivate geospatial literacy across all sectors starting with middle and high school exposure continuing through undergraduate and graduate education. Promote geospatial knowledge in multidisciplinary institutions. Champion lifelong learning ensuring workforce remains equipped with evolving skills necessary to drive innovation and leverage emerging technologies effectively.

Value Communication

Actively promote understanding and value of geospatial data and technologies beyond the geospatial sector. Encourage idea exchange and strengthen awareness of GKI's benefits for the nation and world. Ensure all sectors understand their role in GKI and actively contribute. Engage stakeholders through coordinating associations, member organizations, and academic programs creating workforce familiar with GKI concepts. Build broad awareness among local and state government stakeholders.

5.7 Real-World Applications and Case Studies

Smart Cities Development

GKI facilitates smart city development by integrating data from IoT devices, urban sensors, and citizen feedback platforms. City planners use comprehensive data integration to optimizeinfrastructure deployment, manage traffic flow, enhance public services including waste management and emergency response, and improve quality of life for residents. Real-time monitoring enables proactive rather than reactive management of city systems.

Example implementations demonstrate measurable benefits: traffic management systems reduce congestion by 20-30%, smart lighting reduces energy consumption by 40-60%, wastemanagement optimization cuts collection costs by 15-25%, and integrated emergency response improves response times by 30-40%. These outcomes result from combining geospatial data with real-time sensor feeds, predictive analytics, and AI-powered optimization algorithms.

Precision Agriculture

GKI enables precision agriculture by providing farmers with detailed maps of soil composition, moisture levels, crop health, and growth patterns. Integration of satellite imagery with IoT sensor data supports data-driven decisions, optimizes resource usage, increases crop yields, and minimizes environmental impact. Farmers can target interventions precisely where needed rather than treating entire fields uniformly.

Climate Adaptation

Satellite-based measurement of temperature, cropdevelopment, precipitation, and soil moisture helpsreduce climate change impacts on food productionthrough early warning and adaptation strategies.

Input Optimization

Accurate field boundary measurements enable precisecalculations for fertilizers and crop protection chemicals,reducing waste and environmental contamination while cutting costs.

Yield Prediction

Historical yield data combined with current satellite imagery creates prescriptions for hybrid-specific planting,accurately identifying management zones for optimal production.

Infrastructure Management

Civil engineers and infrastructure managers use GKI to design, maintain, and upgrade transportation networks, utilities, and public facilities. Geospatial data aids in asset inventory,condition assessment, maintenance scheduling, and infrastructure planning ensuring reliability and resilience of critical systems. Digital land records integrated with GKI enable banks to manage loan lifecycles for farmers, homeowners, and commercial construction projects.

Advanced applications provide visibility into previously unseen infrastructure including underground utility locations, subsurface geological conditions for assessing building suitability,mineral deposit mapping for resource development, and underwater natural and human-made infrastructure evaluation for maritime and environmental management.

Healthcare Planning and Emergency Response

GKI aids healthcare planning by mapping population demographics, healthcare facility locations, service areas, and disease outbreak patterns. Health authorities use this information toidentify high-risk areas, allocate resources efficiently, provide real-time service availability information to citizens, and implement targeted interventions during public health emergencies. The COVID-19 pandemic demonstrated the critical value of geospatial analysis for epidemiological research, disease surveillance, water quality monitoring, and healthcare resource allocation.

5.8 Implementation Challenges and Strategic Considerations

Successfully implementing 4IR technologies within geospatial infrastructure requires addressing multiple challenges spanning technical, organizational, policy, and human dimensions.Senior executives must understand these challenges to develop realistic implementation strategies, secure appropriate resources, and manage stakeholder expectations effectively.

1

Technology Consumption Gaps

Significant disparities exist in technology access and digital literacy across regions,communities, and demographic groups. Organizations struggle to find qualified staffwith expertise in both geospatial technologies and emerging IT capabilities. Addressingthese gaps requires sustained investment in education, training, and infrastructure development to ensure equitable access and participation in the geospatial economy.

2

Integration Complexity

Integrating diverse data sources, legacy systems, and new technologies demandssubstantial consolidation effort and streamlined implementation approaches.Organizations must balance maintaining operational systems while modernizinginfrastructure. Successful integration requires clear architectural vision, phased implementation roadmaps, and strong program management capabilities.

3

Cybersecurity Risks

Hyperconnected environments create expanded attack surfaces and vulnerabilitiesrequiring robust security measures. Protecting geospatial data from unauthorized access, breaches, and cyber threats while maintaining accessibility for legitimate users demands sophisticated security architecture, continuous monitoring, and rapid incident response capabilities aligned with national cybersecurity frameworks.

4

ROI Uncertainty

Organizations struggle to demonstrate clear return on investment for 4IR initiativesgiven long time horizons, indirect benefits, and difficulty quantifying value. Building business cases requires identifying tangible outcomes, establishing baseline metrics,and tracking benefits realization systematically over time to build confidence and sustain executive support.

5

Cultural Transformation

Technology implementation succeeds only with accompanying organizational culture change. Resistance to new ways of working, fear of job displacement, and attachment to familiar processes impede adoption. Change management programs must address emotional and psychological dimensions alongside technical training to achieve sustainable transformation.

6

Data Governance

Managing data quality, privacy, security, and access across distributed sources requires comprehensive governance frameworks. Organizations must comply with evolving regulations including Digital Personal Data Protection Act while enabling appropriate data sharing and use. Governance structures must balance control with flexibility to foster innovation.

Critical Success Factor: A well-articulated organizational vision, supported by smart partnerships and skilled, engaged workforce, represents the key driver for successful 4IR implementation. Technology alone cannot drive transformation4leadership commitment, cultural readiness, and human capability ultimately determine outcomes.

5.9 Barriers to AI/ML Adoption

Artificial intelligence and machine learning adoption faces specific challenges beyond general 4IR implementation concerns. Organizations lack workforce ready to apply AI/ML technology to geospatial problems, requiring deep technical knowledge not widely available. GPU-based hardware for running AI workloads costs approximately ten times more than traditional CPUbased infrastructure, creating significant financial barriers. Building extensive training datasets and models requires substantial time and expertise investment.

Cloud-based AI services help address some barriers by providing access to pre-trained models, GPU computing on-demand basis, and platforms reducing technical complexity. However,organizations still need staff capable of formulating problems appropriately, preparing data, interpreting results, and integrating AI capabilities into operational workflows. Building this organizational capability requires sustained commitment to training, experimentation, and knowledge development.

5.10 Summary, Key Takeaways, and Resources

Essential Takeaways for Senior Executives

Strategic Enabler Mindset

Information technology represents far more than operational support4it functions as strategic enabler fundamentally transforming what's possible with geospatial knowledge infrastructure. Cloud computing, AI, big data analytics, and IoT create capabilities impossible with traditional approaches, enabling real-time decisionmaking, predictive insights, and unprecedented scale.

Integrated Technology Value

Maximum value emerges from synergistic integration of multiple technologies rather than isolated implementations. Cloud platforms provide foundation for scalability and accessibility. IoT creates continuous data streams. Big data analytics processes massive volumes. AI extracts insights and automates analysis. Together, these technologies create exponentially greater value than individual components.

Implementation Realism

Successful 4IR integration requires addressing technical, organizational, cultural, and policy challenges simultaneously. Technology alone cannot drive transformation4 leadership commitment, change management, workforce development, and stakeholder engagement determine outcomes. Realistic timelines, adequate resources, and sustained executive championship are essential success factors.

Continuous Evolution

4IR technologies evolve rapidly, requiring organizations to build adaptive capabilities rather than fixed solutions. Successful geospatial infrastructure embraces continuous learning, experimentation, and improvement. Investment in workforce development, innovation partnerships, and flexible architectures enables organizations to capitalize on emerging opportunities while managing technological change.

5.11 Summary, Key Takeaways, and Resources

Technology Mapping Exercise

Identify three priority use cases in your organization where 4IR technologies could significantly improve geospatial capabilities. For each use case, specify which technologies (cloud, AI, big data, IoT) would be required, what benefits you expect, and what implementation challenges you anticipate.

Implementation Readiness Assessment

Evaluate your organization across six dimensions: infrastructure readiness, workforce capability, data maturity,governance frameworks, security posture, and cultural readiness. Identify top three gaps requiring attention and propose concrete actions to address each gap.

Strategic Discussion Questions

Facilitate group discussion addressing: How can we build organizational capability to leverage 4IR technologies effectively? What partnerships or collaborations would accelerate our progress? How do we balance innovation with data security and privacy requirements? What success metrics should guide our implementation efforts?

7.1 Additional Resources and References

- NSDI Strategic Plan 2035: https://www.fgdc.gov/nsdi-plan/nsdistrategicplan2035 - Comprehensive strategic framework for U.S. National Spatial Data Infrastructure providing detailed
- roadmap for modernization
- Geospatial AI/ML Report: https://wgicouncil.org/wp-content/uploads/2023/10/WGIC-Policy-Report-2021-01-Geospatial-AIML-Report.pdf - World Geospatial Industry Council analysis
- of artificial intelligence and machine learning applications in geospatial sector
- Spatial Digital Twins Policy Report: https://wgicouncil.org/wp-content/uploads/2023/11/WGIC-Policy-Report-2022-01-Spatial-Digital-Twins.pdf - Policy frameworks and
- implementation guidance for digital twin technologies
- Metaverse and Geospatial Technologies: https://wgicouncil.org/wp-content/uploads/2023/10/Metavers-Report-Final.pdf - Exploration of emerging immersive technologies and
- implications for geospatial infrastructure
- Industry 4.0 Explainer: https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-are-industry-4-0-the-fourth-industrial-revolution-and-4ir - McKinsey overview of
- Fourth Industrial Revolution technologies and business transformation
- MeitY Cloud Guidelines: Guidelines for government cloud adoption, data localization, and security requirements in Indian context
- Digital Personal Data Protection Act (DPDPA) 2023: Indian legislation governing data privacy, protection, and usage requirements
- National Cyber Security Policy 2013: Framework for protecting critical information infrastructure and promoting cybersecurity awareness

> "The convergence of geospatial technologies with Fourth Industrial Revolution capabilities represents unprecedented opportunity to transform governance, service delivery, and national development. Success requires bold vision, sustained commitment, and willingness to embrace new ways of working. Senior executives championing these initiatives position their organizations and nations for competitive advantage in the digital economy."

LESSON - 6

Integrated Platform Architecture for Governance and Service Delivery

Trainer' s Biodata: Vijay Kumar, CTO Esri India

Mr Vijay Kumar is the Senior Vice President and CTO at ESRI India. He is passionate in helping organizations solving business and social challenges using technologies including mapping, remote sensing, spatial 2D and 3D analytics, data science, machine learning, artificial intelligence, big data and real time analytics. Vijay has been instrumental in conceptualizing, designing and implementing enterprise location platform across various industry sectors globally. He has helped large organizations in creating their organizational road map and location strategy. Vijay is also passionate about business transformation by redefining and executing the long term vision to transform the business outcomes. Vijay continues to maintain strong links with the world of academia. He is a corporate member of the Institution of Engineers (India), Life Member of Indian Institute of Remote Sensing, member of the Institute of Electrical and Electronics Engineers (IEEE). Vijay has been contributing to the advisory activity for various institutes including IITs, NITs, IIRS and active member at OGC India Forum. He has also chaired panel discussions and presented many technology papers in several international conferences as keynote speaker.

6.1 Introduction to the Enterprise GIS System

In a world defined by rapid urbanization, climate stresses, infrastructure demands, public health challenges, and ongoing economic transformation, the need to understand "where" things are happening and why has never been greater. Location intelligence has moved from being a specialised analytical function to a foundational requirement for effective governance and enterprise planning.

An enterprise GIS system fulfils this need by providing an integrated, organization-wide platform for managing and interpreting geospatial information. It brings together diverse datasets, technologies, and workflows to create a shared operational picture that supports both strategic and day-to-day decision-making. By enabling organizations to map conditions, analyse trends, predict outcomes, and collaborate across departments, enterprise GIS becomes a critical enabler of digital transformation. This chapter introduces the significance of such systems and sets the context for understanding how integrated geospatial platforms underpin modern, resilient, and data-driven operations.

6.2 The Evolution of Enterprise GIS

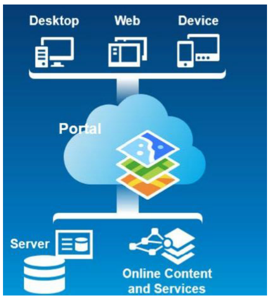
Geographic Information Systems were once limited to specialized desktop tools used by technical specialists. These early systems focused on map creation and basic spatial analysis and were often isolated within individual departments. As organizations expanded, the limitations of siloed data, manual information exchange, and disconnected workflows became more apparent.

Modern enterprise GIS evolved as a response to these challenges. Instead of functioning as standalone components, today's GIS environments operate as connected platforms that support entire organizational ecosystems. The shift from departmental GIS to enterprise-wide systems marked a major turning point—enabling organizations to share authoritative data, coordinate operations, and drive intelligenceled decision-making at scale.

6.3 The Need for an Integrated Geospatial Platform

Organizations today work with immense and diverse spatial datasets—ranging from administrative boundaries and topographic information to IoT sensor feeds, satellite imagery, 3D city models, and real-time field observations. When these datasets reside in silos, the consequences are immediate: duplication of effort, inconsistent information, fragmented decision-making, and significant operational inefficiencies.

An integrated enterprise GIS platform resolves these issues by offering a unified framework where spatial data from all sources is consolidated, standardized, analyzed, and shared. This integration ensures:



- Consistency and governance of authoritative datasets
- Reduced costs linked to redundant data management
- Greater interoperability and system connectivity
- Faster access to real-time intelligence
- Improved collaboration across departments

In essence, an integrated platform transforms location data from isolated assets into organizational intelligence.

6.1.4 A Collaborative Platform for the Entire Organization

Organizations today work with immense and diverse spatial datasets—ranging from administrative boundaries and topographic information to IoT sensor feeds, satellite imagery, 3D city models, and real-time field observations. When these datasets reside in silos, the consequences are immediate: duplication of effort, inconsistent information, fragmented decision-making, and significant operational inefficiencies.

Enterprise GIS is not limited to analysts or GIS professionals. It is built to support the entire organizational ecosystem—from executive-level decision-makers to operational teams and field personnel.

- **Analysts** perform advanced modeling, spatial analytics, and data engineering.
- **Planners and managers** rely on dashboards, indicators, and scenario tools to guide decisions.
- **Field officers** collect real-time observations that feed back into the system.
- **Executives** access strategic insights that support governance, resource allocation, and performance monitoring.
- **Public-facing applications** improve transparency, citizen engagement, and service delivery.

By allowing each user group to participate in the spatial information cycle, enterprise GIS becomes a shared language across the organization.

6.1.5 End-to-End Spatial Workflows

A hallmark of enterprise GIS is its ability to support full lifecycle workflows within a single ecosystem. These workflows include:

- **Data acquisition** from field surveys, sensors, satellites, and external data providers
- **Data management and governance** through secure repositories and metadata control
- **Analysis and modeling** across 2D, 3D, real-time, and predictive domains
- **Visualization and mapping** for operational awareness
- **Application development** to deliver tailored tools for specific needs
- **Collaboration and dissemination** of information across teams and stakeholders

This end-to-end capability eliminates the inefficiencies associated with disconnected tools and enables rapid, evidence-based decision-making.

6.1.6 Scalability, Security, and Enterprise Readiness

Enterprise GIS systems are built to support mission-critical operations. They incorporate architectural principles that prioritize:

- **Scalability**, enabling organizations to manage large datasets, high user volumes, and distributed infrastructures
- **Security,** including enterprise authentication, role-based access control, and encrypted data environments
- **Flexibility,** with deployment options across on-premises, cloud, and hybrid models
- **Resilience,** supporting high availability, load balancing, and disaster-ready architectures

This makes enterprise GIS dependable for sectors that rely on uninterrupted operations—such as utilities, disaster response, public safety, infrastructure, and government administration.

6.1.7 The Strategic Value of Enterprise GIS

Beyond operational efficiency, enterprise GIS provides strategic advantages that allow organizations to navigate complex and dynamic environments. It enhances the ability to:

- Understand community needs and service gaps
- Identify emerging risks and trends
- Align infrastructure planning with long-term sustainability
- Improve transparency and accountability
- Support innovation through AI, automation, and digital twin technologies

By embedding spatial intelligence into daily operations and long-term planning, enterprise GIS becomes a cornerstone of digital transformation and a catalyst for smarter, more responsive governance

6.2 Introduction to the ArcGIS Ecosystem

6.2.1 Overview

This chapter provides a foundational understanding of the ArcGIS system and its core components—ArcGIS Pro, ArcGIS Enterprise, ArcGIS Online. It highlights the versatility of ArcGIS, the diverse audiences it serves, and its ability to integrate with major IT, enterprise, and industry platforms. The chapter also outlines the broad technological advancements within the ArcGIS ecosystem, enabling organizations to leverage spatial data for decision-making, operational efficiency, and strategic planning.

6.2.2 Key Concepts and Definitions

- **GIS (Geographic Information System):** A framework for gathering, managing, analyzing, and visualizing spatial and geographic data.
- **ArcGIS System:** A comprehensive suite of Esri software, tools, and services enabling mapping, spatial analytics, and data management.
- **Spatial Analytics:** Analytical techniques that derive insights from location-based data.
- **Enterprise GIS:** Organization-wide GIS that supports multiple users, integrates with IT systems, and manages large datasets securely.

6.2.3 The ArcGIS Platform: Core Components and Their Roles

The ArcGIS platform offers a comprehensive ecosystem of GIS tools and services — combining desktop power, enterprise-grade infrastructure, and cloud-based flexibility. Its core components work together to meet a range of user needs: from detailed spatial analysis and map design, to large-scale data management, to collaborative web-based mapping and sharing.

ArcGIS Pro

ArcGIS Pro is the flagship desktop GIS application, designed for professionals who require robust spatial workflows. It supports 2D, 3D, and 4D visualizations, advanced geoprocessing, spatial analytics, and cartographic production. With ArcGIS Pro, users can integrate data from multiple sources, perform complex analysis, build models, automate workflows (e.g., via Python or ModelBuilder), and produce high-quality maps and layouts. Importantly, ArcGIS Pro is tightly coupled with the wider ArcGIS platform and allows seamless sharing of maps, data, and services with cloud or enterprise deployments.

ArcGIS Enterprise

ArcGIS Enterprise forms the backbone of organisational-scale GIS implementations. It is a self-hosted (on-premise) or cloud-deployable system that offers full control over data storage, access, and security. With Enterprise, organisations can manage and analyse spatial data internally, host map and feature services, run spatial analysis, handle large datasets, and manage real-time or big-data streams. It supports scalable deployment — from single-machine installations to multi-machine deployments on cloud or private infrastructure. ArcGIS Enterprise integrates with ArcGIS Pro for authoring and publishing, and provides the infrastructure for web GIS, secure data sharing, and organisational collaboration.

ArcGIS Online

ArcGIS Online offers a cloud-based GIS environment — a software-as-a-service (SaaS) platform where users can create, store, and share maps, data layers, web apps, and geospatial content without managing infrastructure. It supports flexible access via web and mobile, sharing with individuals or public users, and integrates with other ArcGIS components. This makes it ideal for organisations or teams that want to deploy GIS quickly, support remote or distributed users, and avoid the overhead of server maintenance.

This Multi-Component Architecture Matters because it offers

- Flexibility: Depending on project needs, you can use ArcGIS Pro for data creation and analysis; ArcGIS Enterprise for secure, scalable data management; or ArcGIS Online for cloud-based sharing and collaboration.
- Scalability: From a desktop analyst working alone, to a small team, to a full organization — the platform scales with infrastructure, data volume, number of users, and required security level.
- Integration: The components are tightly integrated. Data or maps created in ArcGIS Pro can be published to Enterprise or Online. Services hosted in Enterprise/Online can be consumed by web apps, mobile apps, dashboards, or reused in Pro.
- Accessibility: Cloud-based GIS (Online) expands access to GIS capabilities beyond specialists — enabling executives, field staff, public users, or stakeholders to view maps, dashboards, and apps without needing desktop software.

6.2.4 Designed for Everyone

ArcGIS is built as a universal system that supports multiple user profiles within an organization:

- **IT Professionals:** Manage systems, integrations, infrastructure, and deployments.
- **GIS Analysts & Specialists:** Perform data analysis, create maps, run geoprocessing workflows.
- **Executives & Senior Leadership:** Consume dashboards and insights for strategic decision-making.
- **Mobile and Field Workers:** Use field apps for data collection, inspections, and reporting.
- **Casual and Non-Technical Users:** Access simple web maps, story maps, and dashboards.
- **Developers:** Build applications using APIs, SDKs, and automation tools.
- **Public and External Stakeholders:** Engage with public-facing maps, portals, and citizen apps.

This inclusive design ensures GIS is accessible across departments, enabling organization-wide adoption.

6.2.5 Integration with External Platforms

ArcGIS integrates seamlessly with leading enterprise systems, enabling spatial intelligence to be incorporated into existing workflows:

- **Business Platforms:** IBM, SAP, Salesforce
- **Design and Engineering Tools:** Autodesk, Trimble
- **Cloud Platforms:** Amazon Web Services (AWS), Microsoft Azure, Google Cloud
- **Creative and Content Tools:** Adobe
- **Enterprise IT Systems:** Databases, identity management, IoT platforms, and data warehouses

These integrations allow organizations to unify spatial data with business processes, enhancing productivity and enabling spatial context in operations, reporting, and analytics.

6.3 Integration with External Platforms

6.3.1 Overview

This session explains the foundational pillars of the ArcGIS system and how they support enterprise-wide geospatial operations. It introduces the concepts of system of record, system of insight, and system of engagement—three interlinked capabilities that define how organizations store, analyze, and share geographic information. The chapter also provides an overview of ArcGIS's geospatial data management capabilities, collaboration frameworks, and the application of GIS across interdisciplinary domains. This serves as a technical foundation for understanding how ArcGIS functions as a complete geospatial infrastructure.

6.3.2 Key Concepts and Definitions

- **System of Record:** A trusted environment for storing, organizing, and maintaining accurate geospatial data.
- **System of Insight:** Analytical capabilities used to explore spatial patterns, trends, and relationships.
- **System of Engagement:** Mechanisms that connect users through maps, apps, dashboards, and collaborative tools.

- **Geodatabase:** A native data storage model in ArcGIS used to organize, query, and manage spatial data.
- **Versioning:** A method for managing simultaneous edits and maintaining historical accuracy.
- **Data Pipelines:** Automated workflows for integrating, transforming, and updating datasets.

6.3.3 The Three Pillars of ArcGIS

System of Data Management - The system of record provides a secure environment for storing and managing authoritative geospatial data. It includes geodatabases, schema design, field definitions, and rules that ensure data integrity.Organizations rely on this pillar to maintain consistent and validated datasets that represent real-world assets, infrastructure, land parcels, utilities, and environmental conditions.

System of Insight - This pillar empowers users to explore, analyze, and interpret spatial data. ArcGIS enables statistical analysis, spatial analysis, predictive modelling, and cross-domain insights. This supports evidence-based decision-making in areas such as resource planning, risk assessment, forecasting, and operational intelligence.

System of Engagement - The system of engagement connects people through intuitive maps, applications, dashboards, and collaborative tools. It enables internal teams, external stakeholders, and citizens to consume and interact with geospatial information, improving collaboration, transparency, and field-to-office workflows.

6.3.4 Geospatial Data Management

6.3.4.1 Storage and Geodatabases

ArcGIS offers a robust environment for storing and managing geospatial datasets through multiple mechanisms:

- **Geodatabase:** Supports vector, raster, topology, network datasets, and utility networks.
- **Schema Management:** Tools for defining fields, domains, subtypes, and data models.
- **Advanced Field Types:** Including 64-bit IDs for scalability and performance.
- **Time & Date Support:** Enabling temporal analysis and time-enabled layers.
- **Cloud Databases:** Support for relational cloud databases and enterprise-grade storage solutions.
- **Offline Capabilities:** Allows mobile workers to edit data in disconnected environments.

6.3.4.2 Editing and Data Creation

ArcGIS provides a suite of editing tools supporting various data formats and workflows:

- New Web Editor: Modern browser-based editing for hosted data layers.
- Metadata Editor: For documenting dataset lineage, standards, and quality.
- Nonversioned Editing: Fast, direct data updates for operational datasets
- **COGO Editing & Alignment Tools:** For precise infrastructure and survey-related digitization.
- **3D Features & Mesh Editing:** Tools for managing 3D objects, meshes, and scenes.
- **Linear Referencing:** Management of assets measured along linear networks (e.g., roads, pipelines).
- **Feature Template Sharing:** Enables standardized editing workflows across teams.

6.3.4.3 Data Integration Tools

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6.3.5 Collaboration and Data Sharing

ArcGIS enables seamless collaboration across departments, organizations, and the public. Key features include:

- **Distributed Collaboration:** Sharing layers, maps, and apps between ArcGIS Enterprise and ArcGIS Online.
- **End-to-End Data Sharing:** Ensures that data flows across planning, field data collection, operations, and reporting.
- **Open Data Hubs:** Public-facing platforms allowing citizens and external stakeholders to access curated datasets, dashboards, and reports. This promotes transparency, supports research, and improves inter-

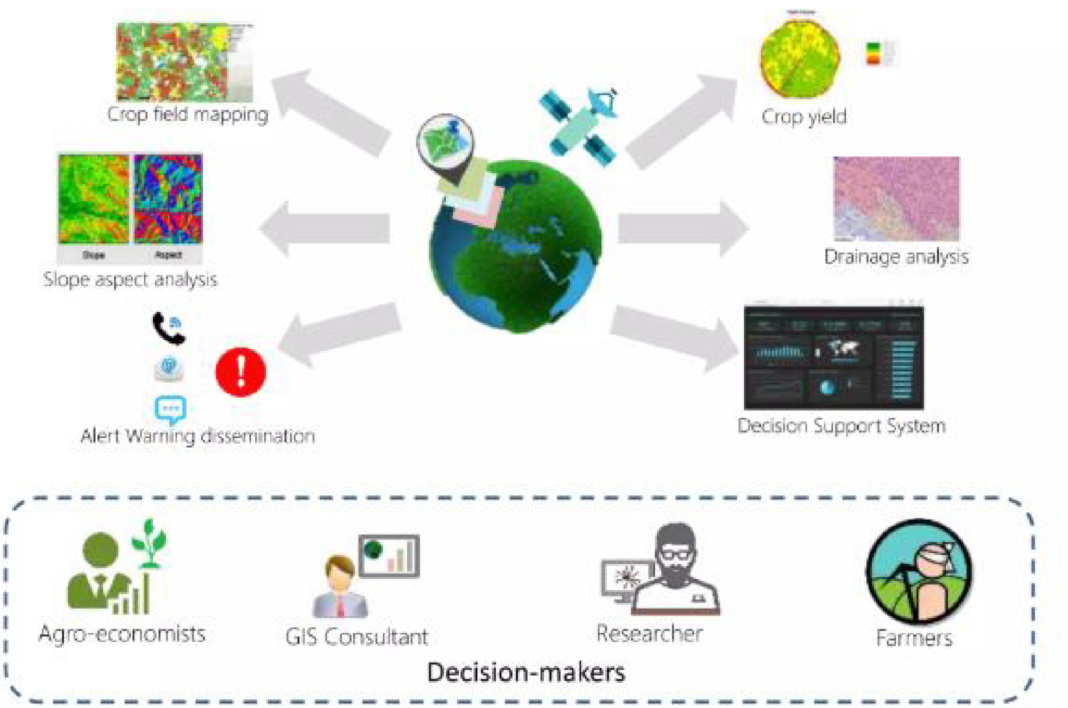
6.4 Use of GIS Across Key Domains

6.4.1 Overview

Geographic Information Systems (GIS) provide a spatial foundation for decision-making across sectors. By integrating maps, data, analytics, and field information, GIS enables institutions to visualize patterns, understand relationships, and respond to emerging challenges with precision. This chapter outlines how GIS strengthens critical domains including agriculture, healthcare, disaster management, demographics, and urban planning.

6.4.2 GIS in Agriculture

GIS has become a cornerstone of modern agricultural planning, enabling departments to understand spatial variations in soil, climate, crop health, and field conditions. Using satellite imagery, remote sensing indices, and geostatistical modelling, planners can identify suitable crop zones, improve diversification strategies, and enhance climate resilience.



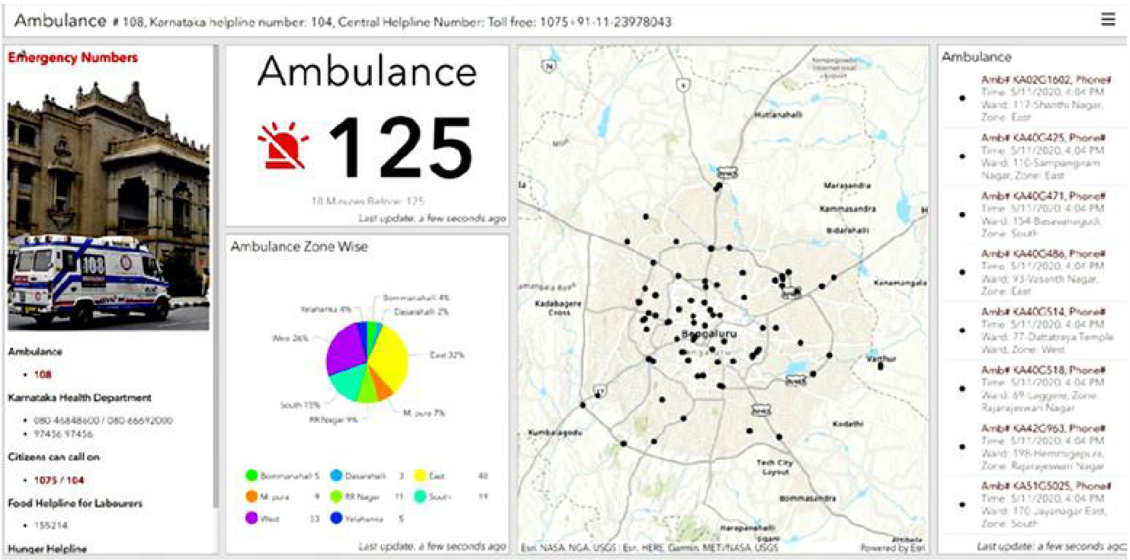
6.4.2.2 Applications

GIS supports data-driven interventions throughout the agricultural cycle. Crop growth monitoring, pest/disease detection, irrigation planning, and yield estimation become significantly more accurate when spatial layers are analyzed together. For government departments, GIS improves transparency in scheme implementation. Mapping crop-cutting experiments, insurance claim areas, and field patrol coverage ensures accountability and timely support to farmers.

6.4.3 Outcomes

Combined with mobile field data and enterprise dashboards, GIS forms an end-to-end agriculture platform. Farmers and field officers gain timely advisories; administrators gain real-time visibility; and states can scale digital agriculture solutions across districts, establishing a replicable and future-ready model.

6.4.4 GIS in Human Health & Healthcare



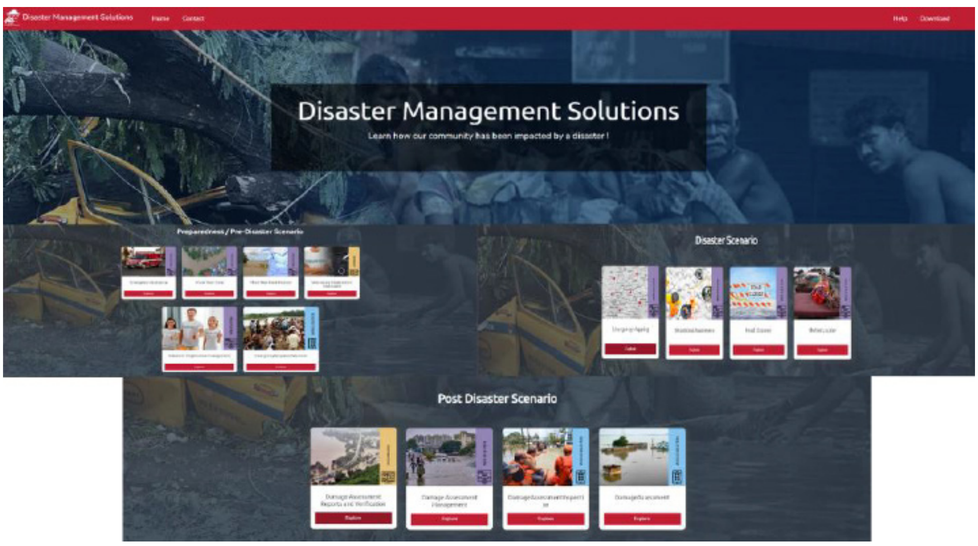
GIS provides powerful tools for understanding public health patterns and managing healthcare services. By spatially linking health records, demographic profiles, environmental data, and mobility trends, departments can visualize disease burdens and identify vulnerable populations.

6.4.5 Applications

GIS enhances epidemiological surveillance by identifying disease clusters such as dengue outbreaks, cancer hot spots, or opioid overdose patterns. Drive-time analysis and accessibility modelling reveal service gaps and guide optimal placement of hospitals, PHCs, mobile units, and emergency response facilities. Field collection tools support monitoring of vaccination drives, health inspections, and community-level surveys.

6.4.6 Outcomes

Through interactive dashboards and map-based analytics, planners can target interventions, allocate resources efficiently, and monitor progress in real time. GIS strengthens preventive healthcare, improves operational efficiency, and supports holistic



6.4.7 GIS in Disaster Response

GIS is integral to disaster preparedness, response, and recovery. Hazards such as floods, cyclones, landslides, earthquakes, and droughts can be better understood and managed when spatial data and real-time intelligence are combined.

6.4.7.2 Applications

Authorities use GIS to map hazard zones, assess vulnerabilities, and simulate event scenarios. During emergencies, live dashboards, drone imagery, social media feeds, and field reports provide situational awareness. Rescue teams can visualize affected communities, blocked roads, relief camp locations, and resource availability. Data-driven coordination ensures faster and more targeted action.

6.4.7.3 Outcomes

In the recovery phase, comparison of pre- and post-disaster imagery enables accurate damage assessments and transparent reporting. GIS supports reconstruction planning and long-term resilience building, forming the backbone of modern disaster

6.4.8 GIS in Census, Population & Demographic Studies

Population data gains significant analytical power when integrated with geospatial layers. GIS transforms static census tables into dynamic visualizations, enabling planners to understand demographic, social, and economic variations across regions.

6.4.8.1 Applications

Mapping population density, age groups, gender distribution, literacy, and income levels helps identify underserved communities, resource gaps, and socio-economic disparities. Spatial demographic analysis supports urban planning, election management, welfare targeting, and market research. GIS also improves census operations by enabling digital enumeration monitoring, boundary verification, and quality checks.

6.4.8.2 Outcomes

By linking population insights with infrastructure, services, and environmental conditions, GIS supports holistic policy design. Decision-makers can prioritize investments and ensure equitable service delivery across communities.

6.4.9 GIS in Urban & Regional Planning

GIS is fundamental to planning sustainable, efficient, and resilient urban areas. Planners use spatial data to visualize land use, infrastructure networks, utilities, natural features, and future growth patterns.

6.4.9.1 Applications

GIS supports preparation of master plans, zoning maps, base maps, and land suitability studies. Transportation modeling, service accessibility analysis, and environmental impact assessment enable evidence-based planning. Utility departments use GIS to manage water supply, sewage networks, streetlights, and other assets. Encroachment detection, building footprint extraction, and infrastructure maintenance are enhanced through remote sensing and field mobility tools

6.4.9.2 Outcomes

Modern cities rely on GIS as a central spatial platform, integrating IoT sensors, live feeds, and citizen services. Real-time dashboards help manage traffic, pollution, waste, and emergencies. By providing a unified operational picture, GIS ensures urban development is data-driven, equitable, and adaptive.

6.5 Field Operations & Data Collection

6.5.1 Overview

Field operations and data collection are critical components of any spatial data initiative. For a GIS system to remain accurate, current, and relevant, field-collected data must be systematically captured, integrated, validated, and synchronized. Leveraging ArcGIS mobile tools ensures that field workflows are efficient, consistent, and linked with the enterprise geospatial database. This chapter describes major field applications, the workflows they support, and best practices for implementation and quality assurance.

6.5.2 Core ArcGIS Field Applications

ArcGIS offers a suite of mobile and field-oriented applications designed to support different types of field workflows. The primary ones include:

- ArcGIS Field Maps — for map-driven data collection, editing, asset finding, and location tracking.
- ArcGIS Survey123 — for form-centric data collection and smart surveys, supporting offline use and quick survey deployment.
- ArcGIS QuickCapture — for rapid, minimal-interaction capture of observations, useful when speed and simplicity matter (e.g., damage assessments, mobile inspections).
- ArcGIS Workforce — to coordinate and dispatch field crews, assign tasks, integrate with maps or surveys, and manage field assignments. Esri+1

Each of these tools addresses different field-data needs — from detailed surveys to quick observations, from asset inspection to workforce management — and can be used standalone or in combination depending on project requirements.

6.5.3 Typical Field-Data Workflows

6.5.3.1 Map-Driven Data Collection & Editing (Using ArcGIS Field Maps)

In this workflow, field personnel use Field Maps on mobile devices to access authoritative basemaps or feature layers, locate assets or features, and add or update spatial data directly from the field. This replaces traditional paper-based or offline GPS + later digitization workflows. Field Maps supports offline map downloads, so users can work in remote areas without network connectivity, then sync changes once connectivity is restored.

This approach ensures:

- Real-time or near-real-time updates to the central GIS database.
- Reduction of data-entry errors (no manual transcription).
- Better tracking of field operations and transparency (who collected/edited what, when, where).
- Efficient asset management, infrastructure mapping, and ground-level validation.

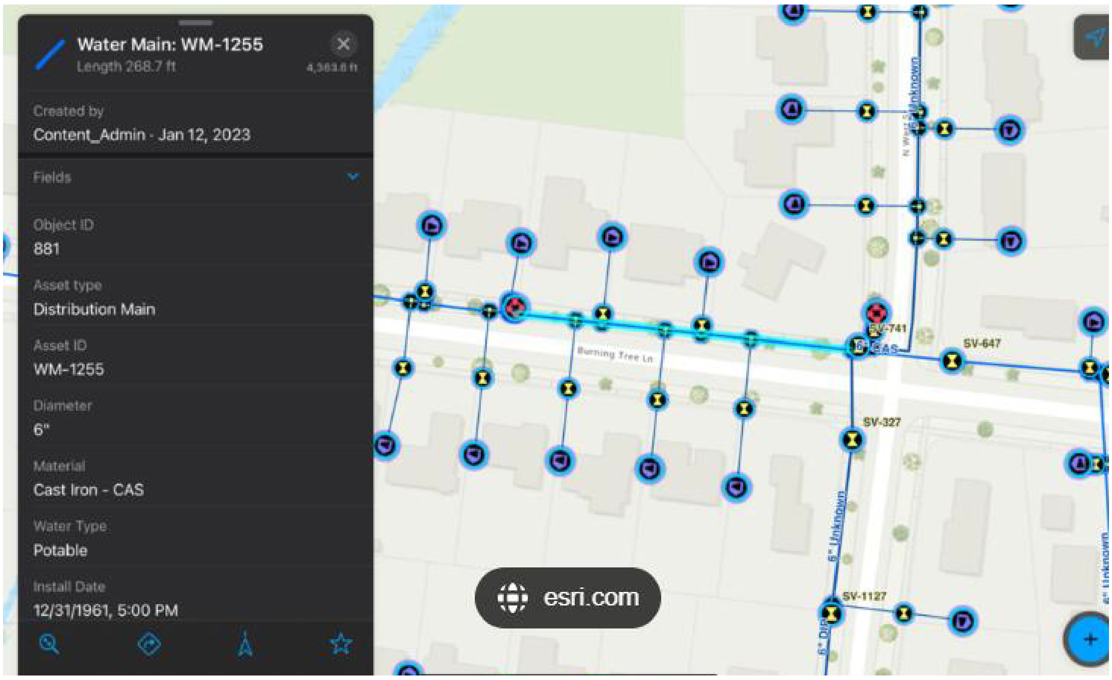
Field Maps is especially useful for asset inventories, infrastructure audits, environmental surveys, utility mapping, and any task requiring spatial accuracy and attribute collection.

6.5.3.2 Form-Centric Surveys and Inspections (Using ArcGIS Survey123)

When data collection involves structured, attribute-heavy surveys — e.g., socio-economic surveys, environmental assessments, house-hold data, field inspections — Survey123 provides a robust solution. Using smart, customizable forms (built via desktop or online tools) and logic (skip logic, required fields, validation, etc.), Survey123 ensures data integrity and uniformity.

Survey123 supports offline data collection, allowing field workers to operate in remote or connectivity-poor zones; data is stored locally and synced when online.

Advanced workflows are possible: e.g., multi-stage inspections — where one survey leads to follow-up surveys; or conditional forms that adapt based on earlier answers. Use cases: census / demographic data collection, agricultural surveys,



6.5.3.3 Rapid Observations & Mobile Assessments (Using ArcGIS QuickCapture)

For workflows requiring quick, simple data capture — such as damage assessment after disasters, road conditions monitoring, environmental observation while moving — QuickCapture offers a one-button approach to collect point, line, or polygon observations. It is suited to situations where speed and minimal user interaction matter.

Because QuickCapture reduces the data-entry burden, it can be used for tasks where field teams need to cover large areas rapidly, or when they have limited training but need to gather geotagged observations.

6.5.3.4 Field Crew Coordination & Task Assignment (Using ArcGIS Workforce + Field Apps Integration)

Field operations often require multiple teams, changing task lists, dynamic assignments, and mapping support. ArcGIS Workforce enables centralized dispatch, assignment creation, and real-time monitoring of tasks for field staff. Esri+2Esri+2

Workforce integrates with Field Maps, Survey123, and QuickCapture: for instance, a dispatcher can assign a task to a field worker, who then opens the assignment in Field Maps (for map-driven data collection), or Survey123 (for a detailed survey), or QuickCapture (for rapid observation).

This integration ensures efficient coordination, standardized workflows, and traceability of who did what, when, and where — a major improvement over traditional manual task allocation and reporting.

6.5.4 Best Practices for Field Operations & Data Collectiongration)

To ensure high-quality, reliable data, it's important to adopt standard procedures and follow proven best practices. Based on Esri guidance and industry experience, the following are recommended:

- Standardize data collection procedures across teams: Use common forms, attribute definitions, field names, and data validation rules to ensure consistency.
- Optimize for GPS accuracy: Where precise location matters (e.g., asset mapping, infrastructure), use techniques like differential corrections or post-processing, avoid obstructions (dense vegetation or tall buildings), and calibrate devices as needed.
- Enable offline workflows when needed: Configure offline map areas or offline-enabled feature services so field teams can collect data even without network connectivity. Sync when connectivity is restored.
- Embed validation and quality control: Use forms with required fields, constraints, skip-logic, and consistent attribute types to minimize errors. Include photo attachments, GPS capture, and metadata where relevant.
- Maintain traceability and audit trails: Track who collected or edited data, when and where — for accountability, verification, and future audits. Field apps support user authentication and edit tracking.
- Integrate field data with central GIS workflows: Ensure that collected data flows into central databases (on-prem or cloud), is version-managed, and is available for analysis, reporting, and decision-making.
- Train field staff properly: Provide training on app usage, map reading, GPS handling, offline workflows, syncing, and data quality. This reduces errors and increases efficiency.

6.5.5 Challenges & Mitigation Strategies

Field data collection is not without challenges. Some common pitfalls include:

- **Poor GPS accuracy** due to terrain, obstructions, or device limitations — mitigated by calibration, use of external GPS receivers, or post-processing.
- **Connectivity issues** in remote or rural areas — addressed by offline map and data collection configuration, local caching, and deferred sync.
- **Inconsistent data entry** across different field teams — avoided through standardized forms, validation, and training.
- **Delayed or missing synchronization,** leading to data gaps — mitigated by clear protocols on sync frequency, reminders, and supervisor oversight.
- **Data overload or large multimedia attachments** (photos, videos) slowing down syncing and storage — managed via data management policies, compression, and purging old attachments.

Recognizing and preparing for these challenges helps ensure reliable and high-quality spatial datasets from field operations.

6.5.6 Integration of Field Data with Enterprise GIS

Once collected and synced, field data becomes part of the enterprise spatial database.

This enables:

- Centralized data management and version control.
- Integration with existing layers (infrastructure, demographics, environmental, assets).
- Real-time or scheduled analytics, dashboards, and reporting.
- Data sharing across departments and stakeholders, with appropriate permissions and data protection.

Using standard workflows and tools (Field Maps, Survey123, Workforce, QuickCapture) ensures interoperability, maintainability, and scalability of GIS projects within the organization. By deploying ArcGIS field applications and adopting best practices, organizations can transform field operations from disconnected, paper-based processes into efficient, transparent, and digitally integrated workflows. Field data collection becomes reliable, scalable, and directly useful for analysis, planning, and decision-making. With robust field workflows, the GIS becomes a living system, continuously updated and reflective of real-world conditions

6.6 GeoAI

6.6.1 Overview

GeoAI represents the integration of artificial intelligence (AI) — including machine learning (ML), deep learning (DL), and natural language processing (NLP) — with geospatial data and spatial analysis frameworks. Within ArcGIS, GeoAI enables automation, enhancement, and scaling of traditional GIS workflows. This chapter describes how GeoAI is embedded within ArcGIS, the tools and models available, required skills, and how GeoAI is applied across different domains to deliver spatial intelligence at scale.

6.6.2 Key Concepts and the GeoAI Framework in ArcGIS

GeoAI in ArcGIS builds on a combination of spatial analysis and AI techniques. In simple terms: spatial data — such as imagery, point clouds, raster layers, tabular data, or even unstructured text — is processed using AI/ML/DL to yield new geospatial information or predictive insights.

- **Machine Learning (ML):** Used for tasks like clustering, classification, regression, and spatiotemporal forecasting, applied on spatial or tabular data layers.
- **Deep Learning (DL):** Used for high-complexity tasks — e.g., image segmentation, object detection in imagery or point clouds, feature extraction, change detection, and even processing of unstructured text for georeferencing or entity recognition.
- **GeoAI Framework Components:** ArcGIS includes a GeoAI toolbox that supports both model training (on user datasets) and use of pre-trained models (e.g., for imagery classification, object detection, NLP on text fields).
- **AI Assistants and Agents:** Beyond raw models, ArcGIS offers AI assistants — tools that allow users to interact with GIS and AI workflows through intuitive, sometimes natural-language interfaces — increasing productivity and simplifying complex tasks.

GeoAI thus transforms GIS from purely manual or rule-based spatial analysis into a hybrid of spatial + data science + AI, enabling automation of previously tedious tasks and allowing new forms of spatial insight.

6.6.3 GeoAI Tools and Services in ArcGIS

ArcGIS provides a suite of tools via the GeoAI toolbox. These include:

- Tools for classification and regression on feature/tabular datasets using ML algorithms.
- Tools for text processing: using NLP / deep learning to analyze unstructured text fields — for example, entity recognition, text classification, transformation, summarization, georeferencing of place names, etc.
- Support for imagery and sensor data workflows: segmentation, object detection (e.g., detecting buildings, roads, features in satellite or aerial images), change detection over time, classification of land cover, and generating GIS layers from raw image or point-cloud data.
- Ability to train custom models using one's own datasets when pre-trained models are insufficient.

6.6.4 Pre-trained Models

One of the major strengths of ArcGIS's GeoAI offering is access to a large library of pre-trained deep learning models (on imagery, point-clouds, feature detection, NLP) — allowing users to bypass the resource-intensive model-training phase.

These pre-trained models support common use cases out-of-the-box: building footprint extraction, land cover classification, object detection (vehicles, infrastructure), redaction of sensitive imagery, point-cloud classification (e.g., trees, powerlines), among others.

6.6.5 GeoAI Analysis: Prediction, Extraction, Text Georeferencing & More

GeoAI can be applied to a range of analytical needs, including:

- **Spatial prediction and forecasting:** Using machine learning/regression tools on spatial/tabular data to forecast trends (e.g., environmental change, population growth, hazard risks). This allows predictive analytics that combine spatial context with data-driven insights.
- **Feature extraction & object detection:** Using deep learning on imagery or point-clouds to automatically detect, classify, and extract features such as buildings, roads, land-cover types, vegetation, utilities — converting raw remote sensing or LiDAR data into GIS-ready vector layers.
- **Change detection & temporal analysis:** By comparing multi-temporal imagery (or other spatial layers), GeoAI can detect changes — e.g. land-use change, deforestation, construction, damage after disasters — enabling dynamic monitoring and timely interventions.
- **Text georeferencing & NLP-based spatial data generation:** GeoAI supports processing unstructured textual data sources (e.g., survey responses, reports, historical records) to extract place-names, addresses, events, and convert them into geospatial features — through entity recognition and geocoding.
- **Integrated spatial + non-spatial analysis:** By combining AI outputs with traditional GIS spatial analysis, planners and analysts can perform complex workflows — e.g., overlay AI-derived features with demographic, environmental or infrastructure layers to generate insights that inform policy, planning, or operations.

6.6.6 Usage of GeoAI across Domains

GeoAI's flexibility makes it applicable across many sectors. Some example domain-level uses:

- **Urban / Regional Planning & Infrastructure:** Automatic extraction of building footprints, road networks, land-cover classification; monitoring urban expansion; disaster risk zoning; change detection after events.
- **Disaster Management & Environmental Monitoring:** Rapid detection of damage (post-disaster), flood mapping, deforestation tracking, environmental impact assessment, change detection in land use/cover. Pretrained models from ArcGIS's Living Atlas help speed up damage assessment workflows.
- **Agriculture & Land Use:** Land-cover classification, crop-type mapping, monitoring field conditions via remote sensing, change detection over seasons, yield estimation models combining spatial predictors with climatic or soil data.
- **Public Health & Epidemiology:** Mapping risk zones based on environmental, population, and infrastructure layers; integrating spatial predictions with health data; georeferencing address- or narrative-based health reports for spatial epidemiology.
- **Census, Demographics & Socioeconomic Planning:** Deriving built-environment features from imagery, integrating AI-extracted spatial layers with demographic and infrastructure data, predictive population growth mapping or settlement growth analysis.

6.7 Digital Twin

6.7.1 Overview

A geospatial digital twin is more than a static 3D model. It is a living, data-driven virtual replica of real-world systems that is time-aware, scalable, and data-rich. Key characteristics:

- **Geospatial foundation:** The twin leverages GIS to represent spatial relationships, geography, topology, networks, and context (terrain, land use, natural features, built environment).
- **Temporal awareness:** A digital twin can capture past states, represent the present, and simulate future scenarios — enabling temporal analysis and scenario-based planning.
- **Data integration:** It integrates diverse data types — BIM/CAD models, satellite imagery, LiDAR, sensor feeds (IoT), utility/asset data, environmental data, demographic data — into a unified framework.
- **Scalability:** Digital twins can represent single assets (e.g. a building), facilities (airport, factory), or scale up to neighbourhoods, cities, or entire natural systems.
- **Interactivity and analytics:** Users can interact with the twin (view in 3D or web apps), run analytics (visibility, network analysis, simulation), monitor real-time conditions (via IoT), and support planning, operations, maintenance, and decision making.

Thus, a geospatial digital twin transforms GIS from a static mapping tool to a dynamic, living system — bridging the physical world and digital workflows.

6.7.2 How ArcGIS Supports Digital Twins: Tools & Core Components

ArcGIS provides a full stack of capabilities to build, manage, and use digital twins — supporting everything from data capture to analytics, from real-time monitoring to simulation and visualization. Some core elements:

- **Reality Capture & 3D / 4D Modeling:** Through tools like photogrammetry, LiDAR integration, textured mesh/point-cloud generation — enabling realistic 3D (or 4D with temporal data) representation of physical environments.
- **Integration of GIS + BIM/CAD + Infrastructure Data:** ArcGIS can combine spatial GIS data (parcels, terrain, utilities, networks) with BIM/CAD models of buildings or assets — enabling a unified "as-built + spatial context" twin.
- **Real-time Data & IoT Integration:** Sensor feeds (e.g., environmental sensors, traffic sensors, utility meters), telemetry, and dynamic data streams can be fed into the twin to reflect current state, enabling monitoring and operational oversight.
- **Analytics, Simulation & Scenario Modeling:** Spatial analytics, network analysis, visibility analysis, performance simulation, prediction of future states (e.g. growth, stress, risk) can be run within ArcGIS, leveraging traditional GIS + digital twin data.
- **Visualization & Collaboration:** Through web apps, 3D scenes, dashboards, interactive maps, and cross-platform access (web, mobile, desktop), digital twins become accessible to planners, managers, stakeholders, and the public.
- **Scalable Data Management & Open Architecture:** ArcGIS supports scalable storage (cloud or enterprise), standard geospatial data models, open APIs, and interoperability with other enterprise systems (e.g. asset management, engineering, utilities) — enabling sustainable implementation of digital twins.

6.7.3 Use Cases & Applications of Digital Twins

Geospatial digital twins built with ArcGIS are being leveraged across many sectors. Some representative applications:

- **Urban Planning, Smart Cities & Infrastructure Management -** Cities use digital twins for urban planning, zoning, infrastructure management, traffic and transport, utilities, resilience planning, and scenario simulation. For instance, combining terrain models, building footprints, networks (roads / utilities), and real-time data (traffic, environment) for dynamic city governance.
- **Asset / Facility / Infrastructure Lifecycle Management -** Facilities like airports, water treatment plants, utilities, transport hubs have built digital twins representing built assets (BIM + GIS), dynamic operational status, maintenance history, performance monitoring, and renovation planning. For example, some organizations integrate live data feeds (e.g. vehicle movement at airports, ground-vehicle locations, sensor data) into their digital twin to monitor operations and manage assets in real time.
- **Environmental Monitoring, Natural Systems & Ecosystem Management**
- Digital twins are used to represent natural environments — landscapes, watersheds, forestry, ecological corridors — combining topographic data, land use, remote sensing, environmental sensor data, temporal data to monitor changes, run impact simulations (e.g. flood, land-use change, climate risk), and support conservation planning.
- **Disaster Management and Risk Assessment -** In disaster-prone regions, digital twins provide a powerful foundation for hazard mapping, risk assessment, real-time monitoring (sensors, IoT), damage assessment (using imagery + 3D models), evacuation planning, and recovery simulations.
- **Utilities, Network Management & Infrastructure Monitoring -** Utility companies use digital twins to model and manage infrastructure networks (electricity, water, transport), overlay BIM/asset data with GIS, monitor usage, plan maintenance, detect issues, and optimize operations.
- **Agriculture & Land-Use / Resource Planning -** Digital twins support monitoring of land use, crop fields, irrigation infrastructure, environmental conditions; integrating satellite imagery, sensor data (soil moisture, weather), land-use, and management data — facilitating precision agriculture, resource optimization, planning, and sustainability.
- **Building and Project Lifecycle Management (AEC) -** By combining BIM (building design/asset models) with GIS context, digital twins help architects, engineers, and planners simulate construction, perform clash detection, plan operations/maintenance, space management, and lifecycle asset management.

6.7.4 Key Considerations and Implementation Guidelines

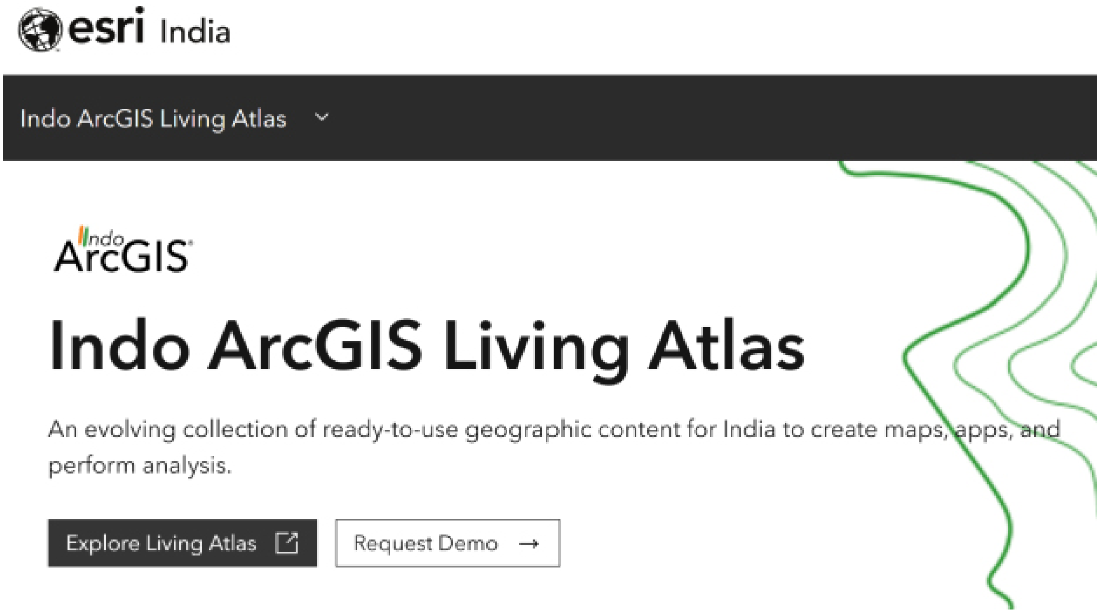
When building a digital twin with ArcGIS, it's important to define scope and manage complexity — especially because data comes from diverse sources and stakeholders. Key factors to consider:

- **Scale and Complexity:** Determine whether the twin is for a single asset, complex facility, urban area, or region — this influences data needs, compute/storage, and maintenance.
- **Data Ownership & Governance:** Multiple datasets (BIM, sensor, GIS, environmental, demographic) may have different owners — so a governance model must be defined, especially for data sharing and updates.
- **Interoperability and Integration:** Ensure BIM/CAD, GIS, IoT/sensor, remote-sensing, asset databases are in compatible formats, coordinate systems, and standards so they integrate into a unified twin without data loss.
- **Maintenance and Update Workflow:** A living twin must be kept updated — sensor feeds, periodic reality capture, regular audits — to remain accurate and useful.
- **User Access & Permissions:** Design access levels depending on stakeholders — decision-makers, planners, operations staff, public — to maintain data integrity while enabling collaboration.
- **Performance & Infrastructure Requirements:** For large twins (city-scale, high-resolution 3D, real-time data), ensure adequate computing, storage, bandwidth, and performance optimization.

6.8 Open Data Cloud & ArcGIS Living Atlas for India

6.8.1 Overview

Modern GIS workflows often require access to large, authoritative, and up-to-date spatial datasets, not just locally collected or organisation-specific data. The "open data cloud" approach embedded in ArcGIS is realised through the ArcGIS Living Atlas of India, which provides a curated repository of geospatial layers, imagery, basemaps, demographic data, infrastructure, environment, and thematic data covering all of India. This chapter explains how Living Atlas works, what kinds of data it provides, how to access and integrate it, and why it is important for GIS users, planners, and decision-makers in India.



6.8.2 What is ArcGIS Living Atlas of India / Open Data Cloud Approach

The ArcGIS Living Atlas of India builds on the global ArcGIS Living Atlas of the World — an evolving collection of ready-to-use global geographic content — but tailored for India. It aggregates authoritative geographic data from multiple credible sources(government, research, private, open-data providers), processes and curates them, and makes them available as usable map layers, basemaps, and services.

In the context of "open data cloud," Living Atlas represents a cloud-hosted, centrally maintained data repository that organisations and users can tap into — eliminating the need to build and maintain their own national-scale datasets. This significantly reduces duplication of effort, improves data reliability, and ensures access to updated, standardized, and inter-operable datasets.

6.8.3 Content and Data Types Available in Living Atlas (India Edition)

The Living Atlas for India provides a wide variety of spatial data layers, covering multiple domains. Some of the main content categories include:

- Administrative Boundaries: State, district, sub-district, village boundaries; postal-code boundaries; electoral/ constituency boundaries; and in some places, ward boundaries.
- Transport Networks: Road networks (national highways, state highways, expressways), railways, railway stations, airports, other transport infrastructure.
- Satellite Imagery & Remote Sensing Data: High-resolution base maps, multi-temporal imagery (including "wayback" historic imagery archives), elevation and terrain data, environmental layers (land use/cover, hydrology, terrain, ecology) useful for environmental, land-use, disaster, and resource-management applications.
- Points of Interest (POI) / Landmarks: Public & private infrastructure such as hospitals, schools, utilities, commercial establishments, etc. Useful for urban planning, service delivery, public-health, accessibility analysis.
- Building Footprints: Derived from high-resolution imagery — helpful for urban planning, population estimates, disaster risk assessments, infrastructure mapping, change detection.
- Demographics & Socio-economic Data: Layers embedded with census or demographic variables (population, density, socio-economic variables) — useful for planning, health, social programs, resource allocation, equity analysis.

- Environmental, Hydrology, and Thematic Data: Including land cover/land use, hydrological networks, environmental risk zones, elevation/terrain layers, habitat/forest/vegetation data, etc. Useful for environment, disaster risk, natural resource management.
- Live Feeds & Temporal Data (where available): Some layers may include live or periodically updated feeds (e.g. environmental, urban change, remote sensing derived layers), enabling near real-time analysis for decision-making.

Such a comprehensive and curated repository significantly lowers the barrier for GIS users needing national-scale data.

6.8.4 Why This Matters for Indian GIS Practitioners and Planners

- **Reduced Data Procurement Effort & Cost:** Collecting national-scale data (boundaries, transport networks, building footprints, demographics, environment, etc.) from scratch is expensive and time-consuming. Living Atlas provides these out-of-the-box.
- **Standardization and Interoperability:** Using a common, authoritative dataset means different teams/projects use the same baseline — enabling consistency across studies, easier collaboration, and comparative analyses.
- **Speed and Efficiency for Projects:** For your work (e.g. urban planning, conservation, disaster risk, environmental assessments, social sector planning), you can jump-start mapping/analysis with baseline layers instead of starting from zero.
- **Support for Multi-Domain & Integrated Analyses:** Because the data spans boundaries, transport, demography, environment, land use, infrastructure — you can run cross-sector analyses easily (e.g. link population and health, or environment and disaster risk).
- **Scalability:** Whether it's a village-level assessment or a state-wide plan — Living Atlas scales with your needs; no need to build different base datasets for different scales.
- **Facilitating Transparency & Public Data Sharing:** Data from Living Atlas can support public-facing maps, dashboards, portals — facilitating transparency, citizen engagement, and informed decision-making.

6.9 Deployment, Adoption & Scalability

6.9.1 Overview

The successful implementation of GIS within an organization is not only about technology, but also about how solutions are deployed, adopted by users, and scaled across teams, departments, or regions. This chapter covers strategies, best practices, and considerations for deploying ArcGIS, ensuring user adoption, and achieving scalable GIS solutions.

6.9.2 Deployment Strategies

ArcGIS can be deployed in multiple ways depending on organizational needs, infrastructure, and budget:

On-Premises Deployment - Organizations host ArcGIS Enterprise on their internal servers. This offers maximum control over infrastructure, security, and data privacy. Key aspects include:

- Infrastructure planning (servers, storage, network)
- Portal configuration for internal users
- Data management within secure environments

Cloud Deployment - ArcGIS Enterprise or ArcGIS Online can be deployed in the cloud using Esri-hosted or third-party cloud services (AWS, Azure, Google Cloud). Benefits include:

- Reduced IT overhead
- Scalable storage and processing power
- Easy remote access for distributed teams

Hybrid Deployment - Combining on-premises and cloud resources to balance control and flexibility. For example: sensitive internal data stored on-premises while public-facing apps are hosted in the cloud.

6.9.3 Adoption Strategies

Even with a technically strong deployment, adoption by end-users is critical. Successful adoption requires addressing people, processes, and training.

Stakeholder Engagement

- Identify key stakeholders and decision-makers
- Communicate benefits and value of GIS solutions
- Involve users in solution design to meet actual needs

Training and Capacity Building

- Provide role-specific training: field users, analysts, managers, executives
- Use workshops, online resources, and hands-on exercises
- Promote GIS champions within departments

Change Management

- Encourage gradual adoption with pilot projects
- Collect feedback and iterate on workflows
- Align GIS solutions with existing business processes to reduce friction

Support and Documentation

- Maintain clear user guides, FAQs, and knowledge bases
- Establish a helpdesk or internal support team
- Document standard workflows and best practices

6.9.4 Scalability Considerations

Scaling GIS solutions involves extending their reach to more users, data sources, or geographies without degrading performance.

Technical Scalability

- Ensure servers and cloud infrastructure can handle increased workloads
- Optimize databases, services, and maps for large datasets
- Implement load balancing, caching, and performance monitoring

Organizational Scalability

- Standardize workflows and data management practices
- Use centralized portals, dashboards, and app templates for repeatable deployments
- Promote inter-departmental collaboration and shared services

Data Scalability

- Plan for increasing volume of spatial and tabular data
- Leverage enterprise geodatabases, cloud storage, and real-time data streams
- Use Living Atlas or open data to supplement organizational data

6.9.5 Key Best Practices

1. **Start Small, Scale Gradually:** Begin with pilot projects before expanding enterprise-wide.
2. **Align GIS with Organizational Goals:** Demonstrate how GIS improves decision-making, efficiency, and transparency.
3. **Governance and Standards:** Establish policies for data management, sharing, and app creation to ensure consistent quality.
4. **Automation and Integration:** Leverage ArcGIS APIs, notebooks, and integration with other platforms (SAP, Salesforce, IoT) for scalable workflows.
5. **Monitor & Improve:** Continuously track usage, performance, and feedback to refine solutions.

6.9.6 Summary / Key Takeaways

Deployment of an enterprise GIS can take place on-premises, in the cloud, or through a hybrid model, with each option offering distinct advantages and operational considerations. Successful adoption goes beyond technology, it requires active stakeholder engagement, comprehensive training programmes, and thoughtful alignment with existing business processes to ensure smooth integration. Scalability must be addressed not only in terms of technical infrastructure, but also with respect to organizational workflows, governance mechanisms, and long-term data management practices. When these elements are supported by well-defined best practices, the resulting GIS environment becomes sustainable, effective, and capable of delivering meaningful impact across the enterprise.

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LESSON - 7

Fundamentals of Positioning, Navigation and Timing and its Relevance in the GKI Ecosystem

Trainer' s Biodata: Major General (Dr.) B. Nagarajan (Retd.), Professor, Department of Civil Engineering, Indian Institute of Technology, Kanpur

Major General (Dr.) B. Nagarajan (Retd.) is a distinguished Professor in the Department of Civil Engineering at the Indian Institute of Technology, Kanpur. A former Additional Surveyor General at the Survey of India, he brings decades of leadership and technical expertise in geodesy, national mapping, and advanced surveying sciences. His research spans satellite altimetry and gravimetric studies, Earth rotation and polar motion, photogrammetry and remote sensing, topographical surveying and mapping, and the development of regional geoidal models. With a career that bridges military service, national surveying leadership, and academic excellence, he continues to contribute significantly to the advancement of India's geospatial science and engineering ecosystem.

Session Overview

- Understanding the fundamentals of PNT systems
- Indian PNT ecosystem and strategic infrastructure
- Sectoral applications and economic relevance of PNT
- Challenges of dependence and data sovereignty
- Future trends and emerging technology integration

LESSON - 8

Interoperability and Integration: Advancing Geospatial Data Infrastructure through Standards and Collaboration

Trainer' s Biodata: Harsha Madiraju, Associate Director, Open Geospatial Consortium (OGC)

Harsha Madiraju is a global geospatial advocate and widely networked geo-specialist. He has over 20 years of experience in international marketing, business development, strategic partnerships, organizational development, and nonprofit management. As the Associate Director, he serves and supports members and communities in India, Africa, and Europe at OGC, the Open Geospatial Consortium (OGC). Previously, as the Associate Director at the World Geospatial Industry Council (WGIC), Harsha worked closely with the private sector, multilateral and partner organizations worldwide. His strategic guidance and direct contributions to a report on Climate Change won the Prince Talal International Prize for Human Development for WGIC, presented at COP 27.

Session Overview

- The role of open standards in ensuring interoperability across national platforms
- Importance of standards and strategies for aligning Centre, state, and local GKI ecosystems
- Eliminating data duplication, addressing fragmentation, and strengthening metadata protocols
- Developing federated NGDI architectures to enable seamless Centre–State data exchange

LESSON - 9

Harnessing Earth Observation Data for National Mapping

Trainer' s Biodata: Dr. Hrishikesh Samant, Professor of Geology, St. Xavier's College, Mumbai

Dr. Hrishikesh P. Samant is Professor of Geology at St. Xavier's College, Mumbai, with over three decades of academic and professional experience in geomorphology, remote sensing, GIS and applied geospatial sciences. Holding a PhD from IIT Bombay, he has served in senior academic leadership roles and contributed extensively to national geospatial education and policy through committees of the Government of India and State Government. His work spans Earth Observation-based terrain analysis, land use studies, coastal management, and capacity building for geospatial professionals. With a sustained track record of research, teaching and professional engagement, Dr. Samant brings deep domain expertise and academic rigor to his role as author and trainer.

1. Session Overview

We live in an era of rising complexity and mounting risks from fragmented systems. From energy grids and global supply chains to emergency response and infrastructure development, the systems we depend on are increasingly interconnected. Yet, the data and decisions guiding them often remain siloed.

Geospatial information provides the foundation for managing this complexity. It tells us where things are, how they move, and how they relate to one another across time and space. From monitoring land use and tracking logistics to securing borders and planning for climate resilience, geospatial systems underpin some of society's most critical operations.

But today, it's not just about location. It's about shared semantics, common frames of reference, data rights, and trust. As systems become more complex and interdependent, knowing "where" is no longer enough. Decision-makers need to understand what it means, who controls it, how it can be used, and how it fits within a broader ecosystem.

This is the promise, and the challenge of the emerging interconnected geospatial ecosystem. According to Coetzee et al. (Towards a Sustainable Geospatial Ecosystem beyond SDIs, 2021):

"A geospatial ecosystem is where people from all over the world interact directly or indirectly, utilizing dependable and accurate location-based data and advanced geo-analytics conveyed through dynamic geomedia or open computing environments. Like a natural ecosystem, geospatial ecosystems are marked by strong interrelationships between actors and their surroundings, constant adaptation, and the potential for significant transformations resulting from certain events."

Table of Contents

Abstract

The rapid pace of urbanisation and national infrastructure expansion in India has created an unprecedented demand for up-to-date, large-scale topographic information. Traditional revision cycles of Survey of India (SoI) topographic maps, primarily dependent on ground surveys, are increasingly unable to respond to the temporal dynamics of landscape transformation. This article critically examines the logic, technological feasibility, and strategic rationale for adopting a Regular Cycle-Based (RCB) update mechanism using Earth Observation (EO) data for revising SoI topographic maps, with particular emphasis on land cover change, urban expansion, and national-scale above-ground infrastructure development. The assessment is structured as a discussion paper for senior Survey of India executives about understanding how EO-driven workflows would be harmonised with national accuracy standards at scales of 1:25,000, 1:10,000 and up to 1:4,000.

Learning Outcomes

On completion of this chapter, participants would be able to:

1. Analyse the technical, strategic, and governance aspects influencing the adoption of an EO-driven Regular Cycle-Based update system for national topographic mapping.
2. Apply conceptual and operational knowledge of EO workflows to interpret change detection processes and their implications for authoritative topographic updates.
3. Design strategy for institutional transformation and policy alignment that enable the transition towards dynamic, continuously updated national mapping systems.

1. The Hidden Price of Outdated Maps

The case for implementing a robust Regular Cycle-Based (RCB) update mechanism for Survey of India (SoI) topographic maps is no longer merely technical or aspirational. This is now about economics, strategy and also increasingly a matter of public safety, as India continues to bear the cumulative cost of outdated or intermittently updated base maps through inefficient infrastructure planning, misaligned land acquisition, duplication of surveys, delayed approvals, compromised environmental assessments and weakened disaster response. Equally concerning is the growing reliance on privately curated, commercially driven mapping platforms, updated primarily for market advantage, often with limited regulatory oversight, uneven quality control and almost zero accountability. The “off-the-shelf” navigation datasets, widely used by platforms such as Uber, Ola and logistics aggregators, frequently rely on fragmented, crowd-sourced or algorithmically inferred inputs that fail to reflect on-ground realities such as new alignments, temporary diversions, closed bridges or hazardous stretches. In critical situations, such inaccuracies move beyond inconvenience and may pose serious safety risks, particularly in unfamiliar terrain, disaster-affected areas or emergency response contexts.

There is also a significant opportunity cost arising from the absence of an authoritative, systematically refreshed national base map, especially under initiatives like PM GatiShakti that demand spatial coherence for integrated, multimodal infrastructure planning (see Section 8). Hence an assured RCB update regime led by SoI, driven by validated Earth Observation workflows and aligned with the National Geospatial Policy 2022 framework, would reaffirm SoI’s knowledge based authority and operationalise the principle of “One Nation One Map”. A continuously refreshed national base map would serve as the single reference layer for Central and State Government departments, utilities, smart city programmes, disaster management authorities and defence agencies, reducing redundancy, improving interoperability and curbing cumulative geospatial expenditure. More crucially, it would restore sovereign control over India’s spatial narrative, anchoring development, governance and safety in credible, current and nationally assured geospatial intelligence. When viewed against the persistent economic leakages, governance inefficiencies and safety vulnerabilities arising from inaction, the investment required for RCB map update implementation is not only justified, but strategically indispensable (also refer Section 6 on the logic of an RCB model). Above all this is also the right of every Indian citizen to be able to access updated base maps.

2. What the Map Scales Actually Imply for EO Data

A fundamental consideration in migrating to an EO-based update regime lies in understanding the relationship between map scale and admissible spatial resolution. A widely accepted cartographic rule suggests that one pixel on the ground should correspond to approximately 0.3–0.5 mm on the final map. This translates to the following practical requirements:

Map Scale	Approximate Pixel Size Required	Typical EO Source
1:25,000	~5–10 m	Sentinel-2, Resourcesat – LISS IV MX
1:10,000	~1–3 m	Cartosat-2/3, VHR commercial
1:4,000	≤0.5–1 m	Cartosat 3 – PAN Sub-metre satellite, aerial, UAV

From a purely resolution-centric perspective, national EO assets are already adequate for 1:25,000 mapping, and increasingly robust for 1:10,000. However, 1:4,000 mapping demands higher precision and often sub-metre accuracy, which logically pushes the system towards hybrid acquisition models that integrate sub-meter satellite, aerial photography and UAV data.

3. India's Existing EO Capability Base

India's capacity in large-scale EO-based mapping is no longer theoretical; it stands clearly demonstrated. Through initiatives such as the Space-based Information Support for Decentralised Planning (SIS-DP) and major urban mapping programmes, SoI and NRSC have already produced 1:10,000 scale map products using Cartosat stereo data. The Cartosat series itself was specifically designed to support cartographic and topographic applications, reinforcing India's operational self-reliance.

The GKI Readiness Index 2025 places India at number 15, with our geospatial related infrastructure at rank 9 and geospatial industry ecosystem at 5. This confirms that the country has crossed the threshold of technological feasibility. The real question is therefore not whether this can be achieved, but whether it can be institutionalised into a sustained, cyclic and operationally robust framework, similar in structure and discipline to the FASAL programme in agriculture (also refer Section 6).

4. International Precedents (Continuous and Cyclic EO-based Topographic Updating)

Across leading National Mapping Agencies, EO integration has evolved from experimentation to operational necessity, yet no country has institutionalised a fully EO-driven, fixed-interval nationwide RCB update system for complete topographic datasets. Instead, hybrid models prevail, where EO supports accuracy and responsiveness alongside traditional methods, indicating a transition toward dynamically updated, GKI-aligned national mapping frameworks.

The six national cases presented below illustrate varying maturity levels in this transition. While some countries demonstrate structured EO-supported cycles for land cover and land use databases that interface strongly with their topographic frameworks, others rely on continuous revision models where EO acts primarily as change intelligence rather than as the chief temporal driver.

4.1 Canada (Incremental EO-Supported Updating within a Continuous Digital Framework)

Canada's National Research Council through NRCan and CCMEO exemplifies a transition from episodic sheet revision to continuously maintained digital topographic databases (CanVec, GeoBase, HRDEM). While EO is deeply embedded in Canada's geospatial ecosystem - particularly through RADARSAT and Copernicus partnerships - there is no nationally declared, fixed-interval EO-driven update cycle for complete topographic layers. Instead, EO supports thematic and regional updates, especially in remote and Arctic zones where aerial surveys are logistically constrained.

Key characteristics:

- Continuous maintenance of national base datasets rather than periodic topo map revision.
- EO primarily used for land-cover monitoring, environmental change detection and elevation modelling.
- Incremental integration of EO into decision support and emergency mapping rather than routine topo regeneration.

Canada thus represents a mature hybrid model where EO is operationally significant but not yet the backbone of a formal Regular Cycle-Based (RCB) topo update regime.

4.2 France (Hybrid EO-Aerial Cyclical Model Anchored in RGE)

IGN France represents one of the closest operational examples of structured EO-supported cyclic updating. Through its Référentiel à Grande Échelle (RGE) and BD TOPO, IGN integrates SPOT 6/7, Pléiades and Copernicus data within a hybrid acquisition strategy that complements systematic aerial surveys. This system supports annual or multi-year updates for urban expansion, transport networks and land-use patterns.

Key characteristics:

- Hybrid acquisition plans combining EO and aerial imagery since mid-2010s.
- Semi-regular EO-supported updates for LCLU and urban change detection.
- AI-assisted classification feeding into BD TOPO revision workflows.

Although not purely EO-driven, France demonstrates a sustained, semi-cyclic EO integration model for authoritative topographic maintenance, positioning it as a global benchmark for structured EO adoption.

4.3 United Kingdom (Continuous Revision with EO as Change Intelligence)

Ordnance Survey (OS) employs one of the world's most advanced continuous revision systems through OS MasterMap, where updates occur weekly to monthly depending on feature class and region. EO data is increasingly used as a change detection trigger, particularly in urban and peri-urban environments.

Key characteristics:

- Continuous update model eliminating fixed revision cycles.
- EO used for automated identification of changes (e.g. new buildings, road realignments).
- Core reliance remains on aerial imagery and ground intelligence.

The UK model validates EO as part of a dynamic revision ecosystem but not as a sole or cyclic driver. It exemplifies best practice in temporal responsiveness rather than structured RCB EO workflows.

4.4 Netherlands (Register-Based Topography with Selective EO Integration)

Kadaster operates BRT and BGT as national key registers updated primarily through annually refreshed aerial imagery, with EO supporting specific thematic enhancements. While EO-derived Copernicus data is used for landscape monitoring and environmental reporting, RCB updating of topographic features remains selectively imagery-driven.

Key characteristics:

- Annual orthophoto-driven revision of topo registers.
- EO applied for rural landscape features and land-use differentiation.
- Strong experimentation in GeoAI and linked data integration.

The Dutch model demonstrates operational excellence in register maintenance but lacks a formal EO-centric cyclic topo update structure.

4.5 Germany (Epoch-Based EO Integration for Land-Cover Linked Topography)

Germany's ATKIS system is continuously maintained, while EO integration is most visible in national land-cover models such as DLM-DE and LBM-DE, updated at multi-year epochs (2009, 2012, 2015, 2021). EO data enhances thematic accuracy but core topographic geometry remains survey-led.

Key characteristics:

- EO-driven land-cover updates aligned with Copernicus epochs.
- Change detection workflows feeding into ATKIS-based mapping.
- No evidence of fixed-interval EO topo revision cycles.

Germany illustrates advanced thematic EO integration without full RCB topo update adoption.

4.6 Spain (Structured Cyclic EO Integration through SIOSE)

Spain's IGN–CNIG demonstrates one of the clearest cyclic EO integration models via the SIOSE database, updated approximately every three years. SIOSE integrates BTN25 geometry with Copernicus EO, LiDAR and PNOA orthophotos, creating a regularly refreshed land-use layer closely tied to topography.

Key characteristics:

- 3–4 year national EO-supported update cycle for LCLU.
- Strong linkage between SIOSE and BTN25 base topography.
- EO embedded within a multi-source hybrid model.

While not a pure EO topo refresh system, Spain offers a sustained cyclic structure that closely approximates RCB update principles.

5. Feasibility by Scale and Theme

5.1 Map scale 1:25,000 – National Land Cover & Urban Expansion

This scale is primarily deployed for landscape-level understanding, including land cover classes, urban extent, major infrastructure corridors, reservoirs, and forest boundaries.

Suitability of EO data:

- Resourcesat-3 data and Sentinel-2 are well-suited for such applications.
- Temporal frequency allows for 6 to 12 months national cycles with annual urban change detection.

- Positional accuracy aligns comfortably with LE90 thresholds expected for 1:25,000 scale mapping.

The adoption of an RCB EO update framework for 1:25,000 scale is both logical and technologically mature for national implementation.

5.2 Map scale 1:10,000 – Detailed Topographic Infrastructure Mapping

At this scale, users expect accurate depiction of road networks, building footprints, rail alignments, and complex urban fabric.

Suitability of EO data:

- 0.8–1 m resolution imagery supports delineation of urban structures and infrastructure geometry.
- Stereo datasets enable elevation modelling and feature extraction.
- A selective update strategy is more pragmatic than national wall-to-wall coverage.

Recommended Cycle:

- High-growth zones: 12 to 18 months cycle
- Stable rural zones: 5 to 7 year cycle

Accuracy Considerations:

With rigorous photogrammetric processing and GCP control, spatial accuracies consistent with 1:10,000 standards are achievable.

A priority-area focused RCB model for 1:10,000 is technologically feasible and administratively justifiable.

5.3 Map scale 1:4,000 – Very Large Scale Mapping

This scale approaches town-planning and engineering detail, where expectations include fine structural features, micro-drainage, compound walls, and precise alignment of utilities.

Suitability of EO data:

- Even with 0.3 m resolution, ambiguity arises in dense urban canyons and multi-level infrastructure.
- Vertical accuracy and feature completeness are constrained.

International practice at this scale strongly favours aerial or UAV data complemented by LiDAR. Satellite-only RCB systems are insufficient for consistent 1:4,000 standards. Cartosat 3 PAN data can support land cover update in urban areas. However, a hybrid model is logically necessary for targeted urban zones. The RCB update would not be helpful, and a pragmatic, location based update commensurate with the pace of urban infrastructure development is required.

6. Logic of Adopting a FASAL-like RCB Model for Survey of India

The conceptual parallel between crop forecasting and topographic updating rests in structured temporal observation and systematic change detection. An RCB-Topo system may be envisioned as a three-tier architecture:

Tier 1: National Land Cover Backbone (1:25,000)

- EO-driven land cover classification and infrastructure mapping every 2–3 years.

Tier 2: Priority Development Corridors (1:10,000)

- High-resolution updates for growth corridors and strategic zones.

Tier 3: Critical Urban Zones (1:4,000 and larger)

- Hybrid data acquisition for metros, smart cities, and major infrastructure nodes.

This mirrors the agricultural pipeline of pixel-data zonal analysis district-level decision-making, thus reinforcing its operational logic.

7. The RCB Workflow

The RCB update model rests on a structured and repeatable workflow that converts raw EO data into authoritative topographic updates. The process follows core GKI principles of automation, standardisation, scalability and institutional control (also refer Section 6 on the logic of adopting an RCB model).

7.1 Data Tasking, Acquisition and Ingestion

The cycle begins with demarcation of Areas of Interest (AOIs) derived from the SoI National Topographic Grid. These tiles act as the basic units for satellite tasking, data ingestion and change analysis. Priority is given to zones of rapid transformation such as urban fringes, infrastructure corridors, mining belts, river systems and coastal stretches, consistent with the impact areas highlighted in Section 1.

Key process sequence:

- Identification of AOIs using SoI standard grid tiles.
- Prioritisation of tiles based on:
  - o Urban expansion zones
  - o Infrastructure corridors
  - o Mining areas
  - o Riverine and flood-prone belts
  - o Coastal and disaster-prone regions (refer Section 1).
- Satellite tasking and acquisition planning.
- Retrieval of EO data from national and approved commercial sources.
- Metadata verification as per ISO 19115:
  - o CRS confirmation
  - o Sensor and orbit details
  - o Temporal accuracy
  - o Quality descriptors.
- Ingestion of validated data into an OGC-compliant cloud data lake.
- Organisation of data through STAC architecture for efficient retrieval and tracking.

All acquired imagery undergoes metadata verification as per ISO 19115. This ensures completeness of spatial reference, acquisition details, sensor information and quality parameters. The data is then ingested into an OGC-compliant cloud data lake structured through STAC specifications, enabling organised access for subsequent processing stages.

7.2 Preprocessing and Conversion to Analysis-Ready Data

Raw EO data cannot be used directly due to sensor noise, atmospheric interference and geometric distortions. A defined preprocessing chain converts it into Analysis Ready Data (ARD).

This includes radiometric correction, geometric adjustment and atmospheric correction using processors such as Sen2Cor. Orthorectification is carried out using SoI DEMs, including CartoDEM, in compliance with ISO 19111. Co-registration aligns imagery to SoI's official CRS using WKT standards. Automated cloud masking removes atmospheric obstruction. The processed data is then tiled and stored as cloud-optimised assets for classification.

Key process sequence:

- Radiometric correction to normalise sensor variations.
- Atmospheric correction using Sen2Cor or equivalent processors.
- Geometric correction and rectification.
- Orthorectification using SoI DEMs including CartoDEM.
- CRS alignment using WKT standards as per ISO 19111.
- Co-registration of multi-temporal datasets.
- Automated cloud detection and cloud masking.
- Tiling and conversion into cloud-optimised geospatial formats.
- Storage of ARD in structured repositories for classification.

This stage ensures uniformity, positional reliability and comparability across time.

7.3 Land-Cover Classification and Change Detection

Land-cover classification forms the analytical core of the workflow. It follows national LULC standards prescribed by NRSC. Sensor-specific machine learning models are used, including CNNs for high-resolution optical data, Random Forest for medium resolution and SAR coherence analysis for radar datasets.

Change detection uses temporal differencing, spectral indices and semantic algorithms. Parameters such as NDVI, SAR coherence and brightness indices help identify vegetation loss, urban expansion, surface water variation and land disturbance. Each change is assigned a confidence level, guiding automatic acceptance, expert review or field validation (see Section 9 on state-level validation roles).

Key process sequence:

- Application of NRSC-compliant LULC classification schema.
- Selection of models based on sensor resolution:
  - o CNNs for high-resolution data
  - o Random Forest for medium resolution
  - o SAR coherence for radar datasets.
- Generation of baseline and temporal land-cover layers.
- Use of indices:
  - o NDVI for vegetation dynamics
  - o Brightness indices for surface change
  - o SAR coherence for structural alterations.
- Temporal differencing to detect change zones.
- Semantic classification of detected change.
- Assignment of confidence scores to each change feature:
  - o High confidence - auto integration
  - o Medium confidence - expert review
  - o Low confidence – field validation.

7.4 Extraction of Topographic Features

Several topographic elements change rapidly and require periodic updating. These include roads, rail lines, reservoirs, altered river courses and expanding settlement edges. Feature extraction models are customised for each class. All outputs conform to ISO 19110 Feature Catalogue standards, ensuring thematic consistency within the DTDB and alignment with national mapping norms.

Key process sequence:

- Identification of feature classes prone to frequent change:
  - o Roads and rail networks
  - o Reservoirs and canals
  - o River course shifts
  - o Settlement expansion
  - o Infrastructure nodes.
- Deployment of feature-specific extraction algorithms.
- Vectorisation of detected features.
- Classification as per ISO 19110 Feature Catalogue.
- Attribute tagging and standard coding.
- Validation against historical layers and reference data.
- Preparation for DTDB integration.

This ensures thematic consistency and alignment with SoI cartographic standards.

7.5 Integration into the Digital Topographic Database

Validated features and land-cover updates are integrated into SoI's DTDB through automated ETL pipelines. Topological integrity is checked against ISO 19107 to eliminate overlaps, gaps and geometry errors. Quality checks focus on positional accuracy, thematic precision and logical consistency. Each update is versioned and documented as per ISO 19115 lineage standards, ensuring traceability and historical continuity.

Key process sequence:

- Automated ETL execution for feature ingestion.
- Topological integrity verification as per ISO 19107:
  - o No overlaps
  - o No gaps
  - o Closed geometries
  - o Correct connectivity.
- Quality assurance checks:
  - o Positional accuracy
  - o Thematic accuracy
  - o Logical consistency.
- Version control and tagging.
- Lineage documentation as per ISO 19115.
- Archival of previous versions for historical comparison.
- Synchronisation with national map repositories.

This ensures data credibility and full auditability.

7.6 Production and Dissemination of Updated Map Layers

Approved layers are generated at 1:50,000 and 1:25,000 scales, in line with national dissemination norms (see Section 5). District and state-level change bulletins highlight key spatial transformations. Updates are published through WMS, WFS, WCS and OGC 3D Tiles. These datasets feed into platforms such as the GDPDC Data Registry, BharatMaps and the India GeoPlatform, supporting integrated planning under programmes like PM GatiShakti.

Key process sequence:

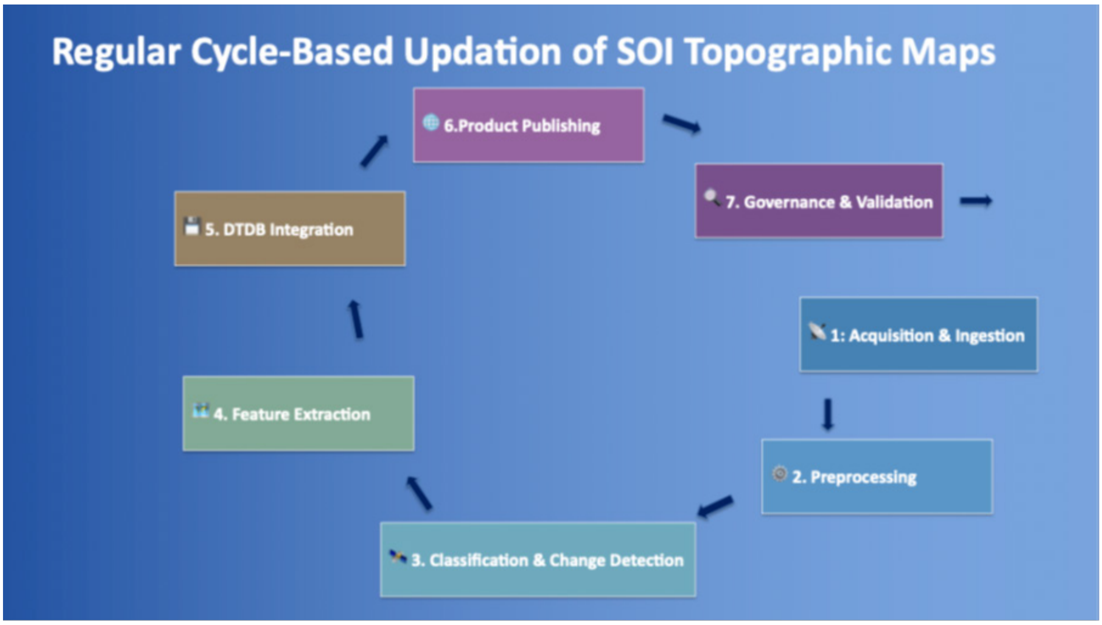
- Generation of updated layers at:
  - o 1:50,000
  - o 1:25,000 scales (refer Section 5).
- Preparation of district and state change bulletins.
- Creation of updating schedules aligned with RCB timelines.
- Publishing through:
  - o WMS
  - o WFS
  - o WCS
  - o OGC 3D Tiles.
- Integration into:
  - o GDPDC Data Registry
  - o BharatMaps
  - o India GeoPlatform.
- Distribution to:
  - o Central ministries
  - o State departments
  - o Disaster authorities
  - o Planning agencies.
- Enablement of interoperability with PM GatiShakti and other national platforms.

This ensures that updated maps translate into operational governance intelligence.

7.7 Governance and Validation

A layered governance model ensures credibility and consistency. District Survey Offices validate low and medium confidence changes using ground inputs or UAV support. State Remote Sensing Centres conduct thematic audits. National oversight is retained by SoI and NRSC. This structure ensures harmonisation between local relevance and national standards (refer Section 9). Machine learning models are continuously recalibrated using validated datasets, improving accuracy with each update cycle.

Figure 1: The RCB update flowchart.



8. The Real Bottlenecks

The primary constraints lie not in technology but governance and institutional structuring:

1. 1Standards and Acceptance: Clear protocols for positional accuracy, feature completeness, and EO-authenticity.
2. Institutional Design: Defined roles for SoI, NRSC, state agencies, and urban local bodies.
3. Sustained Funding: Long-term commitment for data procurement and processing infrastructure.
4. System Integration: Seamless linkage with GatiShakti, Digital Land Records, and municipal GIS systems.

9. Strategic Role of State Governments in RCB-Based National Map Updating

State Governments act as the closest operational interface with ground realities and are critical enablers of the RCB update framework.

A. Through State Remote Sensing Centres (SRSCs), State Spatial Data Infrastructures (SSDI) and line departments, states can provide:

i. Field validation and ground-truthing of EO-derived changes.

ii. Local contextual intelligence to refine map accuracy.

iii. Thematic overlays relevant to state governance priorities.

B. States support rapid change detection by communicating on-ground developments such as new infrastructure, land use transitions and hazard-prone zones.

C. Institutionalised data-sharing protocols and feedback loops with Survey of India and NRSC strengthen a decentralised yet harmonised update mechanism.

D. Integration of updated SoI base maps into state functions enhances:

i. Land administration and cadastral modernisation.

ii. Infrastructure and transport planning.

iii. Environmental governance and compliance monitoring.

iv. Disaster preparedness and emergency response.

E. Active state participation reinforces the national vision of ‘One Nation One Map’, transforming them from passive map users to co-creators of a dynamic national spatial database.

F. Despite disparities in Geospatial Knowledge Infrastructure (GKI) maturity, a common framework allows progressive scaling and capacity building across states.

G. Alignment with the National Geospatial Policy and GKI principles ensures coherence with national spatial governance objective

10. State-Led Applications of EO for Topographic and Land Cover Updating

(Indian Case Studies Demonstrating Operational Readiness)

10.1 Case Study: Odisha

Integrated EO-Based Land Use and Terrain Mapping for Disaster-Resilient Planning

Odisha has emerged as an early and proactive user of EO-based mapping for land use planning and disaster risk management, particularly in flood-prone and coastal districts. Through ORSAC, the state undertook systematic updates of LULC, drainage patterns and terrain features across key river basins and coastal stretches. High-resolution satellite data was combined with field-validated GIS layers, reflecting a coordinated, multi-departmental approach led by the Revenue and Disaster Management Department and supported by allied line departments.

Sentinel-2 and Cartosat data formed the foundation of change detection workflows, supplemented by NRSC thematic products and time-series analysis. ORSAC identified shifts in agricultural land, wetland shrinkage, embankment modifications and expansion of peri-urban settlements. These outputs were overlaid on SoI base maps and cadastral layers for validation, highlighting the need for regularly refreshed national topographic references (also refer Section 7 on integration workflows).

This initiative strengthened Odisha's internal spatial planning capability and demonstrated how EO-derived intelligence can feed into authoritative national mapping systems. SoI retained its role as the custodian of base maps, while NRSC supported technical processing and data supply. The outputs directly supported flood zoning, CRZ enforcement and cyclone preparedness planning. The case reflects a mature state EO ecosystem aligned with the broader RCB vision outlined in Sections 6 and 9.

10.2 Case Study: Telangana

EO-Driven Topographic Modernisation under Mission Bhagiratha

Telangana has strategically used EO data to modernise its topographic and infrastructure planning systems, especially under Mission Bhagiratha and its land records modernisation initiatives. TRSAC worked closely with irrigation, roads and revenue departments to generate spatial datasets supporting alignment planning, utility mapping and terrain evaluation.

High-resolution EO data, including Cartosat-2 and Resourcesat imagery, was processed for terrain modelling, road network monitoring and change detection. These outputs were cross-referenced with SoI topographic sheets to identify newly created features such as canals, reservoirs and urban growth corridors. NRSC provided technical support and satellite access, while SoI maps served as the spatial reference baseline.

A key strength of Telangana's model lies in its institutionalised geospatial governance structure. EO-derived outputs were linked directly to departmental workflows in design, tendering and execution monitoring. However, reliance on episodic updates and fragmented department datasets highlighted the limitation of static national base maps, reinforcing the operational need for an RCB-based system led by SoI (see Sections 1 and 8).

This case illustrates how a technologically capable state can serve as an effective partner in a decentralised yet nationally harmonised EO-based update framework.

10.3 Case Study: Maharashtra

EO-Based Coastal and Urban Land Cover Updating for Regional Planning and Risk Mitigation

Maharashtra has consistently applied EO data for monitoring urban expansion, coastal dynamics and regional development planning, led by MRSAC. Working with planning, coastal and disaster management authorities, the state carried out EO-based land cover assessments across key metropolitan and coastal districts.

Multi-temporal satellite data from Sentinel-2, Cartosat and IRS platforms was used to track urban sprawl, industrial growth, wetland degradation and shoreline changes. These EO-derived layers were aligned with SoI topographic maps and cadastral data to ensure spatial consistency and improved positional accuracy. NRSC supported data provisioning and processing frameworks, ensuring continuity and standardisation.

The outputs directly informed Development Plan revisions, CRZ compliance assessments and infrastructure corridor planning, especially along the Konkan coast and peri-urban zones of the Mumbai Metropolitan Region. While state-level efficiency improved, dependence on static SoI base maps exposed the disconnect between dynamic EO updates and legacy national cartography (also refer Section 4 on international parallels).

This case clearly demonstrates the value of integrating regularly updated SoI maps into state EO ecosystems, enabling seamless governance workflows anchored in a harmonised national geospatial framework, as envisioned in the RCB model.

Conclusion

It is both logical and technologically feasible to adopt a Regular Cycle-Based EO update system for Survey of India topographic maps with respect to land cover change and rapid infrastructure development.

- 1:25,000: Fully feasible nation-wide
- 1:10,000: Feasible through selective regional implementation
- 1:4,000: Technically possible only through hybrid acquisition approaches

The adoption of such a framework represents not merely a technological shift but a paradigmatic evolution of national geospatial governance, aligning Survey of India with contemporary international mapping practices while responding effectively to India's development trajectory.

A structured RCB framework powered by Earth Observation, integrated with national policy instruments and spatial governance mechanisms, can enable Survey of India to transition from episodic revision to dynamic, responsive topographic intelligence. This evolution is imperative for supporting national planning, infrastructure development, and resilient urban growth in the 21st century Indian context.

Appendix I : List of Abbreviations

AOI: Area of Interest

ARD: Analysis Ready Data

ATKIS: Authoritative Topographic-Cartographic Information System (Germany)

BD TOPO: Base de Données Topographiques

BGT: Basisregistratie Grootschalige Topografie (Key Register of Large-scale Topography)

BRDF: Bidirectional Reflectance Distribution Function

BRT: Basisregistratie Topografie (Key Register of Topography)

BTN25: Base Topographique Nationale 1:25,000

CartoDEM: Cartographic Digital Elevation Model

CCMEO: Canada Centre for Mapping and Earth Observation

CNN: Convolutional Neural Network

CNIG: Centro Nacional de Información Geográfica

Copernicus: European Union Earth Observation Programme

CRS: Coordinate Reference System

DCDB: Digital Cadastral Database

DEM: Digital Elevation Model

DLM-DE: Digital Landcover Model for Germany

DTDB: Digital Topographic Database

EO: Earth Observation

ESA: European Space Agency

ETL: Extract-Transform-Load

FASAL: Forecasting Agricultural output using Space, Agro-meteorology and Land-based observations

GDPDC: Geospatial Data Promotion and Development Committee

GeoAI: Geospatial Artificial Intelligence

GKI: Geospatial Knowledge Infrastructure

HRDEM: High Resolution Digital Elevation Model

IGIF: Integrated Geospatial Information Framework

IGN: Institut National de l'Information Géographique et Forestière

ISO: International Organization for Standardization

ISRO: Indian Space Research Organisation

Kadaster: Netherlands' Cadastre, Land Registry and Mapping Agency

LBM-DE: Landbedeckungsmodell Deutschland (Landcover Model for Germany)

LE90: Linear Error at 90% Confidence Level

LST: Land Surface Temperature

LULC: Land Use / Land Cover

MRSAC: Maharashtra Remote Sensing Applications Centre

NDVI: Normalized Difference Vegetation Index

NRCan: Natural Resources Canada

NRSC: National Remote Sensing Centre

OGC: Open Geospatial Consortium

ORSAC: Odisha Space Applications Centre

OS: Ordnance Survey

PNOA: Plan Nacional de Ortofotografía Aérea

RCB: Regular Cycle-Based

RGE: Référentiel à Grande Échelle

SAR: Synthetic Aperture Radar

SIOSE: Sistema de Información sobre Ocupación del Suelo en España

SOI: Survey of India

SPOT: Satellite Pour l'Observation de la Terre

SRSC: State Remote Sensing Centre

SSDI: State Spatial Data Infrastructure

STAC: Spatio-Temporal Asset Catalogue

TRSAC: Telangana State Remote Sensing Applications Centre

UAV: Unmanned Aerial Vehicle

WCS: Web Coverage Service

WFS: Web Feature Service

WKT: Well-Known Text

WMS: Web Map Service

Appendix II : ISO Standards Referenced in the RCB Workflow

1. ISO 19115 : Geographic Information: Metadata

- This standard defines how to document geospatial data, including source, quality, lineage, sensor, resolution, projection, and processing details.
- Ensures all EO satellite scenes have complete, interoperable metadata.

2. ISO 19111: Spatial Referencing by Coordinates

- Standard for coordinate reference systems (CRS), datums, and transformations.
- Sets standards for Orthorectification and co-registration of satellite imagery to SOI's official CRS.

3. ISO 19107: Spatial Schema

- Defines geometry and topology rules for vector data (points, lines, polygons), ensuring proper adjacency, connectivity, and closure.
- It validates topographic features (roads, rivers, boundaries) before DTDB integration.
-

4. ISO 19110: Feature Catalogue

- Defines how geographic features must be described, including attributes, codes, and definitions.
- It ensures feature extraction (roads, rivers, settlements) follows SOI's official feature definitions.

5. ISO 191xx Series (General Reference)

- This refers collectively to the broader ISO 19100 series of geospatial standards, covering:
  - data quality (19157),
  - schemas (19109),
  - metadata extensions (19115-1, 19115-2),
  - services (19119), etc.
- It provides the overarching standards framework for interoperability in GKI/IGIF.

6. ISO 19115 Lineage

- (Part of ISO 19115 but referenced separately in workflow)
- Specifies provenance, i.e., how data was created, processed, and updated.

It is required for DTDB versioning and quarterly update traceability.

Appendix III: Data Providers with capability and capacity to supply EO data for RCB

EO Data Providers for RCB-Style National Topographic Update

Provider	Key Sensors / Assets	Resolution & Revisit	Indicative Cost Level	RCB Relevance
Copernicus / ESA	Sentinel-1 SAR, Sentinel-2 Optical	10m, 5-day revisit	Free (Open Data)	Baseline, change detection, QA
USGS / NASA	Landsat 8/9	30m, 8–16 days	Free	Historical trend analysis
ISRO/NRSC	Cartosat, Resourcesat, RISAT	0.25–5m, days–weeks	Low–Moderate (Subsidised)	Primary Indian backbone
NSIL	Commercial Cartosat & RISAT	≤1m, tasking-based	Moderate	High-res priority coverage
Pixxel	Hyperspectral Constellation	5m class, improving	Commercial	Thematic & SDG layers
Maxar	WorldView Series	0.3–0.5m, daily	High	VHR urban mapping
Airbus	Pléiades / SPOT	0.3–1.5m, daily	Moderate–High	Precision cartography
Planet Labs	PlanetScope / SkySat	3–5m & 0.5m	Low–Moderate	Frequent monitoring
ICEYE	SAR Constellation	Sub-meter SAR	Moderate	All-weather updates
Capella Space	VHR SAR	0.5m SAR	Moderate	Cloud-resilient mapping
Satellogic	Optical	0.7–1m, weekly	Low	Cost-efficient national cover
KOMPSAT (SIIS)	Optical & SAR	0.4–0.7m	Moderate	Asia-Pacific VHR source
EO Aggregators	UP42, Arlula, EOSDA	Multi-source	Varies	Pilots & gap-filling

LESSON - 10

GKI Workflow Integration Across the AEC / Infrastructure Sector

Trainer' s Biodata: Professor John P. Wilson, USC Professor and Founding Director, Spatial Sciences Institute, University of Southern California

He is an experienced professor at the University of Southern California with a distinguished record of advancing the geographic information sciences. As the founding director of both the USC Spatial Sciences Institute and the Wilson Map Lab, he has played a central role in shaping the university's geospatial education and research landscape. His work focuses on applying geographic information science, spatial analysis, and computational models to study human and environmental systems, with a particular emphasis on understanding how people, their surroundings, and human health are interconnected. He also developed USC's online GIS graduate programs, which have expanded into a comprehensive suite of master's degrees and graduate certificates. A recognized leader in the field, he has championed spatial sciences as a foundational, cross-cutting discipline. He has spearheaded the creation of 18 spatially inspired academic programs that integrate multidisciplinary scientific study with geospatial technologies—including GIS, GPS, and remote sensing. Through these efforts, he has helped develop a generation of graduates with advanced technical expertise, strong analytical capabilities, and a deep understanding of spatial principles that illuminate the role of location in both Earth systems and human life.

Session Overview

- Leveraging GKI for smarter infrastructure design and development in the Indian context
- Digital Twins in AEC: GKI's role in real-time data, monitoring, and simulation
- Integration of GKI with BIM for streamlined project management
- Enhancing sustainability in AEC projects through geospatial analysis
- Case studies showcasing GKI implementation in large-scale construction and urban development projects

LESSON - 11

GKI Workflow Integration for Natural Resource Management and Ecological Restoration

Trainer' s Biodata: Chiranjit Guha, General Manager, Foundation for Ecological Security (FES)

Chiranjit Guha is an experienced Analyst with over 20 years of expertise in the non-profit sector. He possesses a strong background in Environmental Awareness, Mining, Hydrogeology, Remote Sensing, and Geographic Information Systems (GIS). With a Master of Technology degree in Applied Geology from the Indian Institute of Technology, Roorkee, India, Chiranjit is dedicated to advancing sustainable natural resource management. He has developed several user-friendly tools to support informed decision-making in soil and water conservation, water budgeting, aquifer mapping, and land mapping. These tools have been effectively implemented across more than 50,000 villages in India through extensive collaboration with field teams, NGO partners, and Government departments. Chiranjit has played a key role in ensuring the adoption of technology at the community level by conducting trainings, providing ongoing support, and monitoring the practical impact of these interventions on natural resource management. Presently, Chiranjit is working as General Manager in the India Observatory program of Foundation for Ecological Security and heading the Data and Analytics team of the organization.

11.1 Session Overview

This session explores how **Geospatial Knowledge Infrastructure (GKI),** together with the work of the Foundation for Ecological Security (FES) and the **India Observatory (IO),** is transforming natural resource governance and ecological restoration in India.

It highlights how geospatial tools, public data systems, and community-led processes enable informed decision-making from the national to the village level.

The session matters because:

- India's ecological challenges—land degradation, groundwater depletion, biodiversity loss, and climate stress—require **location-specific, data-driven interventions.**
- Government programs such as **MGNREGA, National GIS initiatives, Forest Working Plans,** and **village-level planning mandates** increasingly depend on credible spatial information.
- Large-scale community participation and decentralized governance can only succeed when **reliable data, analytical tools, and actionable insights are available.**
- FES and IO offer practical examples of how **geospatial systems at scale** can converge national policies with state capabilities and community institutions.

11.2 Learning Objectives

By the end of this session, participants will be able to:

- Explain the importance of geospatial data and GKI in addressing India's land, water, forest, and biodiversity challenges.
- Describe how FES and the India Observatory develop and deploy spatial tools to support state and community-level decision-making.
- Apply key geospatial tools (e.g., CLART, CLM, GWMT, IFMT, GEET) to interpret landscapes, assess resource conditions, and design restoration actions.
- Evaluate how geospatial systems can strengthen governance, transparency, and service delivery in rural areas.
- Integrate NRM and geospatial insights into planning, monitoring, and policy execution at district, block, and village levels.

11.3 Key Concepts and Definitions

Ecological Security

The condition in which communities have access to healthy land, water, and forest ecosystems, enabling sustainable livelihoods and resource use.

Commons / Common Lands

Shared natural resources such as pastures, forests, wastelands, and water bodies used collectively by rural communities. These lands support millions and generate substantial ecological and economic value.

Geospatial Knowledge Infrastructure (GKI)

A national ecosystem of policies, platforms, tools, standards, and human capacities required to collect, manage, analyze, and apply location-based data.

India Observatory (IO)

A comprehensive geospatial platform designed to democratize data, promote scientific thinking, and support decisions for natural resource management, ecological restoration, and rural development.

Natural Resource Management (NRM)

A coordinated approach to conserving, restoring, and managing land, water, forests, and biodiversity to ensure ecological balance and community well-being.

Geo-Spatial Decision-Support Tools

Applications such as **CLART, CLM, GWMT, GEET, IFMT**, and **IBIS** that convert raw data into meaningful insights for planning, monitoring, and governance.

Species Distribution Modelling (SDM)

A statistical method to predict where species occur based on environmental variables—helpful for conservation planning and invasive species control.

11.4 Core Content

11.4.1 Foundation for Ecological Security (FES): Mission and Strengths

FES focuses on strengthening ecological security by restoring land, water, and forest systems while empowering local communities.

Key strengths include:

- Large-scale field implementation in diverse landscapes
- Partnerships with states, central agencies, NGOs, and communities
- Robust data analytics, remote sensing, and GIS capacity
- Prakriti Karyashala, a national-scale training ecosystem
- Expertise in commons restoration, gender inclusion, and practice–policy–research integration

The organization's work demonstrates how technology, data, and community institutions converge to strengthen ecological resilience.

11.4.2 India Observatory: Democratizing Data for Local Governance

The India Observatory, led by **Foundation for Ecological Security (FES),** is a collaborative tech initiative that is action-oriented. It aims to demystify and present comprehensive information on India's social, ecological and economic parameters on a single spatial and temporal platform. India Observatory aims at embedding nature conservation and natural resource management into mainstream thinking on 'rural development'. It is designed to supplement local level decision making by village communities, Panchayats, NGOs and government officials. The India Observatory provides a freely accessible, interdisciplinary spatial data infrastructure, enabling:

- Visualization of **social, ecological, and economic parameters**
- Contextual understanding of landscapes
- Scientific and community-led planning
- Action at scale in land and water restoration
- Decision support for state and district administrations

Its central goal: **make high-quality geospatial information usable for everyone—from policymakers to Gram Sabha members.**

11.4.3 Geospatial Data for NRM

India Observatory (IO) has the 'Data Platform' at its core, which is built on open source and brings together data on over 1900+ parameters, ranging from village to national level and is, presented in the form of maps, graphs, tables and infographics. It is freely available for civil society organizations, students, government departments and citizens.

India Observatory has also developed a set of unique platforms and tools namely Indian Biodiversity Information System (IBIS), Composite Landscape Assessment and Restoration Tool (CLART), Integrated Forest Management Tool (IFMT), GIS Enabled Entitlement Tracking Tool (GEET), etc. addressing specific issues.

India Observatory is anchored on a belief that sustained collaborative efforts are fundamental for furthering the impact of tools, analytics, data and their widespread implementation. India Observatory invites other organisations and groups to join hands to share data, analytics and tools to enable local communities, NGOs, governments, academicians and researchers for better decision making on ground.

India's diverse landscapes require multi-layered information systems. The IO integrates:

1. **Ecological Data** - Land use/land cover, geology, soil types, slope, drainage, hydrology etc.
2. **Socio-economic Data** - Population, infrastructure, education, health, livelihoods etc.
3. **Floral–Faunal & Biodiversity Data** - Species occurrence, habitat types, conservation value etc.
4. **NRM and Governance Data** - Watersheds, village boundaries, common lands, tenure status.

Together, these create a **multi-dimensional, spatio-temporal dataset** supporting scientific NRM

11.4.4 GKI Interface for Data-Driven NRM Approaches

The GKI Interface connects:

- National geospatial policies
- State-level planning systems
- Community-led governance
- Tools for analysis and monitoring

It operationalizes the Integrated Geospatial Information Framework (IGIF) through India-specific applications and platforms

11.4.5 Tools and Platforms

11.4.5.1 Composite Landscape Assessment and Restoration Tool (CLART)

It is a Geographic Information System (GIS) based Android tool –developed to enhance the planning of region-specific soil and water conservation measures. CLART enables rural communities in designing measures that would either help recharge of ground water or augment surface water availability, depending upon the location specific geo-hydrological characteristics. Made available in a user-friendly manner for semi-literate village communities, it enables them to undertake major part of the planning and designing, thereby assisting the local government functionaries in speeding the process of approvals, as well as improving the efficacy of ground level implementation. This is a flagship tool enabling scientific planning under MGNREGS.

Challenges addressed:

- Lack of technical capacity at village level
- High dependence on engineers for approvals
- Site assessments often based on intuition, not data

CLART innovations:

- Using geospatial data such as lithology, slope, drainage, recharge potential etc for providing site suitability of soil and water conservation
- Automatically generates **plans, cross-sections, and cost estimates**
- Supports large-scale planning in a standardized way
- Enables village communities to prepare evidence-based water conservation plans

11.4.5.2 Common Land Mapping (CLM):

Common Land Mapping (CLM), is a tool that identifies and demarcates shared land resources through geo-referencing with a set of relevant questions such as category of land, status of tenure, current land use, community regulations, if any. The information recorded can be depicted using map-based views. CLM helps mapping and recording evidences for preparation of community-based conservation and management plans and supports implementation of Gram Panchayat Development Plans (GPDP). It also addresses the low level of documentation of land rights and helps demarcate land under Individual Forest Rights and Community Forest Rights on one platform for claiming under Forest Rights Act and recording pastures under Panchayat Assets Registers. It helps local communities' debate and resolve conflicting claims with respect to customary boundaries. This is participatory and data-driven approach to mapping, governing, and restoring commons.

Key functions:

- Demarcation using satellite imagery and village records
- Encroachment identification
- Baseline governance assessments
- Cross-village boundary verification
- Restoration and management planning
- Conflict resolution and tenure claims

CLM also supports **Community Forest Rights (CFR)** documentation and social audits of access and use.

11.4.5.3 Forest Rights Act Tool

The Forest Rights Act, 2006 is a landmark legislation in India that aims to address the historical injustices faced by forestdwelling communities. It recognizes and vests forest rights in Scheduled Tribes and Other Traditional Forest Dwellers, ensuring their access to land, minor forest produce, water bodies, and other resources. FES prepared an android based tool with a specialized module supporting:

- Documenting traditional rights
- Validating claims
- Improving transparency
- Enabling Gram Sabha-led decision making

11.4.5.4 Integrated Forest Management Tool (IFMT)

The Integrated Forest Management Toolbox (IFMT) is a forest management planning tool, developed to assist officers in India's state forest departments to develop working plans in accordance to the NWPC 2014. It aims to bridge the knowledge gap and addresses the requirements of NWPC by supporting forest officials with required data and tools for planning and preparation of working plans for sustainable management of forest resources.

IFMT consists of a suite of tools for collecting/ collating geo-spatial and ground level data and identifying potential forest management activities based on flow of ecosystem services. The tools were developed to meet the requirements of NWPC. IFMT adopted by 180 forest divisions to update Working Plans.

Impacts:

- 7 million hectares managed
- 41,000+ sample plots surveyed
- 6,500+ staff trained
- Improved evidence-based forest governance

11.4.5.5 Ground Water Monitoring Tool (GWMT)

India is the largest groundwater user in the world, using 25% of all groundwater extracted every year globally. 70% of agriculture and 85% of our drinking water supply depends on groundwater. The major component of the groundwater extracted (89%), is used in the irrigation sector, followed by domestic use (9%) and lastly industrial use (2%). 50% of urban water requirements and 85% of rural domestic water requirements are fulfilled by groundwater.

India is fast moving towards a crisis of groundwater overuse and contamination. The data on groundwater levels for most parts of the country is unavailable. Lack of good quality, location-specific data hinders sustainable management of groundwater in the country.

There is an urgent requirement to make a shift from groundwater development to its management by identifying and mapping aquifers, quantifying the available groundwater potential, and proposing plans appropriate to the aquifer characteristics, the scale of demand, and the institutional arrangements for management. A robust understanding of the state of aquifers in India will help in their management and governance at the local level.

The Groundwater Monitoring Tool (GWMT) is aimed at addressing this major challenge in the estimation of groundwater resources and help bridge this gap. The GWMT, an open-source android tool, enables the collection of water level data of wells and its collation on a web platform for easy access by all.

The Tool uses a standard methodology for data collection to ensure data quality. Addressing the inconsistency in existing datasets, the tool pools together data from various decentralized data repositories present with various Non-Government Organisation (NGOs) and Community Based Organisations (CBOs), thus giving a more detailed picture of the groundwater level across the country.

Further, the primary data collected on ground by an organisation or field cadre is combined with various secondary data layers present on the India Observatory platform to gain further insights through analysis.

Finally, by making good quality granular data available on an open-access web platform, it improves access to data for all stakeholders.

GWMT functions:

- Crowd-sources primary data twice a year (pre- and post-monsoon)
- Aggregates datasets from NGOs, community groups, and government
- Produces recharge–discharge maps
- Identifies aquifer zones
- Assesses water availability for Rabi crops
- Enables year-to-year comparisons for long-term trends

The initiative parallels the national Jaldoot program.

11.4.5.6 GIS-Enabled Entitlement Tracking (GEET)

GEET helps rural communities in accessing government entitlements and schemes that they are eligible for by providing them information about the same on a single platform. It is a community-focused tool ensuring:

- Access to government schemes
- “No one left behind” monitoring
- Real-time tracking of eligibility and coverage

11.4.5.7 Indian Biodiversity Information System (IBIS)

Discover the Indian Biodiversity Information System (IBIS) - the ultimate reserve of scientific information about Indian Biodiversity. IBIS provides you with immediate access to data on Indian flora and fauna in a user-friendly and freely accessible format, from anywhere in the world. It's an initiative from the Foundation for Ecological Security (FES) and is modelled on the concept of citizen science that helps and guide biodiversity action plans and restoration strategies.

- It is a national repository integrating:
- Taxonomic databases
- Geospatial habitat analytics
- Crowdsourced information
- Species distribution models

11.4.5.8 Species Distribution Modelling (SDM) & Invasive Species Management

SDM is used for:

- Predicting suitable habitats
- Conservation prioritization
- Identifying climate vulnerabilities

Invasive species work includes:

- Remote sensing and drone surveillance
- Rapid detection
- Ground surveys and citizen science
- Centralized data platforms for coordinated removal efforts

11.4.5.9Ravine Reclamation (Case Example)

Along the Mahi River in Gujarat, ravine systems were mapped to understand extent and progression.

Outcomes:

- 50% reduction in ravine areas over 23 years
- Community-driven SMC and regeneration
- Significant improvement in ecological and soil conditions

This case shows how **geospatial diagnosis + community action = large-scale transformation.**

11.4.5.10 CoAST: Pandemic Response Platform

During COVID-19, the platform mapped:

Resting points, medical camps, Volunteers, Water points etc for the service provider to understand the status of the service seeker and meet the requirement on a near real time platform. This enabled safe passage for migrants and better coordination among agencies. This shows the power of geospatial data during any disaster and readiness for mitigate the need of hours.

11.5 Lessons Learned

- Community-led processes scale better when supported by scientific evidence.
- Geospatial democratization increases transparency and strengthens governance.
- Tools must be simple, intelligible, and actionable for frontline workers.
- State adoption accelerates when tools align with national policies and guidelines.
- Data integration across thematic domains creates more resilient NRM outcomes.

11.6 Knowledge Assessment

- How do geospatial datasets improve planning for soil and water conservation?
- Why is community participation essential in tools such as CLM and FRA Tool?
- How does GKI support governance at village, district, and state levels?
- What challenges can arise when implementing geospatial tools at scale?
- What is the role of India Observatory in strengthening GKI in India?
- How does CLART improve the quality of water conservation planning?
- Why is mapping commons essential for ecological restoration?
- How can GWMT support water governance planning at village level?

11.7 Summary / Key Takeaways

- India's geospatial ecosystem is rapidly evolving to meet national priorities.
- FES and the India Observatory demonstrate how geospatial tools can strengthen natural resource governance.
- Tools such as CLART, CLM, GWMT, IFMT, GEET, and IBIS enable **scientific, participatory, and scalable** restoration for planning, monitoring, and governance.
- Community institutions remain central, with data acting as an enabler rather than a replacement for local knowledge.
- GKI operationalization requires partnerships across government, civil society, and communities.
- GKI empowers data-driven NRM and ecological restoration across India.
- FES and IO have built robust geospatial systems accessible from village to national levels.
- Community institutions remain central to all interventions.
- Geospatially enabled systems enhance sustainability, resilience, and equitable livelihoods.
- The integration of national priorities and state capabilities is essential for scaling ecological security

11.8 Other Resources

- India Observatory: www.indiaobservatory.org.in
- National Geospatial Policy of India
- UN Integrated Geospatial Information Framework (IGIF)
- MGNREGA GIS Portal
- State Forest Working Plan Codes (2014 & 2023)
- Biodiversity Data Portals and IBIS Viewer
- NRSC-Bhuvan portal

LESSON - 12

GKI Workflow Integration for Disaster Management

Trainer' s Biodata: Dr. Shirish Ravan, Director, EarthSight Foundation

Shirish Ravan, through his EarthSight Foundation and DevTA (Development Technologies Accelerator), is driving geospatial and frontier tech innovation and advancing sustainability through grassroots initiatives. With 18 years in senior roles at the United Nations, he led global programmes such as Combating Opium Cultivation in Afghanistan and the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER). While contributing to UN programmes to promote peaceful uses of outer space, he visited over 70 countries, delivering high-level policy advocacy, technical advisory services, and curating more than 25 international conferences focused on sustainable development and disaster resilience. Earlier, during 12 years at IIRS, C-DAC, and MRSAC, his work spanned ecology, disaster management, environment, agriculture, and sustainable development

12.1 Introduction: The Changing Disaster Landscape

Over the past two decades, disaster frequency, severity, and economic losses have increased dramatically. This rise is driven by climate extremes, rapid urbanization, environmental degradation, and socio-economic vulnerability. The disaster–climate–development nexus shows that disasters are no longer isolated events—they now disrupt development pathways and worsen poverty and inequality.

The training emphasizes that modern disaster management requires:

- Risk-focused, not event-focused planning
- Evidence-based decision-making
- Technology-enabled preparedness
- Integration across sectors, agencies, and data systems

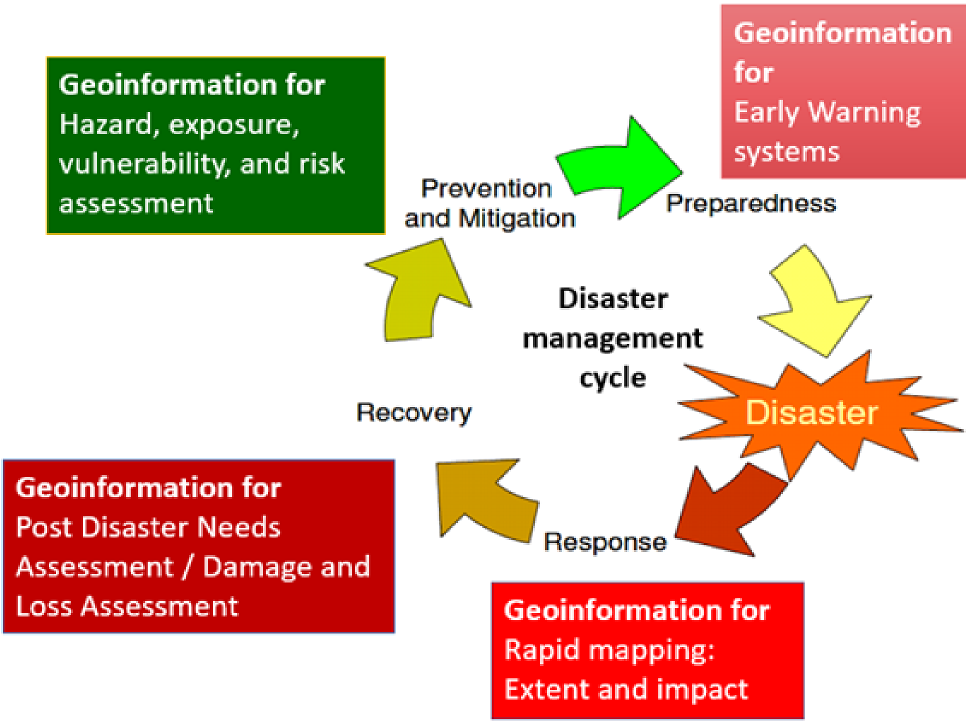
Global frameworks—Sendai Framework, SDGs, and the Paris Agreement—provide the policy backbone guiding resilience actions.

12.2 Session Overview

This session explores how geospatial technologies and frontier innovations enable a comprehensive disaster management workflow. It covers:

- Earth Observation (EO)
- Geospatial Knowledge Infrastructure (GKI)
- IoT & PNT-based sensor systems
- AI/ML & GeoAI
- Computer vision analytics
- Digital Twins & Smart Infrastructure

Participants learn how these components work together to support early warning, real-time monitoring, rapid response, and resilient reconstruction



12.3 Learning Objectives

By the end of this training, participants will be able to:

1. Explain **geospatial thinking** and its role in disaster governance.
2. Describe how **GeoAI and ML** enhance preparedness and response.
3. Understand how **frontier technologies** support the Early Warning for All (EW4All) initiative.
4. Apply the concept of **GKI** to resilient infrastructure planning and risk analytics

12.4 Global Disaster Frameworks

12.4.1 Sendai Framework for Disaster Risk Reduction (2015–2030)

It shifts focus from disaster response to risk prevention and resilience building.

Four priorities :

1. Understanding disaster risk
2. Strengthening governance
3. Investing in resilience
4. Preparedness & Build Back Better

Sendai Targets A–G emphasize reducing mortality, minimizing economic loss, strengthening infrastructure, and enhancing early warning coverage

12.4.2 Sustainable Development Goals (SDGs)

SDG 11 (Resilient Cities) and SDG 13 (Climate Action) are closely linked to disaster risk reduction. The manual highlights how geospatial data enables monitoring of progress on SDG indicators.

12.4.3 Paris Agreementience

Nationally Determined Contributions (NDCs) link climate adaptation, mitigation, and resilience—supported by EO and geospatial intelligence

12.5 Geospatial Knowledge for Risk Governance

Risk is spatial. Hazards, exposure, vulnerabilities, and capacities each have geographic patterns. GKI enables:

- Standardized datasets
- Interoperable platforms
- Shared risk intelligence
- Transparent decision-making

It supports:

- Local planning
- Infrastructure siting
- Emergency logistics
- Resource prioritization

12.6 Earth Observation for Disaster Risk Monitoring

EO provides multi-scale, multi-temporal insights essential for:

Applications (examples)

- Flood mapping (SAR imagery) – e.g., Rishikesh and Wayanad floods
- Landslide monitoring – Malin, Maharashtra
- Forest fire detection – thermal and optical data
- Urban subsidence measurement – Jakarta case
- Heatwave and drought analysis

EO supports:

- Early warning
- Exposure mapping
- Post-disaster damage assessments
- Long-term scenario modelling

30 July 2014 Malin village before and after landslide (Credits: BBC News)

12.7 IoT and PNT-Enabled Sensor Systems

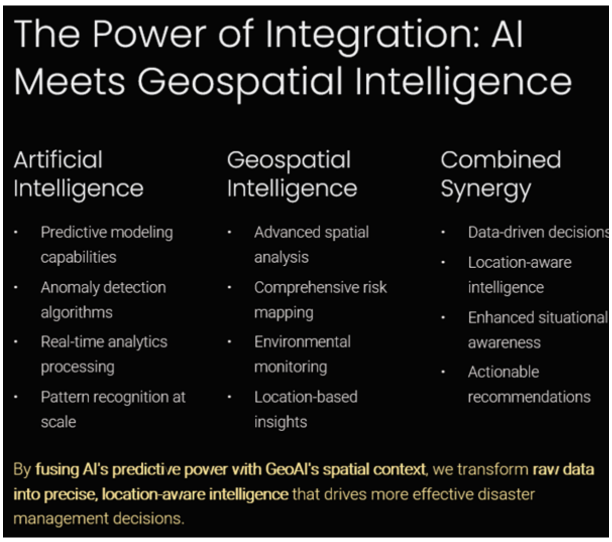
Positioning, Navigation, and Timing (PNT) systems enable real-time sensing through IoT networks. They provide:

- Precise location tagging
- Time synchronization
- Geo-fencing
- Automated alerting

Examples

- Landslide motion sensors
- River-level gauges for flash floods
- GNSS-enabled deformation monitoring of dams, bridges, slopes
- Asset-level monitoring for infrastructure resilience

12.8 AI/ML, Computer Vision & GeoAI



AI enhances analytical efficiency across the disaster cycle:

- Predicting extreme events (heatwaves, cyclones, landslides)
- Automated feature extraction from satellite imagery
- Damage classification
- Population & vulnerability mapping
- Evacuation route optimization

GeoAI integrates geospatial data with ML models, enabling faster, unbiased decision-making

12.9 Digital Twins & Resilient Infrastructure

A Digital Twin is a dynamic virtual replica of physical infrastructure.

Uses

- Flood scenario simulations
- Heat island mitigation planning
- Infrastructure stress testing
- Emergency response routing

India's National Geospatial Policy (2022) envisions a **National Digital Twin ecosystem** to support climate-resilient cities

12.10 Digital Twins & Resilient Infrastructure

A GKI-driven workflow integrates:

1. EO-based hazard detection
2. IoT sensor feeds (PNT-enabled)
3. AI forecasting models
4. GIS/cloud platforms
5. Community alert dissemination systems

Use cases

- Heatwave alerts
- Flood forecasting
- Forest fire early detection

12.11 Digital Twins & Resilient Infrastructure

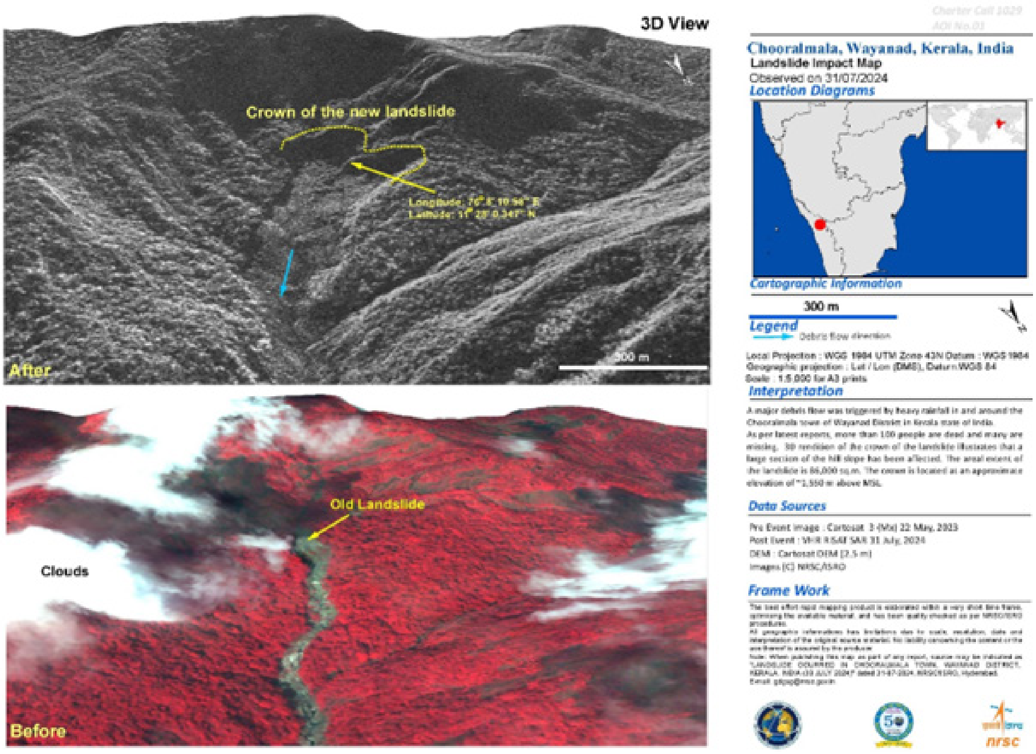
Global mechanisms include:

- International Charter: Space and Major Disasters
- UN-SPIDER Technical Advisory Support

They provide access to rapid mapping, satellite data, and technical assistance during floods, landslides, storms, and other hazards.

Case Examples

- Wayanad 2024 floods
- Chooralmala landslide
- Tropical Storm Megi



12.12 High-Impact, Low-Frequency Risks

Examples:

- Pandemics (COVID-19)
- Near Earth Object (NEO) impacts – Threats for Outer Space

These require:

- Early detection
- Cross-sector governance
- Communication strategies
- Global cooperation

12.13 India's Policy Landscape

Key policies:

- National Space Policy (2023)
- National Geospatial Policy (2022)
- Social Scientific Responsibility Guidelines (2022)

These frameworks empower public and private actors to operationalize GKI-enabled disaster management solutions

12.14 Exercises & Activities

Activity 1: Draft a GKI-enabled workflow for a chosen disaster

Activity 3: Case for Safety of the Inland Water Transportation

12.15 Final Takeaways

- Disasters are accelerating—risk management must be proactive.
- GKI provides the backbone for modern resilience planning.
- EO, IoT, PNT, and AI deliver real-time decision intelligence.
- Digital Twins will shape the future of resilient infrastructure.
- Preparedness saves lives, livelihoods, and development gains

12.16 References/reading material:

1. https://www.undrr.org/implementing-sendai-framework/what-sendai-framework
2. https://disasterscharter.org/
3. https://www.un.org/en/climatechange/early-warnings-for-all
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