DEVELOPMENT OF CONTEXTUAL UNDERSTANDING, INFORMATION, AND ANALYTICS TOWARDS DETERMINING THE NATIONAL GEOSPATIAL INFORMATION ECOSYSTEM

DISCUSSION PAPER
July 2022

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PREAMBLE

To move from the present to the future desired state, the national geospatial information ecosystem will need to undergo a shift in its future geospatial, technological, and human resource arrangements. A key element of the UN-GGIM Committee of Experts and its related community is to provide strategic leadership, support, and make necessary policy decisions to drive change that will deliver the transformative shift where the community provides solutions to the world's most pressing problems with its geospatial information and knowledge, technologies, and processes, leveraging the globally developed and adopted Integrated Geospatial Information Framework.

This discussion paper explores some initial contextual understanding and will benefit from feedback from the UN-GGIM community, from its Member States and relevant stakeholders, to support this discussion and contribute to making informed decisions. The provision of your thoughts and comments, as submissions via email to the UN-GGIM Secretariat (ggim@un.org) with the subject 'The national geospatial information ecosystem', will be most appreciated. The closing date for submissions is 31 October 2022.

We look forward to your contributions.
Thank You.

UN-GGIM Secretariat
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1. OVERVIEW

Technology is widely accepted to be a key driver of economic development – of countries, regions, cities, and villages. A dynamic technology ecosystem broadly encompasses a huge body of knowledge and tools which eases the use of economic resources to produce innovative goods and services efficiently. For economic prosperity, the adoption of technology is recognized as critical as it transforms almost every aspect of our lives, and all sectors of economy at an unprecedented pace and scale. The resulting interconnectedness of people, devices, and information, anytime and anywhere, raises the importance of 'Geospatial' information (Schwab, 2016) which is a critical part of a vibrant technology ecosystem and is ubiquitous across all sectors for socio-economic and environmental progress of the world and society.

'Geospatial' in simple words is defined as the 'data' that is associated with a particular location, captured via varied technologies inclusive of earth observation (remote sensing, drones, aircrafts), Global Positioning Systems (GPS) /Global Navigation Satellite Systems (GNSS), and scanning tools. The technology architecture of geospatial data and information for countries was initially conceptualized in 1980's and 1990's, to take the form of a National Spatial Data Infrastructure (NSDI) of a country. At the time, global geospatial practitioners looked at the NSDI's or the SDIs as the only source of reliable fundamental geospatial data and a connection to other national information systems (inclusive of non-spatial information systems) to achieve national priorities. Built on the concept of road and railway infrastructure, the SDI concepts began to be referred to as a platform on which products and services are built, with governments playing a central role in its establishment, operations, and maintenance [1]. The SDI as a concept brings together a framework of policies, institutional arrangements, technologies, data, and people that enables the sharing and effective usage of geographic information with an intent to reduce duplication of efforts among governments and make geographic data more accessible to one and all to bridge the socio-economic gaps. However, as technology continued to evolve at a rapid pace, and as time progressed, there was an increasing recognition among stakeholders of the national geospatial information ecosystem of revisiting and revising the concept of an SDI to partake more digitalization and data integration. Since SDI's continue to be a 'work-in-progress', and even today in many countries is a catalogue offering data downloads of historical spatial data, a need for a new dynamic framework surfaced which could deliver significant local, national, and regional benefits in new effective and efficient collaborative way.

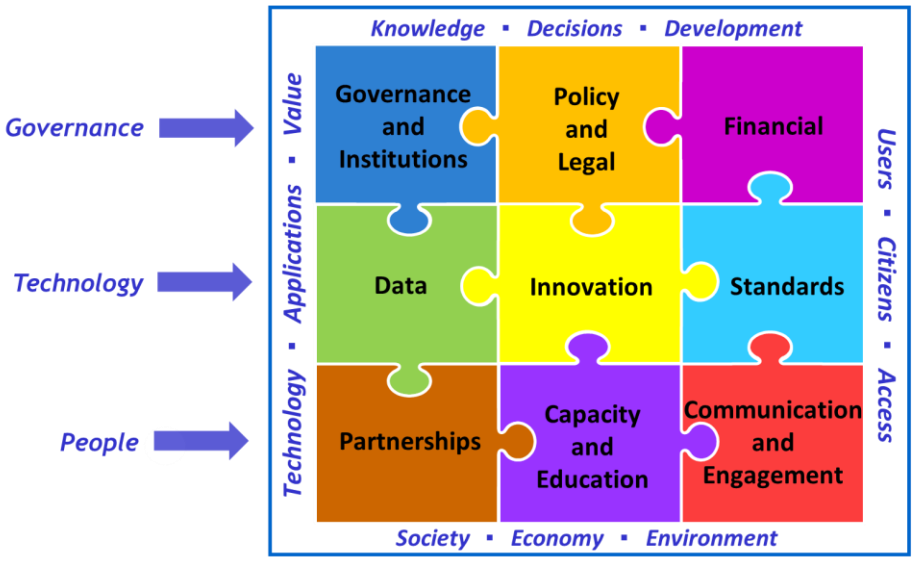
This need for transformation towards digitalization of the national geospatial information ecosystem, gave rise to the concept of Geospatial Knowledge Infrastructure (GKI). The GKI, a concept jointly developed by Geospatial World and the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM), has been created with the vision for putting 'geospatial knowledge at the heart of tomorrow's sustainable digital society' [4]. The concept builds on the fact that the geospatial ecosystem now has to move up from 'data' at the centre of the geospatial value chain to 'knowledge' by leveraging many new opportunities enabled by 4th industrial revolution technologies (inclusive of big data, cloud, artificial intelligence (AI), machine learning (ML), and Internet of Things) to accelerate automation and knowledge-on-demand. The GKI concept integrates digital economies, societies, and citizens with geospatial approaches, data, and technologies to deliver the location-based knowledge, services and automation expected of the fourth industrial revolution.

Figure 1: The six elements of a Geospatial Knowledge Infrastructure. All elements contribute to improved national outcomes, both individually and collaboratively

Source: 'The Power of Where', Geospatial Knowledge Infrastructure-White Paper

At the centre of this transformation from the SDI to the GKI framework lies the United Nations' multi-dimensional Integrated Geospatial Information Framework, most known as the IGIF. The IGIF provides an overarching strategy, implementation guidance, and action plans to develop a country-level action plan for strengthening the national geospatial information management. The framework has been developed understanding that there needs to be more institutional collaboration, coordination, interoperability, and integration across the various national data information systems and platforms [8]. It contains a vision, mission, strategic drivers, seven principles, eight goals, nine strategic pathways, and many defined benefits at the strategic level which is useful for the ecosystem to transition from a SDI framework to a GKI framework. Anchored by nine Strategic Pathways, the IGIF is a mechanism for articulating and demonstrating national leadership in geospatial information and the capacity to take positive steps. The IGIF is a fundamental framework which recognizes, builds substantially upon, and augments previous investments and achievements in planning SDI's and NSDIs.

Figure 2: The IGIF is anchored by nine strategic pathways and three main areas of influence. Once implemented the strategic pathways realize many benefits



Source: 'Integrated Geospatial Information Framework' – A strategic guide to develop and strengthen National Geospatial Information Management; Part 1: Overarching Strategic Framework

1.1 Determining the National Geospatial Information Ecosystem

Recent decades are a witness to the dramatic advancements in the development and adoption of new technologies. This rapid technology change, even if the adoption is uneven across different parts of the world, is affecting national economies, societies, and culture – and a national geospatial ecosystem is no different. The changing geospatial ecosystem landscape inclusive of the innovations in geospatial technology platforms, volume, and nature of geospatial information being generated, increasing importance of location and positioning, navigation and timing (PNT) solutions, dynamic public policy reforms and regulations (for technology and applications), more advanced analytical tools such as artificial intelligence and machine learning (AI/ML); implementation of digital twins, increasing public-private partnership and the enhanced workflow integration of geospatial in critical economic sectors has necessitated the need for developing the NextGen National Geospatial Ecosystem.

Furthermore, the world has advanced from the traditional definition of geospatial information to a much more dynamic definition of geospatial application inclusive of digital twins and the metaverse. Digital Twin a digital representation of a near-real-world entity/asset helps to create real-life simulations of different scenarios for improved decision making at an asset, city, state, and country level. On the other hand, a metaverse is a *'persistent and interconnected network of 3D virtual worlds that will eventually serve as the gateway to online experiences and underpin much of the physical world'*. [2] In other words, a metaverse integrates both virtually enhanced physical reality; and physically persistent virtual space. [3] It is where immersive technologies like Virtual Reality (VR) and Augmented Reality (AR) sit on top of (and within) a 3D geospatial accurate digital twin which is continuously evolving. To build a sustainable and operational national geospatial ecosystem of the future, a functional and scalable metaverse will be critical so that different components can integrate smoothly.

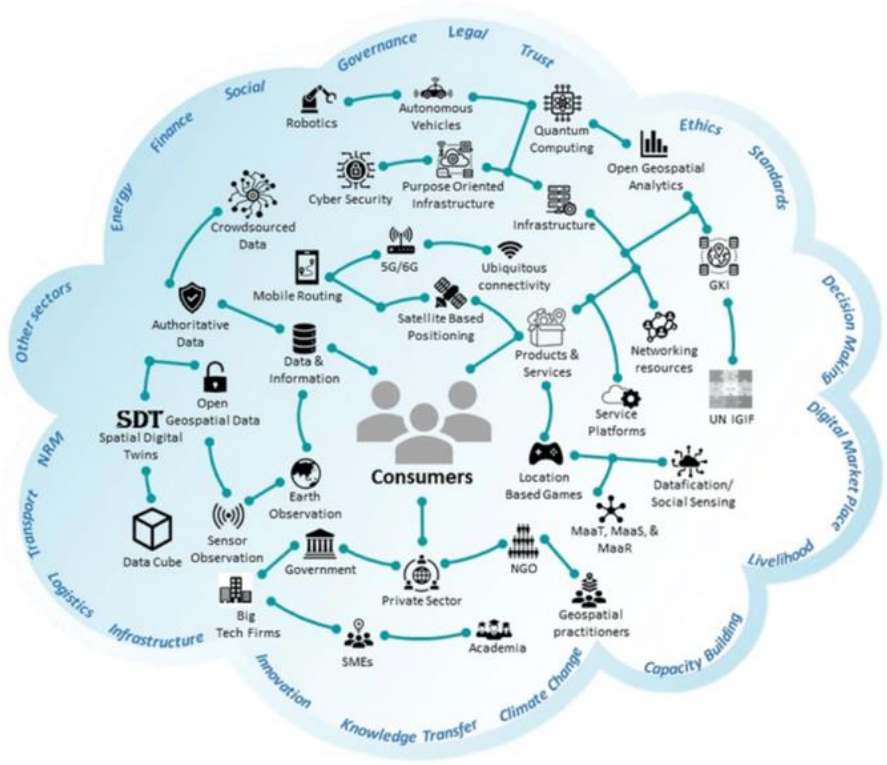
Alternatively, along with the positive technology advancements the increasing 'digital' and 'geospatial' divide between developed and developing nations, the widening technology understanding gap among the users, lack of skilled personnel to exploit new opportunities, and the need to protect the privacy and deal with bias and cybersecurity issues, has necessitated government's worldwide to explore a modern and knowledge-

driven national geospatial information ecosystem. With rapid technology convergence with geospatial ecosystem, and democratization of access to data and emergence of new actors, and innovation – there is a requirement to begin defining the most suitable and appropriate way in which countries can adapt and adopt to the fast changing geospatial ecosystem to keep up with the complexities of geospatial information use and its application across range of use-cases to align with strategic national priorities.

2. THE FUTURE NATIONAL GEOSPATIAL ECOSYSTEM

What was science-fiction once, is a reality today. What is seemingly science fiction today, will be a reality tomorrow. With rapid technology advancements, its' difficult to predict what the future national geospatial ecosystem will look like and it most certainly is a long process. The adoption and implementation of it will also depend on the governments and national geospatial agencies willingness to reinvent the wheel in response to the changing political, institutional, socio-economic and technological circumstances [5].

Figure 3: The Geospatial Ecosystem



Source: Towards a sustainable geospatial ecosystem beyond SDIs [1]

To develop a conceptual model of the future national geospatial information ecosystem, there is a need to appropriately define the 'ecosystem'. Over the past decades with geospatial becoming ubiquitous, the stakeholder ecosystem has evolved considerably; and is not limited to the geospatial community anymore. The geospatial ecosystem comprises of billions of 'actors' (citizens, companies, governments, civil society organisations, Internet of Things (IoT) devices, and increasingly also 'intelligent' machines) producing and consuming geospatial information, mediated through ever-changing platforms, an increasingly diverse set of geo-analytical tools, and dynamic, constantly evolving networks [6]. A futuristic national geospatial information ecosystem needs to include all these stakeholders from far and beyond the geospatial community, including vertical/economic sector stakeholders, and information and communication technology (ICT) stakeholders and citizens. Additionally, there is an immense need to include the economists

in the geospatial community. A dynamic and implementable national geospatial information ecosystem is only possible when it takes into account the economic priorities of a country, and delivers economic value to the country's growth and development.

Furthermore, as the geospatial ecosystem widens, and all the required data is available through both open and commercial sources, there is still a conundrum, among the 'new generation' stakeholders of this ecosystem on data availability, data use, data standards, to name a few. The future national geospatial information ecosystem requires it to cater to this new generation of geospatial users, and use cases based on consumers demand of knowledge rather than just data with an intent to solve the strategic priorities of governments, citizens and businesses.

A modernized and evolved national geospatial ecosystem cannot only be developed based on the innovations and advancements in technology but has to be based on the individual priorities of the stakeholders (including nations). To address such strategic priorities, a carrot and stick approach will not work, and to ensure sustainability, the geospatial community, particularly the national geospatial agencies (inclusive of space agencies, mapping agencies, geological agencies), should reflect on the existing geospatial ecosystem models and transform themselves to be agile and enhance their capacities – from people, process and technology perspective to confront and overcome the challenges they face. The focus must be on the nature of the problems and the dilemmatic situation to address the challenges, dilemmas, paradoxes and ambiguities that face regions, countries, cities and villages. This requires stakeholders to explore adapting to the IGIF framework, identify the emerging trends and its potential impact on the development of the future national geospatial ecosystem and in addition take into consideration the political, economic, social and technological (PEST) analysis (discussed in section 3) to assess the factors which drive the adoption and implementation of geospatial in their respective ecosystem. It is also simultaneously imperative for the geospatial community to expand and explore the cross linkages of geospatial technology implementation for socio-economic and environmental progress.

2.1 Emerging Trends and its Potential Impact on the Development of the Future National Geospatial Ecosystem

This section of the paper addresses the key new, and some old, trends (from and beyond the geospatial ecosystem) and their potential impact on the development of the future national geospatial ecosystem. This section draws on the consultant's discussions and interactions with the geospatial community, existing reports, including the report on future trends in geospatial information management report by UN-GGIM [12], the document on '**Towards a sustainable geospatial ecosystem beyond SDIs'** by UN-GGIM [1], geospatial technology trends identified by the GeoBuiz 2022: Global Geospatial Industry Outlook report by Geospatial World [11], interactions at the Geospatial Knowledge Infrastructure (GKI) virtual summit and training program at Geospatial World Forum 2022, and the workshop organized by UN-GGIM on the 'Future of Geospatial Ecosystem' at Geospatial World Forum 2022. This section aims to highlight the current discussions and deliberations, and political, social, economic and technological trends driving the geospatial community and the potential impact it may have on the current definition of the national geospatial information ecosystem.

Table 1: Emerging trends and its potential impact on the development of future national geospatial ecosystem

Emerging Trends	Impact/Role
Digital Technology Advancements	• The existing geospatial ecosystem is struggling to keep up with the rapid pace of the technological advancements of the fourth industrial age and is unprepared for the fifth industrial age wherein a much deeper working relationship is foreseen and expected between the smart technologies and human intelligence. Static adoption of technologies is not suitable for advancing the geospatial data ecosystem. • The future or the desired national geospatial ecosystem requires the geospatial ecosystem as a whole to transform itself to keep up with the innovations in the digital economy to 'break and connect the silos' and adapt and work in coordination with these technology innovations to simplify spatial data use across all ecosystems.
New Geospatial Data Sources and Geospatial Technology Innovations	• The existing national geospatial ecosystems are driven primarily by governments – politically and legally and therefore, they are unsuitable to take into account the advancements in new sources of geospatial data collection, including new generation of technologies and applications. Static metadata records and data catalogues are today ill-suited for the advanced geospatial applications and services required by today's users (geospatial/non-geospatial experts) • The future national geospatial ecosystem must take into consideration the innovations happening in the geospatial space with respect to collecting next-generation of geospatial data. Innovations in earth observation with respect to data resolution, and platforms such as drones, availability of ground-based terrestrial PNT systems (as an alternate to GPS) for position, navigation and timing information, robotic scanners, wearables, and IoT sensors are few technology innovations which are today expanding the horizons of the offerings of a national geospatial ecosystem. It is necessary for countries to develop a dynamic geospatial ecosystem based on modern geospatial technologies and practices. • The future national geospatial ecosystem should also take into consideration the advancements in digital twins and metaverse as a concept, and embody ways to address privacy, ownership and interoperability concerns present in the existing national geospatial ecosystem.
Emphasis on Geospatial Data and its Dynamics (Standards and Interoperability)	• The existing national geospatial ecosystem continues to be governed primarily by dynamics related to geospatial data quality, and authoritative geospatial data. • The future national geospatial ecosystem must take into consideration a 360-degree view of the 'geospatial data'. With increasing sensor-data fusion, integration of geospatial with the technology advancements of the fourth industrial revolution technologies, and increasing digitalization and workflow integration across all vertical sectors, the future national geospatial ecosystem must adequately and appropriately address concerns of and beyond data quality and authoritative data – such as geospatial data standards, data interoperability, data sovereignty, data privacy, data ownership and management, data security, to name a few. There is a need to

	appropriately address issues pertaining to authoritative data, intelligent data management (basis Findability, Accessibility, Interoperability, and Reuse (FAIR) principles), and data export to scale the applications and services provided by the national geospatial information ecosystem.
Analysis and Automation	• The existing national geospatial ecosystem functions with data as a fundamental outcome. Data is critical even today, however, it is no longer valuable as a stand-alone entity. The changing user expectations and the widening geospatial ecosystem requires more automation, analysis and intelligence, i.e., knowledge than just 'data'. • The increasing demand and transition towards analytics, and automation in the fourth industrial age, necessitates the future national geospatial ecosystem to deal with vast amount of near-real time geospatial datasets for intelligent decision-making. Also, increasing sensor data fusion and workflow integration of geospatial data requires intelligent analytics for efficient and productive action-oriented operations. The world is transitioning from data to insights and knowledge and the future national geospatial ecosystem should cater to this transition, appropriately addressing the needs of the next generation of geospatial data users.
Evolving Role of Federal Geospatial Data Providers	• The old and existing geospatial ecosystem limits the role of the Federal Geospatial Data Providers to the traditional definition of being just 'data providers'. • Within the future geospatial ecosystem, the Federal Geospatial Data Providers should evolve themselves and take the role of a leader and facilitator to champion the use of geospatial data effectively, while simultaneously being responsible for – strengthening and developing an agile geospatial data infrastructure, building, facilitating and supporting enabling geospatial regulatory frameworks, enabling intra-government collaborations for enabling use of data for public good, and enabling public and private partnership for geospatial knowledge co-creation.
Advancing User Demand and Expectations	• The current/existing geospatial ecosystem is struggling to cater to the non-geospatial experts of the expanding geospatial ecosystem. • The users' expectations from a geospatial ecosystem have evolved from just data or digital data libraries to knowledge-based solutions and services, catering to a wide range of economic sectors and cross-linkages within the sectors. The future national geospatial ecosystem, therefore, must cater to the users or non-geospatial experts outside the 'traditional users' of geospatial community.
Progressing to Become a Multi-Stakeholder Ecosystem	• The national geospatial ecosystem, traditionally, and until recently continued to be driven by the governments and federal geospatial data providers. The existing national geospatial ecosystem too is largely dependent on the government for developing/upgrading geospatial data infrastructure, funding, technology adoption, to name a few. • The last decade has reinforced the critical role of and need for geospatial data and technologies, and also established that the geospatial ecosystem cannot be solely driven by the government and the federal geospatial data

	providers. While a key player in the ecosystem, the success of the future national geospatial ecosystem relies on agility, and multi-stakeholder collaboration and coordination – including commercial geospatial technology providers, geospatial data and technology users (private/government), academia and researchers, and the civil society (citizens).
Realignment of Business Models	• To serve the diverse needs of the broader geospatial community, it is must for the future national geospatial ecosystem to strongly realign the industry business models based on real-consumer demand. The 'data' alone cannot lead to scalability, and needs to be supported by innovative business/finance models, with a focus on the real needs of the ecosystem. The evolution of the geospatial industry's business model to Anything (X)-as-a-Service is one such factor, which addresses the push and pull from the geospatial market and can be readily adopted within the future national geospatial ecosystem to serve knowledge-as-a-service.
Focus on Strategic National Priorities and SDGs	• The existing national geospatial ecosystem conceptualized primarily to share and drive the usage of geospatial information, lacks purpose and objective. • In today's uncertain times wherein, the world is facing several challenges with respect to its resiliency and sustainability, the future national geospatial ecosystem should be established on the premise of a defined-objective-oriented purpose – driven by the strategic national priorities of the country and the focus areas of the sustainable development goals (SDGs) as defined by 2030 Agenda. A purpose-driven national geospatial ecosystem has the potential to be more effective, problem-solving, dynamic and agile in nature.
Unearthing the 'Economics' of Geospatial	• Traditionally, the geospatial community and the economics community have not interacted with each other and therefore, the true economic value of geospatial continues to remain hidden even today. In the conventional national geospatial ecosystem, the 'all-geospatial' stakeholder community found the 'economics of geospatial' to be inconsequential to their purpose – however, that is changing with the broadening of the geospatial ecosystem and the influx of new generation of stakeholders. • The future national geospatial ecosystem must take into consideration the economics of geospatial. The growing importance of geospatial technology is linked to marketplace transformation, improving living standards, improved productivity, efficiency and compliance in both traditional and non-traditional sectors, and has virtually revolutionized every industry in the global economy. While its true value remains hidden from the traditional economic metrics of GDP, and corporate profits, the opportunity lost and gained, and the return on investments generated is imperative to define the way forward of the future national geospatial ecosystem. Therefore, the future national geospatial ecosystem must have metrics to create, measure and track the geospatial economic metrics to gain competitive advantage over the existing ecosystem.

2.2 Shaping the future national geospatial ecosystem beyond Spatial Data Infrastructure (SDI) and Geospatial Knowledge Infrastructure (GKI)

Predicting the future of anything in the medium to long term (from 10-20 years) is an exercise fraught with uncertainties, difficulties, and irrationality. Often while predicting the future, there is an overemphasis on the rapid technology advancement; the outlook of the information technology environment; however, not enough focus is placed on value and impact from a socio-economic perspective. Things become even more complicated when dealing with the geospatial ecosystem – an underpinning technology ecosystem, today, for everything. ***The future of the national geospatial ecosystem, or what may be termed as the 'desired geospatial ecosystem,'*** relies heavily on advancements in the technological environment. While many of the current technology trends are already assimilated in the existing geospatial ecosystem frameworks, the potentially desired geospatial ecosystem, will imbibe the leading emerging technologies, data formats, technology architecture, and information models to be adequately prepared for the future.

In the broader context, complementary initiatives like the Geospatial Knowledge Infrastructure (GKI) and the European Union Location Framework Blueprint provide indirect linkages to strengthen the national integrated geospatial information management and define the appropriate desired state of the geospatial ecosystem [1]. The Integrated Geospatial Information Framework (IGIF) provides an integrated overarching paradigm to strengthen further the nationally integrated geospatial information management for the Member States who are in the early stages of adopting spatial data infrastructure but also for those who have successfully implemented spatial data infrastructure capabilities and want to 'leapfrog' to an advanced (and desired) geospatial ecosystem [1].

Beyond SDIs, the GKI framework, enhanced and enabled by the strategic pathways of the IGIF framework, provides a broader definition of what the geospatial information will look like in the short term (5 years). The GKI concept is built on developing an increasingly dynamic and liberalized geospatial infrastructure. It expands the focus of NSDI from 'data provision' to 'knowledge creation,' using the 4IR technologies and the growing digital infrastructure [4]. In summary, GKI positions geospatial, a general-purpose capability encompassing governance, technology, data, and people, at the heart of knowledge co-creation [4].

While there is still time for the many Member States to transition from data-centric to analytics-centric, there is a need to evaluate what comes after GKI. It is imperative to envision the future, prepare ourselves beforehand, and develop an informed and desirable national geospatial ecosystem, which goes beyond knowledge to wisdom – that is, transitioning from knowledge to 'applied knowledge' or 'applied intelligence' for impactful value-creation. In this context, the *desired geospatial ecosystem* will, thus, be based on the ecosystem integration model with a phased shift to the value integration model of the ecosystem evolution. The *desired geospatial ecosystem* will be far wider and intelligent than ever before, and will transcend the boundaries of digital modelling, and applications to cognitive modelling, hyperconnected data models and adaptive and autonomous analytics for value impact-centric decisions. This is a step beyond 'knowledge infrastructure' wherein the geospatial ecosystem moves beyond the realms of predictive analysis (insight and foresight) to prescriptive and adaptive and autonomous analysis, i.e., towards wisdom. The foundational geospatial data, however, will remain a foundation of the *desired geospatial ecosystem*.

Table 2: Transcension towards the Desired Geospatial Ecosystem from Spatial Data Infrastructure (SDI) and Geospatial Knowledge Infrastructure (GKI) Framework

Spatial Data Infrastructure (SDI) [4]	**Geospatial Knowledge Infrastructure (GKI) [4]**	***Desired Geospatial Ecosystem (Future)***
Data-centric	Analytics-centric (fit for analytics data)	**Decision-centric** (decision-based outcomes)
Centralized system	Distributed system	Distributed System / ***Data Mesh Architecture***
Desktop/web-portal	Distributed cloud-based	Distributed Cloud-based / ***Ubiquitous/Pervasive Computing***
2D representation	4D/5D representation	5D/6D representation
Supply-centric	Demand-centric (user-centric)	**Value-Impact Centric**
Limited data range	Dynamic data with wide range of data (crowdsourced, mobile, IoT, etc.)	**Bidirectional flow of data**; **synthetic data layers**; **integrated data layers** (statistical/socio-economic/user sectoral, space, etc); **new data collection tools** (autonomous vehicles, digital twins, indoor positioning, terrestrial positioning, robots, etc.)
Professional users only	Including non-spatial users	Includes Machines
Linear and Independent	Intelligent Search	***Cognitive Search*** (Indexing, NLP, Machine Learning, and Natural Human Interaction (NHI)) to ***Neural Lace*** (human brain merged with computers – such as Siri, Alexa, etc.)
No Analysis	On-the-fly data analysis	***Advanced Augmented Analytics*** (Machine Learning Automation, Pervasive Computing, Conversational Analytics (NLP, NLQ, and NLG), and auto-visualization
No Modelling	Predictive Modelling/Analytics (Insights and Foresight, Quantify cause-and-effect using machine learning)	***Prescriptive Analytics***– Optimized Human Decision Making – prescribing actions and recommendations using supervised machine learning ***Adaptive and Autonomous Analytics*** – The Learning and Cognitive Enterprise – Continuously-learning, autonomous enterprise using artificial intelligence, deep learning, and reinforcement learning for dynamic simulation models
Government	Government, industry and citizens	Government, Consumers and Citizens, Academia and R&D, Private Sector (Users), Big Technology Firms, and NGO's
Web 1.0-Web 2.0 **–** *Information and Commerce*	*Web 3.0 – Semantic Web – Connects knowledge (Internet of Things; Platform and Digital Economy)*	***Web 4.0 – The Meta /Intelligent web –*** *Connects Intelligence (Blockchain; Token economy, and virtual economy)*
	Ecosystem thinking and behaviour	***Network of Integrated Ecosystems of Ecosystems***

**The content in italics in the SDI and GKI paradigm and across all of the desired geospatial ecosystem are the Consultant's view based on the interactions and analysis of the contributions received and documents reviewed.*

Thus, the transcension of the geospatial ecosystem to the desired state will shift towards cognitive and autonomous intelligence, wherein an integrated ecosystem of the ecosystem will be critical. New ideas and innovations in the information technology space will alter the broader ecosystem contours – such as processes, people, policy, stakeholders, and ultimately the operational ecosystem, i.e., the operational environment. The transition to the *desired geospatial ecosystem* will be dependent on the network of integrated ecosystems of ecosystems which will lead to new business models, create new markets, and radically change or disrupt existing markets. As the *desired geospatial ecosystem* will require more technology interfaces for decision-based outcomes to create value/impact, the ecosystem will continuously change. The *desired geospatial ecosystem* will be based on cross-linkages among varied actors/stakeholders of the geospatial ecosystem (as mentioned in the table above) and the interactions of actors within those ecosystems as well. This approach will require implementing visionary multi-dimensional thinking wherein aligning with the value impact will be critical. The role of consumers and small-and-medium size enterprises would be vital to driving innovation and nurturing the niche area of relevance to develop a robust and agile ecosystem.

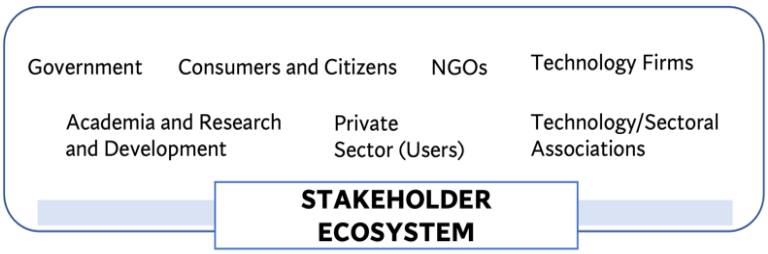
The geospatial ecosystem is multifaceted, with multiple interactive components to address complex data relationships. Today, 3D and 4D spatial data representation are emerging as new norms for the geospatial ecosystem. Looking beyond seven to ten years, machine-led decision making, machine-to-machine and machine-to-human interfaces will increasingly become a norm for ubiquitous computing, analytics, and automated decision making, translating spatial data representation to 5D and 6D. The future will be driven by machines as they shall become critical stakeholders in the desired geospatial ecosystem, independently undertaking data collection, real-time data processing, and analytics for informed decision making. A deep, multi-level cooperation will be seen among humans and machines for co-existing in an interoperable environment for open innovation, automation and customization/personalization of solutions for the value/impact matrix. Further, the data architecture will evolve to include data from varied sources – including the bidirectional flow of data, synthetic data (artificially generated data addressing data privacy issues and concerns associated with real data), integrated data sets from different sources and contexts, including data captured and collected by autonomous vehicles, digital twins, robots (cobots), indoor positioning, etc., and finally have the influence of integrated technology (space) and sectoral layers (cities, utilities, infrastructure, climate change, etc.) as well as developments in the broader IT environment. The data mesh architecture [13], a new distributed architectural paradigm will hyper connect the data and data models from disparate sources in a domain-oriented decentralised environment to scale value-based data analytics in a secure and interoperable manner. A data mesh architecture system will make data more available, accessible, and discoverable – resulting in a paradigm shift in the way geospatial data and metadata are collected, managed, represented and exploited.

For the Member States to leapfrog to this desired geospatial ecosystem, the digital infrastructure will be enabled by a unified communication infrastructure, which will integrate all tools of communication. The connectivity issues in the existing geospatial ecosystems will subsequently decrease as 5G/6G networks will fill the gap between the societal and business demands owing to a higher frequency and much lower latency. Thus, the initial evolution of the *desired geospatial ecosystem* approach will be fragmented, but it will be countered by integration facilitated by policy, standards, and interoperability frameworks along with technology synergies. Core to the evolution of the desired geospatial ecosystem would be synergizing people, processes, policies and strategies, and technologies to transform knowledge into wisdom to utilize the ecosystem to adequately address significant global, national, and local challenges.

2.3 What does the future's desired national geospatial ecosystem look like?

Post Covid-19, it is hard to predict what will happen tomorrow, it is even unpredictable to make an estimation of what will happen by 2030 or beyond. Yet from a technology perspective – and data perspective, there are few clear indications around what is going to come next, and the role these ecosystems will play in the diversification of the desired geospatial ecosystem. In our definition of the desired geospatial ecosystem, we look at the geospatial ecosystem from the perspective of the value and impact creation. Post-Covid-19 the world has moved forward from the concept of sustainability as a definition focussing on climate change, carbon footprint, energy efficiency to a broader concept of 'sustainability and resiliency of everything'. With the impact of the pandemic, while the ecosystem will focus on demand of the consumers, it will be to derive and manifest a greater socio-economic-environment impact. The consumers in this case will become an integral part of the stakeholder ecosystem and collaborate to create larger value-impact. This value-impact will be specifically defined by the priorities of each Member State at a national level and broadly defined by the 2030 Agenda for the Sustainable Development Goals (SDGs). Furthermore, the desired geospatial ecosystem will take into consideration the people, process, technology (IT/geospatial), policy and strategy frameworks, standards and interoperability frameworks, and finally the continually changing operational environment.

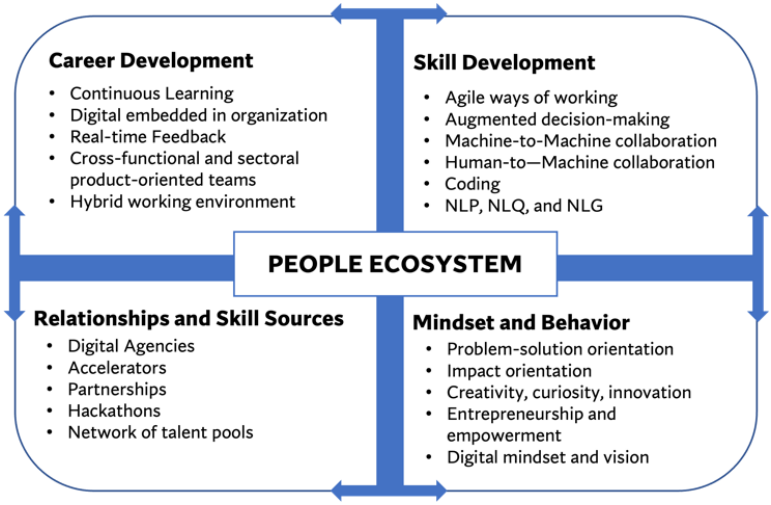
2.3.1 Stakeholder Ecosystem



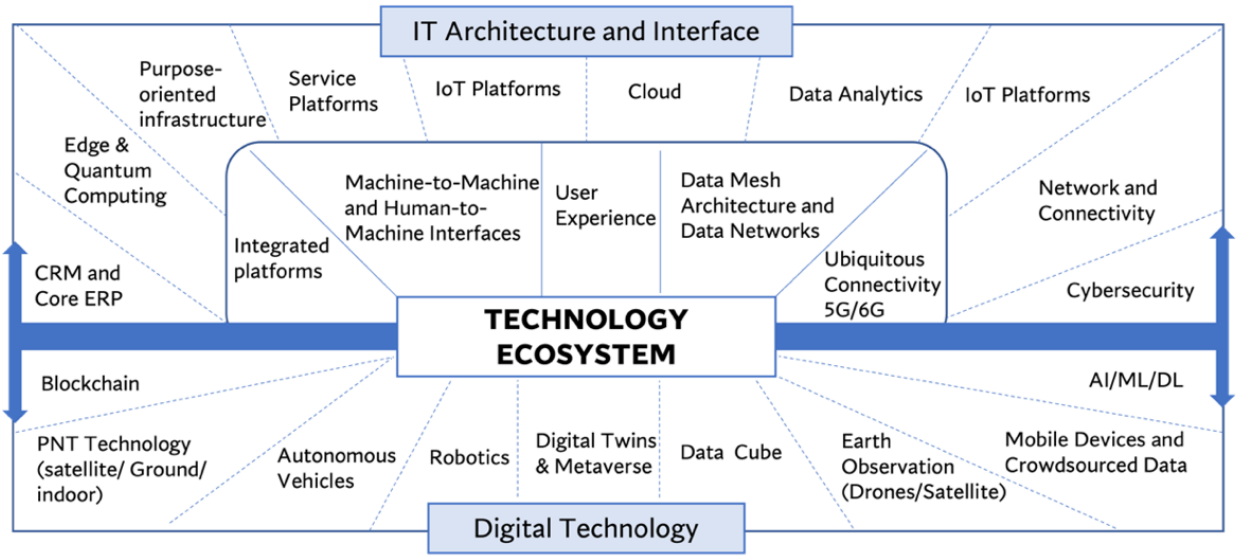
The stakeholder ecosystem of the desired geospatial ecosystem includes a collaborative and coordinated partnership between Government, Consumers and Citizens, NGOs, Technology Firms (Big and SMEs), Academia and Research Organizations, Private Sector (Users), and Technology and Sectoral Organizations. It will include cross-linkages among all the actors, i.e., stakeholders of the geospatial ecosystem for them to collaborate and take informed decisions for broader value/impact. Each actor/stakeholder in the ecosystem will address – their own demand; and the impact/value that is generated from their decisions. The technology firms will innovate and develop products, services and solutions which are decision-centric and provide the consumer ecosystem with prescriptive analytics and cognitive search capabilities. A key part of the desired geospatial ecosystem will be technology and sectoral associations who will drive technology adoption, and innovation of geospatial and 4IR allied technologies across sectoral workflows and play a defining role in policy and standards formulation.

2.3.2 People Ecosystem

There is virtually no ecosystem in place which does not include people, or is shaped by the people and the services provided by them. A true people ecosystem within the desired geospatial ecosystem, will prepare the geospatial and 4IR professionals with continuous learning processes, agile ways of working, teach machine-to-machine and human-to-machine collaboration, coding, etc., with an intent to provide solutions for problem, and create a digital mindset and vision.

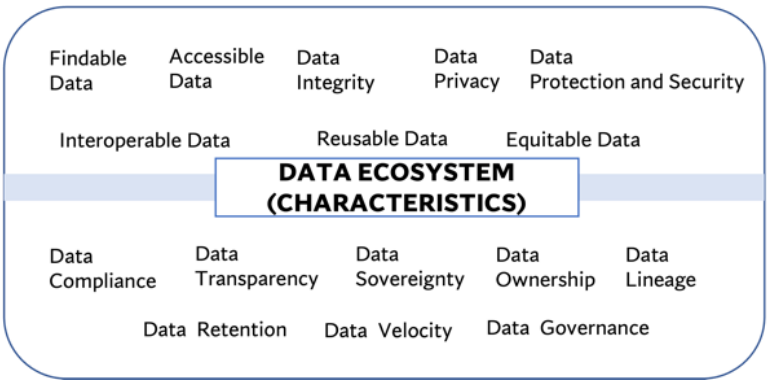


2.3.3 Technology Ecosystem



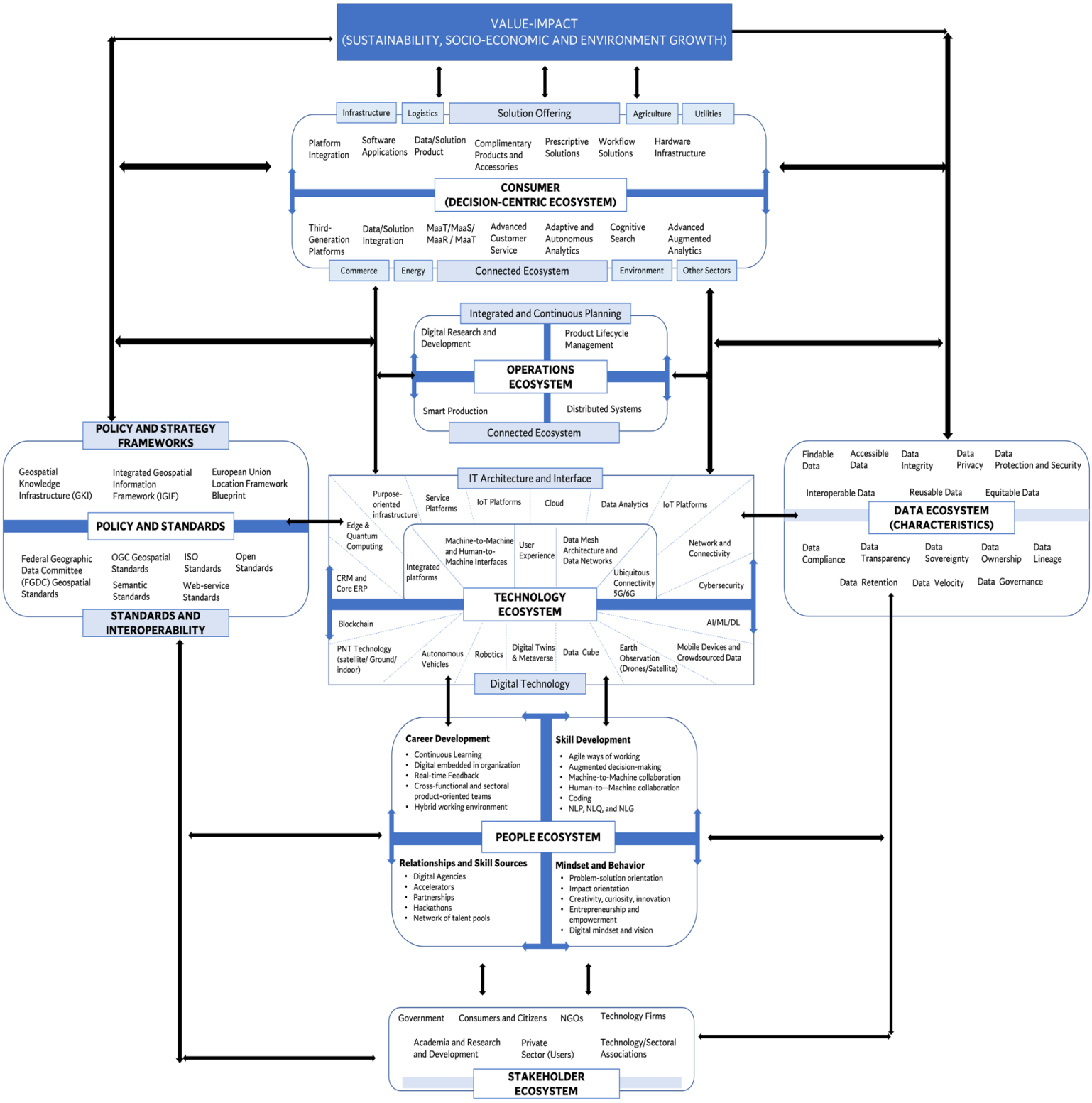
Technology is the most critical ecosystem within the desired geospatial ecosystem inclusive of key technology parameters – Information Technology (IT) Architecture and Interface, and Digital Technology – both of which will be interlinked in a semantic, connected graph. The desired geospatial ecosystem will focus on integrated platforms, machine-to-machine and human-to-machine interfaces, user experience, data mesh architecture, and ubiquitous connectivity (5G/6G) as the foundation of its ecosystem. Simultaneously, the digital technology piece in the technology ecosystem will enable connectedness in cloud; include varied sources of data collection, inclusive of robotics, digital twins, PNT technology, etc.; and data processing tools – including AI/ML/DL, Data Cube, Edge and Quantum Computing to name a few. The technology ecosystem will facilitate and enable a dynamic data ecosystem with all required characteristics; and policy and standards framework.

2.3.4 Data Ecosystem (Data Characteristics)



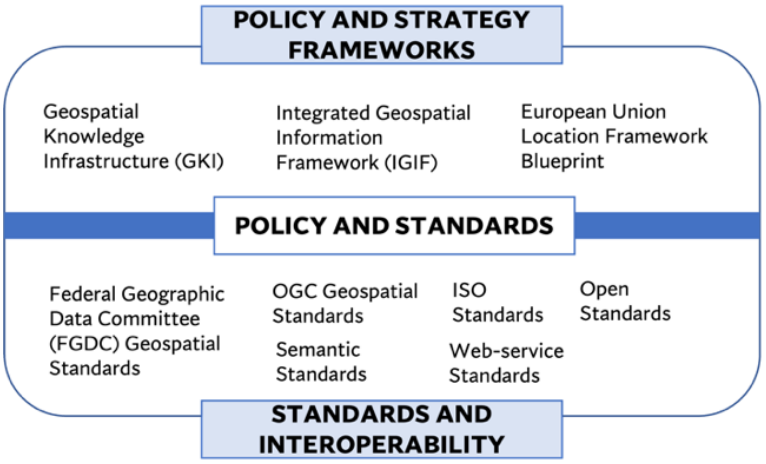
The rapid evolution of technology will lead to zillion bytes of raw and unstructured data collected every single day from the Technology ecosystem covered in section 2.3.3. Therefore, once data is collected from different sources, it's important for the raw data to be separated from the noise and to be structured further with specific usable characteristics. In the desired geospatial ecosystem, the data will be findable, accessible, available, reusable, and equitable. The data will also be secure, interoperable and maintain all the characteristics of data security and data sovereignty.

Figure 4: The Desired Geospatial Ecosystem: Network of Integrated Ecosystems of Ecosystems



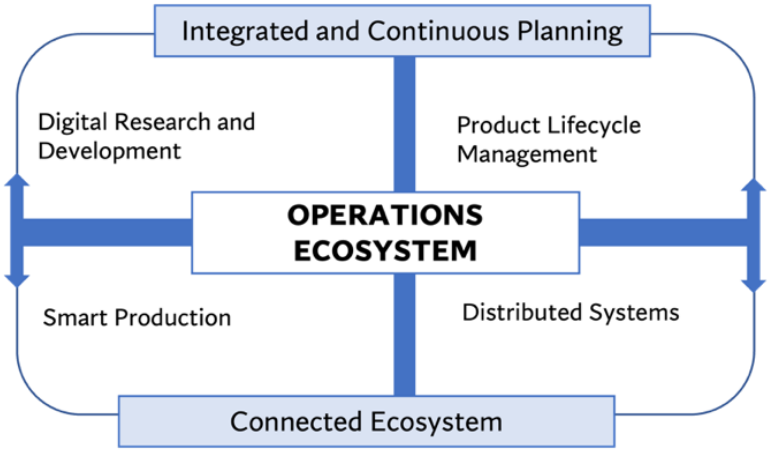
2.3.5 Policy and Standards Ecosystem

Policies and standards are critical to the development and implementation of the desired geospatial ecosystem. Frameworks such as GKI, IGIF and the European Union Location Framework Blueprint play a defining role in developing the desired geospatial ecosystem. Alternatively, standards defined by bodies such as FGDC, OGC, and ISO will continue being the commonly used geospatial standards to harmonize technical specifications, optimize operations and improve quality. Both policy and standards ecosystems will be critical for developing interoperability, and increasing the compatibility of components, products and services to make them decision-centric and impact-value centric to address sustainability of everything.



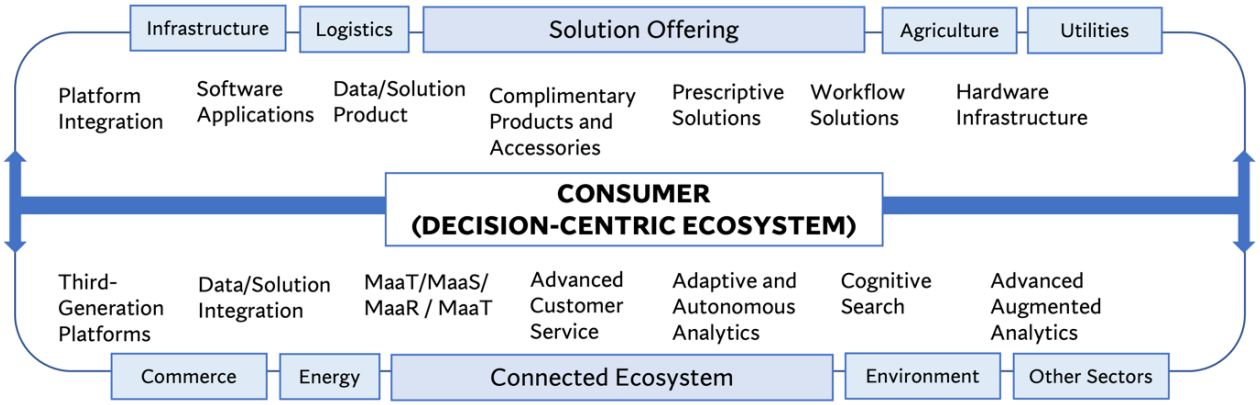
2.3.6 Operations Ecosystem

The rapid evolution in the technology ecosystem will also alter the operating environment of the existing geospatial ecosystem. The operating ecosystem of the desired geospatial ecosystem will evolve with integrated and continuous planning, and connectedness – focussing on digital research and development, product lifecycle management, smart production, and distributed systems. With these facets, the desired geospatial ecosystem will create an integrated applications environment in cloud which will be useful for the consumer and citizens to develop their products and services for creating high value-impact-centric outcomes.



2.3.7 Consumer Ecosystem

The consumer and citizen ecosystem are the most important pillar of the desired geospatial ecosystem, wherein different user sectors will dynamically interact with the other ecosystems, namely, technology, data, policy and standards, and operating environment to create advanced, connected, compatible, interoperable solution offerings. The consumer and citizen ecosystem will be interconnected with capabilities in platform integration, software applications, prescriptive solutions, workflow solutions, cognitive search, and advanced augmented analytics. All these capabilities will enable the consumers to develop products, services and solutions which will create value-impact for sustainability, and socio-economic-environment growth.



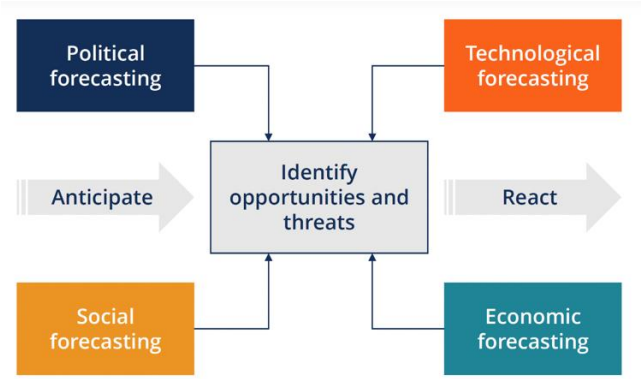
In conclusion, the desired geospatial ecosystem, therefore, should include an ecosystem of ecosystem approach where all ecosystems key for the geospatial players and for creating larger value and impact work in convergence with each other with bidirectional partnerships and collaborations. In summary, the desired ecosystem should have value and impact at its centre (or goal) with all stakeholders and all ecosystems working together to achieve sustainability of everything.

To adapt and develop the desired geospatial ecosystem, it is imperative for Members States to conduct a PEST analysis which prepares them to develop and enhance those attributes and parameters which would hamper their transition to the desired geospatial ecosystem.

3. PEST FRAMEWORK FOR ADOPTION AND ADAPTATION OF INTEGRATED GEOSPATIAL INFORMATION FRAMEWORK AND THE DESIRED GEOSPATIAL ECOSYSTEM

Countries wanting to adopt the IGIF framework, need to identify the emerging trends and directions of the geospatial ecosystem in their respective countries, and assess the potential impact of these trends on the development of their national geospatial ecosystem. However, the development of a national geospatial ecosystem, or the adoption and adaptation of the IGIF framework, depends significantly on the political, economic, social, and technological environment in the country. While the strategic framework is largely used by the business community to evaluate the external environment, countries are increasingly using the PEST analysis to benchmark the country's capabilities enabling the decision-makers of a country to take current and potential factors into consideration in order to anticipate opportunities and threats and create an action-oriented strategy.

Figure 5: PEST Framework: Definition by CFI's Business and Corporate Course



As part of this study a conceptual PEST model is developed – taking into consideration the factors, which particularly affect the national geospatial ecosystem development and the adaptation and implementation of integrated geospatial information management. Since the establishment of SDI's and NSDI's, geospatial information management has been under a constant evolution especially to integrate geospatial data which is available outside the traditional SDI's framework. With increasing availability of open data sources, and open source software, increasing sensor-data fusion capabilities for rapid innovation, and participatory approaches (citizens, government, business) to generate high-quality spatial data quality – there is a need for countries to appropriately assess the external environment which will enable them to leapfrog in the race to develop a dynamic desired geospatial ecosystem which will prepare them for the ubiquitous penetration of geospatial information and take benefits of the rapid advancements in the digital and geospatial ecosystem.

The following table developed thru secondary literature review and via interactions with geospatial technology providers aims to serve as an initial outline for the geospatial ecosystem stakeholders – and can be used likewise by decision-makers at country level, business organizations, academia and research groups, user organizations, to name a few enabling them to recognize and define the conducive environment for development of the desired geospatial ecosystem. The PEST framework presented below, also takes into consideration few key emerging trends listed in Table 1 to appropriately capture the macro environment for geospatial ecosystem development.

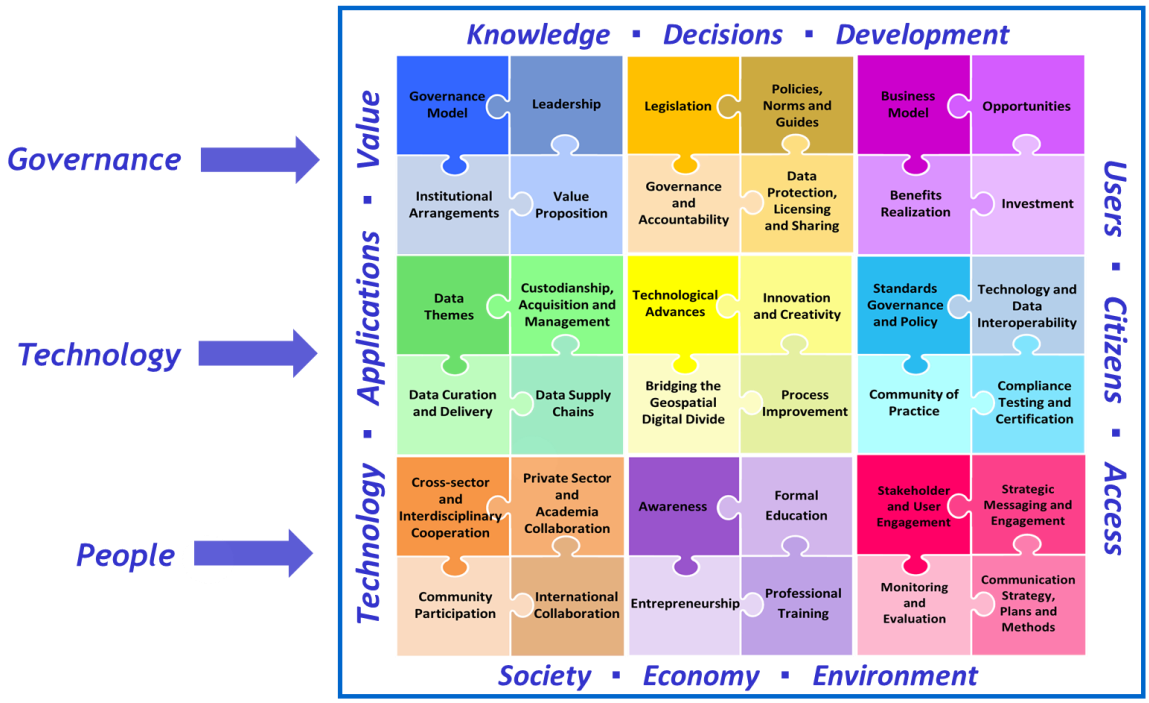
Table 3: PEST framework for macro-environment analysis of desired geospatial ecosystem development

Factors	Specific Queries
Political	• Government type and stability • Government willingness towards digital and geospatial technology enablement • Anticipate changes in the political environment (political environment) • Government funding, grants and initiatives for economic sectors and technology (digital and geospatial) adoption • Government policies and it's interconnectedness with international legislation trends (in technology domain) • Partnerships and Collaborations with international governments (inclusive of technology transfer policies, and trade policies) • War and Conflict situations (current and anticipated)
Economical	• Home economy situation and trends vis-à-vis international economies situation and trends • Impact of Globalization • Economic stability with respect to GDP, GVA, employment rates, Foreign Direct Investment (FDI), etc. • Business/Enterprise Directives / market and trade cycles • International trade/ monetary issues
Social	• Demographics • Law changes affecting social factors • Educational Capacity (computer and geospatial literacy)
Technological	• Pace of adoption of digital technology advancements (or emerging technologies) • Speed of technological transfer • Rate of technology obsolescence

	• Rate of Internet use and network coverage, i.e., broadband capacity • Indigenous technology (digital and geospatial) developments and innovations • Indigenous patents and licenses in digital and geospatial technology domain • Existing research and development activities (including funding) in IT and geospatial-related domains • Existing technology readiness and maturity across economic sectors • Standards and Interoperability frameworks for technology platforms • Enabling/supportive measures for the development and diffusion of digital and geospatial technology

The use of geospatial information has evolved in an unprecedented way, and today is largely driven by the socio-economic, and political characteristics of a country. In order to reduce the geospatial divide and enable countries to leapfrog and develop a dynamic geospatial knowledge infrastructure, the IGIF provides an enabling framework – with country-level action plans designed to help nations build and maintain their geospatial knowledge ecosystem. The IGIF framework provides an enabling framework for the nations via the nine strategic pathways and thirty-six key elements as shown in Figure 5. However, the IGIF, also established 135 guidance actions for implementation of which one of the tools to assist in completing the actions for strengthening the Geospatial Information Management is the PEST and SWOT analysis of a country. While the IGIF lays down a broad framework for Environmental Scanning as part of Activity 5 – Environmental Scanning, for a country's PEST analysis for geospatial information management, this report suggests a broader contour for the PEST analysis which can be used by countries to evaluate and monitor their countries' standing on the PEST parameters and to prioritize the strategic pathway basis the national priority, and national capability identified.

Figure 6: Nine Strategic Pathways and Thirty-Six Key Elements of IGIF



A broader contour of the PEST analysis for the development of the development of the desired geospatial ecosystem at a country level, takes into account the parameters listed in Table 1 and Table 2. The draft PEST framework – a conceptual model currently may be composed of the following execution plan – parameter by parameter.

3.1 Political Factors

To develop a sustainable national geospatial information ecosystem in a country, a willing, stable and supportive political environment is critical. For countries from across developed, and developing and particularly those from emerging countries, to leapfrog to develop a dynamic and knowledge-services oriented SDI which caters to the broader geospatial ecosystem of the country, the government and its associated stakeholders at both national, and international level play a critical role. Prior to adopting and implementing the IGIF action plan, the country's geospatial stakeholder ecosystem needs to assess the political factors which may impact – positively and negatively – the geospatial ecosystem of a country. Since the government plays a critical role in enhancing and driving the adoption of technology, openness of the country to adopt international ICT-related guidelines, partnerships and collaborations with international governments for technology transfer, and funding, grants and initiatives for economic sectors – it is imperative for the geospatial ecosystem to critically evaluate the maturity of the existing Political environment and anticipated in the country which will have an impact on the development of the desired geospatial ecosystem at a country level.

Table 4: Questionnaire for 'Political' Maturity Assessment for development of the desired geospatial ecosystem at a country level *

S. No	Proposed Questions for Political Maturity Assessment
1	What type of government does your country have? ☐ Democratic ☐ Monarchy ☐ Republic ☐ Dictatorship
2	**Do you define the government of your country to be stable?** ☐ Yes ☐ No **If yes, do you identify these on the basis of the following necessary conditions desirable to achieve stable governance (by United States Institute of Peace)** ☐ Provision of Essential Services ☐ Stewardship of State Resources ☐ Political Moderation and Accountability ☐ Civil Participation and Empowerment ☐ Any other_____ **If no, what is the reason for unstable government, please highlight** _____ _____ _____

	Do you anticipate a change in the government ecosystem in next 3-5 years? ☐ Yes ☐ No **Does the country anticipate any war/conflict like situation in the next 3-5 years?** ☐ Yes ☐ No
3	**Is your government an enabler and facilitator of adopting digital technology (including artificial intelligence, IoT, cloud, etc.) in your country?** ☐ Yes ☐ No **If yes, does the government endorse the adoption of geospatial technology as one of the key enablers** ☐ Yes ☐ No **If yes, what are some of the strategic measures undertaken by the government of your country to facilitate and enable a geospatial ecosystem –** ☐ Encourage and facilitate an enabling geospatial policy environment ☐ Enable geospatial industry development and enhance public-private partnership ☐ Encourage geospatial information and technology implementation in key economic sectors ☐ Strengthen technology adoption backed with strong political support ☐ Any other _____
4	**Does the government have long-term strategic vision plans in line with national priorities and Agenda 2030?** ☐ Yes ☐ No **If yes, does the government prioritize the value of ICT (including geospatial) adoption to fulfil the identified national priorities?** ☐ Yes ☐ No **If yes, does the government allocate specific funding for ICT adoption in the country to fulfil these national priorities?** ☐ Yes ☐ No

	If yes, does the government allocate specific grants for geospatial adoption and development of national geospatial information ecosystem with an intent to fulfil these national priorities? ☐ Yes ☐ No
5	**Is the political environment of your country supported by enabling ICT policies?** ☐ Yes ☐ No **If yes, which of the following ICT policies has the government pushed for –** ☐ Information, Communication and Technology Policy ☐ Science and Technology Policy ☐ Innovation Policy ☐ Roadmap for ICT implementation ☐ Any other_____ **Is the ICT policy open and interconnected with international legislation trends?** ☐ Yes ☐ No **Does the government endorse the geospatial policy/strategy/plan of the country actively? (can ignore in case of missing geospatial policy)** ☐ Yes ☐ No **If yes, is this endorsement at federal, state, and local level?** ☐ Yes ☐ No **If the answer to all the above questions is NO, what are the reasons for the same. Please mention** _____ _____
6	**Is the government collaborative in its approach with other national and international governments? (not specific domains)** ☐ Yes ☐ No **If yes, does this partnership and collaboration framework extend for technology cooperation and technology transfer?** ☐ Yes ☐ No

	If yes, are there any specific agreements in place for geospatial technology collaboration and knowledge transfer? ☐ Yes ☐ No **If yes, what are the specific outlines with regards to geospatial-related partnerships and collaboration particularly with international multi-lateral organizations and international governments.** _____ _____

**Questions can be expanded further to include trade interventions, employment interventions and can be expanded to include country-specific parameters for deeper analysis.*

As per the above draft questionnaire for the 'Political' Maturity Assessment in the PEST analysis as a tool for the development of a national geospatial information ecosystem, as more countries respond in 'Yes' to the above questions (as per the positive context defined), it shows the governments maturity in positively intervening in the economy to drive ICT and geospatial adoption and development of the desired geospatial ecosystem at a country level.

3.2 Economic Factors

Technology for economists is anything that can be produced faster, better and cheaper and can be sustained over a long period of time. The understanding of economic factors is critical to the development of a national geospatial information ecosystem for economic stability of a country often defined by the Gross Domestic Product (GDP) and the Gross Value-Added (GVA), employment rates, and Foreign Direct Investment, signify growing opportunities within a country's ecosystem. An evaluation of macro-economic factors, particularly is critical for it helps to identify the resources and capabilities of an economy, and help to design and derive effective ways to increase the national income, boost productivity, and upscale the economy in terms of monetary development. A vibrant macro-economic ecosystem of a country enables them to actively assess and evaluate the economic standing, and thereafter address the national priorities of the countries accordingly. While technology – ICT and geospatial is an economic growth driver – it is a major factor of growth development driven by professional skills, market and trade cycles, etc.

Table 5: Questionnaire for 'Economical' Maturity Assessment for development of the desired geospatial ecosystem at a country level *

S. No	Proposed Questions for Economical Maturity Assessment
1	**What type of economic system does your country follow?** ☐ Traditional economic system ☐ Command economic system ☐ Free-Market economic system ☐ Mixed System **To what extent does the government intervene in the economic ecosystem?** ☐ Drives the economic ecosystem ☐ Very much ☐ Moderate

	☐ Not much
2	**Is the economic ecosystem of your country stable?** ☐ Yes ☐ No **If yes, how do you fare with respect to GDP and GVA vis-à-vis world average (World Bank data)?** ☐ Very well ☐ Average ☐ Need to improve **Which is the area which contributes the most to GDP in your country?** ☐ Personal Consumption ☐ Business Investment ☐ Government Spending ☐ Net Exports **Is your country a primary (agriculture related), secondary (industry related) or a tertiary (services-related) country?** _____ _____ **What are the key economic goals of your country?** ☐ Price Stability ☐ Faster Economic Growth vis-à-vis Population Growth ☐ Low Unemployment Rates / Full Employment ☐ Equitable Distribution of Income and Wealth ☐ Efficiency and Productivity ☐ Economic Stability ☐ Any Other _____ **What are the key priority economic sectors for your country?** _____ _____ **Which of the five pillars of economic development critical for your country's economic growth?** ☐ Human Resource ☐ Natural Resource ☐ Capital Formation ☐ Technological Development ☐ Social and Political Development ☐ Any Other _____

3	**What is the current economic status of full employment in your country?** _____ **What is the current unemployment rate in your country?** _____ **What is the current employment rate in ICT and related fields?** _____ **What is the current employment rate in ICT and related fields in key economic sectors?** _____ **What is the current expenditure of your country's GDP on Research and Development?** _____
4	**Has there been a significant impact of globalization on your economy?** ☐ Yes ☐ No **If yes, which of the following are the positive impacts of globalization on your country?** ☐ Reduction in Cost of Manufacturing ☐ Availability of variety of quality products at lower price ☐ Increase in standard of living ☐ Increase in Foreign Direct Investment ☐ Increase in Employment Rate ☐ Increase in Technology Transfer ☐ Any other _____
5	**With respect to Market and Trade Cycles, where is your country positioned currently in the economic cycle curve –** ☐ Expansion ☐ Peak ☐ Contraction ☐ Trough **Do you see this change in the next 3 years?** ☐ Yes ☐ No **If yes, where would you think your country will be positioned in the economic cycle curve (use sources like IMF for forecast)?** ☐ Expansion ☐ Peak ☐ Contraction ☐ Trough

6	**Where do you rank in the Ease of Doing Business Ranking for your country (World Bank)?** _____ _____ **Which of the parameters does your country perform well in Ease of Doing Business Ranking?** ☐ Starting a Business ☐ Dealing with Construction Permits ☐ Property Registration ☐ Electricity Availability ☐ Credit Availability ☐ Protecting Minority Investors ☐ Paying Taxes ☐ Trading across Borders ☐ Contracts Enforcement ☐ Resolving Insolvency **Are there steps taken by your government to improve the Ease of Doing Business Ranking in order to improve the Business Economics of the country?** ☐ Yes ☐ No **If yes, please Elaborate** _____ _____
7	**Does your country has a high trade deficit?** ☐ Yes ☐ No **Does your country import or export technology as part of international trade?** ☐ Export ☐ Import **How is your country involved in export/imports of technology trade?** ☐ Trade in information technology services ☐ Trade in information technology hardware ☐ Trade in information technology software **Are there any specific guidelines with respect to trade related to intellectual property rights and patented licensed technology?** ☐ Yes ☐ No

	What is the percentage of high-technology trade as percentage of total international trade in your country? _____ _____

**Questions can be expanded further to include trade interventions, employment interventions and can be expanded to include country-specific parameters for deeper analysis.*

As per the above draft questionnaire for the 'Economic' Maturity Assessment in the PEST analysis as a tool for the development of the desired geospatial ecosystem at a country level, countries which are at the peak of economic transformation have much more ability to make investments in ICT adoption for the economic development of their country. The interlinkage and the connectedness among the political and economic factors are key and will help countries to adequately identify the economic priorities of their country and take strategic steps across the board including ICT and geospatial technology adoption to address the key national priorities. The two questionnaires developed when conducted within the ecosystem are self-validating and aim to present an accurate picture of the economic factors driving a country's development, and thus, it's implementation of IGIF in the future.

3.3 Social Factors

Social Factors in the PEST analysis includes the changing demographics (age, gender, race, family size); consumer attitudes and buying patterns, population growth rate, employment patterns, cultural changes, educational skills to name a few. While these factors do not have a direct impact on the development of a national geospatial information ecosystem; factors such as demographics and educational capacity (computer and geospatial literacy), population growth rate and employment patterns have a crucial role to play in being decisive about the strategic priority of the country with respect to IGIF implementation.

Table 6: Questionnaire for 'Social' Maturity Assessment for development of the desired geospatial ecosystem at a country level *

S. No	Proposed Questions for Social Maturity Assessment
1	**What is the demographic profile of your country?** ☐ Media Age_____ ☐ Population Growth Rate _____ ☐ Dependency Ratio_____ ☐ Net Migration Rate_____ ☐ Population Distribution _____ ☐ Urbanization_____ ☐ Sex Ratio_____ ☐ Health Expenditures_____ ☐ Literacy Rate_____ ☐ Education Expenditures _____ ☐ School-Life Expectancy _____
2	**What is the current spend on ICT or digital literacy as a percentage of GDP in your country?** _____ _____

What is the current ICT or digital literacy rate in your country?

_____

_____

How would you rate on an average the ICT literacy level in your country?

- ☐ Below Basic
- ☐ Basic
- ☐ Average
- ☐ Excellent

What is the current spend on Geospatial Literacy as a percentage of GDP in your country?

_____

_____

What is the current Geospatial Literacy rate in your country?

_____

_____

How would you rate on an average the Geospatial literacy level in your country?

- ☐ Below Basic
- ☐ Basic
- ☐ Average
- ☐ Excellent

What is the net migration rate for ICT and Geospatial skilled professionals?

_____

_____

**Questions can be expanded further for country specific parameters*

As per the above draft questionnaire for the 'Social' Maturity Assessment in the PEST analysis as a tool for the development of the desired geospatial ecosystem at a country level, the impact of demographics is critical to the faster adoption of the digital technology advancements. For instance, country with a young population is expected to adopt to latest technology innovations in the field of artificial intelligence, big data, internet of things, etc., then a country with aging population. Alternatively, the ICT and digital literacy levels and geospatial literacy levels play a critical role as well with respect to adoption and understanding of technology for broader implementation. A country with higher geospatial literacy levels and wherein significant percentage of GDP is spent on technology (inclusive of geospatial) literacy, will be better positioned to leverage the nine strategic pathways and its implementation. Alternatively, if the net migration rate of ICT and geospatial skilled professionals is on the high – it may signify lack of significant growing opportunities in the domestic country, which would require the country to prioritize focus on geospatial implementation. Therefore, social factors can play an influential role in helping the decision makers decide which strategic pathway to prioritize for the development of the desired geospatial ecosystem at a country level.

3.4 Technological Factors

From a geospatial perspective, the technological factor in the PEST analysis is the most critical. The technological factor – not limited to geospatial – but to overall ICT and digital technology covers key aspects of technology evolution in a country ranging from its broadband capacity to the pace of adoption of digital technology advancements to suitability and sustainability analysis of technology to finally standards and interoperability frameworks for appropriate deployment and diffusion of technology in the country for its national priorities. In addition, this parameter also addresses the indigienous capabilities within the country focussing on innovation, SME development, and research development. Together, with the political, economic and social factors, the various variables of the technology factor which relate to the existence, availability and development of technology is critical for the utilization of geospatial data and information; and for the development of national geospatial information ecosystem. Without positive technology variables, a country will not be able to make significant advancements in developing a dynamic and futuristic national geospatial information ecosystem and nor be able to bridge the geospatial divide.

Table 7: Questionnaire for 'Technological' Maturity Assessment for the development of the desired geospatial ecosystem at a country level*

S. No	Proposed Questions for Technological Maturity Assessment
1	**In the Technology Adoption Curve, where does your country stand?** ☐ Innovators ☐ Early Adopters ☐ Early Majority ☐ Late Majority ☐ Laggards What is the technology adoption rate in your country? _____ _____
2	**Are you aware about the 4th industrial revolution?** ☐ Yes ☐ No **What is the pace of adoption of the following technologies in your country; Mention as Fast, medium and slow?** ☐ Artificial Intelligence ☐ Internet of Things (IoT) ☐ Cloud ☐ Big Data ☐ Genetic Engineering ☐ Quantum Computing ☐ Drones ☐ Robotics ☐ Building Information Modelling (BIM) ☐ Digital Twin ☐ Augmented Reality (AR) /Virtual Reality (VR) /Extended Reality (XR)

	☐ Metaverse ☐ Blockchain ☐ 5G and Beyond ☐ 3D Printing ☐ Assured Positioning, Navigation, and Timing Solutions ☐ Any other
3	**What is the speed of technology transfer in your country across sectors, organizations, etc.?** ☐ High ☐ Medium ☐ Low **What are the different types of technology transfers in your country?** ☐ General Knowledge (Services) ☐ Specific Knowledge (skill-based) ☐ Hardware ☐ Behaviours **How fast does technology become obsolete in your country?** ☐ 14 to 18 months ☐ 3 to 5 years ☐ Beyond 5 years
4	**What is the broadband penetration rate in your country?** _____ **What is the average internet usage rate in your country?** _____ **What is the bandwidth and data transmission rate in telecommunications in your country?** _____ **Is 5G a reality in your country?** ☐ Yes ☐ No **If not, by when do you think will 5G be a reality for your country?** _____
5	**Does your country have organizations with technology innovations capabilities?** ☐ Yes ☐ No

	If yes, are these technology innovations in the field of digital technology advancements such as AI, Cloud, Big Data, 5G, etc? ☐ Yes ☐ No **Does some of these innovations fall in the following categories – Mark as yes/No** ☐ Cloud-native applications ☐ Internet of Things ☐ Autonomous Driving ☐ Drone applications ☐ Smart Grid ☐ Any other **What is the number of patents or IPRs issued for innovation in geospatial technology in your country over the last 3 years?** _____ **Are there organizations innovating in the field of geospatial in your country?** ☐ Yes ☐ No **Please mark in which field of geospatial are these innovations taking place –** ☐ Earth Observation (satellites, Drones) ☐ GNSS and Positioning (Navigation and Positioning Capabilities) ☐ Scanning Tools (LiDAR, RADAR, GPR) ☐ GIS and Spatial Analytics (visualization, analysis, application development) ☐ Any other _____ **What is the number of patents or IPRs issued for innovation in geospatial technology in your country over the last 3 years?** _____
6	**Are there any specific research grants for ICT related innovations and technology development?** ☐ Yes ☐ No **If yes, on an average what is the value of these grants and what is the time period associated with them?** _____

	Is the government funding specific research and development innovations in the field of ICT through strategic reforms? ☐ Yes ☐ No **If yes, please highlight the focus areas of the research and development innovation programs?** _____ **Are there any specific research grants for geospatial related innovations and technology development?** ☐ Yes ☐ No **If yes, on an average what is the value of these grants and what is the time period associated with them?** _____ **Is the government funding specific research and development innovations in the field of geospatial through strategic reforms?** ☐ Yes ☐ No **If yes, please highlight the focus areas of the research and development innovation programs?** _____ **Are there steps taken to promote innovations in ICT and geospatial from SMEs in the country for economic development?** ☐ Yes ☐ No **Which of the following steps are taken to build a competitive business environment to aid technology innovation and development?** ☐ Investments and Seed Funding ☐ Strengthening Stronger Alliances between large and small players for technology transfer, test bedding and commercialization ☐ Providing strategic incentives for companies to develop innovative products and services ☐ Enhancing access to human capital, by broadening the scope of internship programs and creating network opportunities.
7	**What is the ICT readiness in your country?** ☐ High ☐ Medium ☐ Low

	What is the ICT maturity across key economic sectors? Rank high, medium, low for sectors identified in Table 4 on Economic priorities ☐ High ☐ Medium ☐ Low **What is the geospatial readiness of your country?** ☐ High ☐ Medium ☐ Low **What is the geospatial maturity across key economic sectors? Rank high, medium, low for sectors identified in Table 4 on Economic priorities** ☐ High ☐ Medium ☐ Low **Are organizations in your country able to cater to the changing user expectations to knowledge-based solutions and services?** ☐ Yes ☐ No **Are there steps being taken to ensure changing user demands with respect to data and knowledge is met?** ☐ Yes ☐ No
8	**Does your country have established frameworks for standards and interoperability for technology platforms?** ☐ Yes ☐ No **If yes, are the standards and interoperability frameworks aligned with international standards?** ☐ Yes ☐ No **Are there specific frameworks for standards and interoperability for geospatial data, and geospatial data platforms?** ☐ Yes ☐ No

	If yes, what is the implementation rate of these frameworks? ☐ High ☐ Medium ☐ Low
9	**Are there existing enabling/supportive policy measures for the development and diffusion of ICT technology?** ☐ Yes ☐ No **Are there existing enabling/supportive policy measures for the development and diffusion of geospatial technology?** ☐ Yes ☐ No

**Questions can be expanded further for country specific parameters*

As per the above draft questionnaire for the 'Technological' Maturity Assessment in the PEST analysis as a tool for the development of a national geospatial information ecosystem, the impact of technology factors such as broadband penetration, supportive policy measures, research and grants for R&D and innovation, steps taken to meet the changing user expectations, are few of the factors which can define a roadmap for a country to identify its priorities with respect to technology evolution. A positive response to all questions – is self-validating and would signify that a country which is technology ready has a better chance to leapfrog into building a dynamic future knowledge-oriented ecosystem as compared to a country which faces challenges at technology innovation and implementation level. Therefore, a thorough assessment of technology variables is critical to defining and identifying the focus of a country to develop and implement the national geospatial information ecosystem.

4. CONCLUSION

In conclusion for a country to adequately transform itself from traditional SDI's and NSDI's, and shift from data to knowledge – in the geospatial context, while adopting IGIF as a framework or a tool to achieve the vision of a future geospatial ecosystem, an identification of emerging trends is critical. Digital technology advancements, reinventing the business model wheel, evolution of federal geospatial data providers, changing user expectations and requirements, standards and interoperability frameworks, etc., are few of the emerging trends which are going to pave way for the next generation of geospatial information ecosystem. These trends have the ability to help emerging countries who are still at the nascent stage of SDI and NSDI development to leapfrog, bridge the digital and geospatial divide and build a geospatial infrastructure which is dynamic, and futuristic. The desired geospatial ecosystem will expand beyond the realms of consumer demand and will be decision-centric with value-impact at the centre of the ecosystem. The actors/stakeholders in the desired geospatial ecosystem will demand decisions, prescriptive analysis and will develop cross-linkages across each other ecosystems enabled by enabling policy and strategy frameworks, and standards. An integrated ecosystem of ecosystem approach will be critical and will define the holistic view of the desired geospatial ecosystem.

However, this cannot be done without a thorough assessment of the country's political, economic, social and technological (PEST) environment assessment. An environment scanning – as defined in Activity 5 of the IGIF, is necessary for countries to first identify the existing capabilities and variable driving the geospatial information and technology implementation. A PEST analysis (based on the above questionnaires) is aimed at providing countries a framework to self-evaluate their environment, and make informed decisions with respect to their choice of the strategic pathway, and the next action items to develop the desired geospatial ecosystem.

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