Report 2021

GEOSPATIAL INDUSTRY ADVANCING SUSTAINABLE DEVELOPMENT GOALS

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Prepared by

GEOSPATIAL WORLD
ADVANCING KNOWLEDGE FOR SUSTAINABILITY

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FOREWORD

Geospatial Value Impact for 'Sustainability of Everything' through Technology Innovations, Collaborative Workflows, Public Policies, and Partnerships

'Sustainability' is likely to take centre stage as the world prepares to recover post-COVID-19 - an incident that brought forward the cruelty of economic disparities and self-centred human nature. While it is noteworthy that the past 75 years have been the most peaceful in the history of humankind, witnessing a greater degree of deliberations and collaborations towards an inclusive and sustainable society; it is equally important to acknowledge that there has been no significant evidence of international cooperation in dealing with COVID-19.

Further, while OECD countries driven by a knowledge economy adjusted well to the new normal of work from anywhere; developing countries driven by manufacturing and having limited digital infrastructure were forced to lose their livelihoods. Moreover, developed countries provided an economic stimulus to boost economies and retain jobs, but, unfortunately, that hasn't been the case in the rest of the world, eventually causing severe economic impacts in developing countries. Moving forward, the path and pace of economic recovery would find traction mainly in developed countries, further widening the socio-economic divide.

The next few years will be a 'testing time' for international institutions and development organizations to stay focused and bring back the topic of 'sustainability on the priority of global debate. There is no doubt, its likely to be an 'Herculean Ask' to mobilize resources and partnerships towards supporting developing countries; however, that's not going to be a 'choice' anymore but a 'must do' to preserve global peace and economic parity.

Pandemic has few positives too, and growing relevance and value of 'geospatial knowledge' is one amongst, and has been consistently demonstrated and recognized across the entire gamut of leadership. COVID-19 pushed humans, without any choice, in the digital age; and geospatial information infrastructure and services played a key role in empowering digital workflows across almost every walk of living. Further, knowledge-driven economies will continue to harness value of geospatial and digital tools not only in managing COVID-19 but also recovery programs.

Given the role of technology innovation (4IR) and geospatial infrastructure in socio-economic development, and the acute need, especially for developing countries, to leapfrog in the development journey, it is imperative to invest in developing robust geospatial knowledge infrastructure and its integration with domain workflows of major economic industries, - enhancing productivity, efficiency, and cost-effectiveness as important instruments of 'sustainability of everything'.

Having a peep across public policy debates in the past two years, I feel excited that domains of geospatial and location have gained momentum worldwide. While there has been concerns about privacy issues and ethics associated with location data, the aggregate outcome has been in form of policy reforms towards adoption of technology innovations, open and linked data platforms, integration of data eco-systems and standards, and knowledge services interface in partnership with social and commercial entities.

The need of the hour is, thus, to work together to strengthen geospatial infrastructure at local, national, regional, and global levels and harness the potential of geospatial knowledge services by developing innovative, effective, and scalable solutions to address sustainable development goals (SDGs). Recognizing the critical role of national geospatial agencies, the commercial sector and user industries in this noble movement, it is time to develop a conducive environment for public-private partnerships between government agencies, geospatial companies, and extensive user-specific business enterprises.

Sanjay Kumar
Chair – UNGGIM PSN & CEO, Geospatial World

1. INTRODUCTION

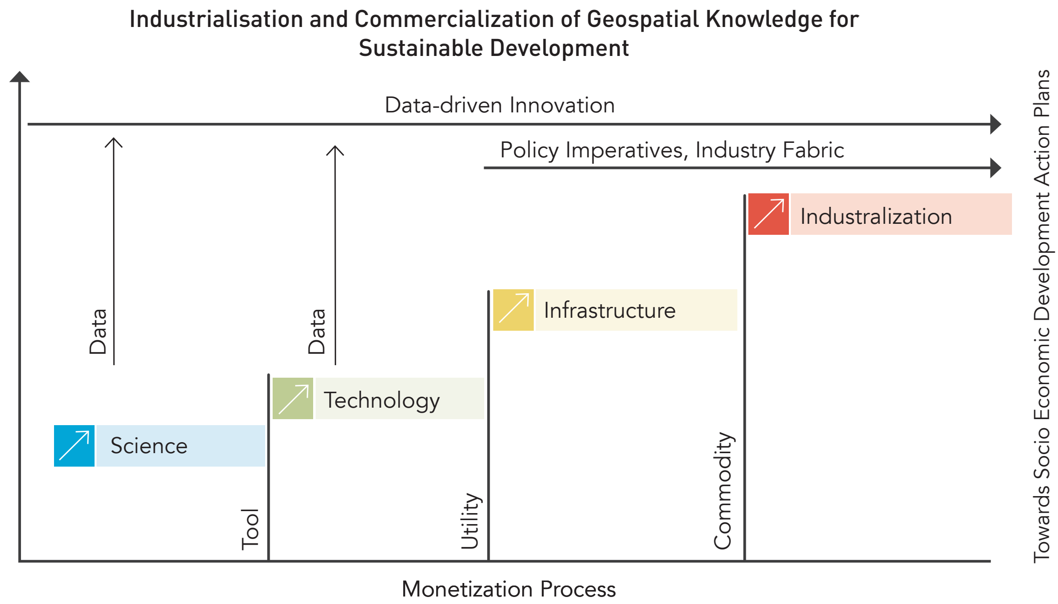
Over the past decade, the world economy and society have been under acute pressure from major economic, political, and environmental changes owing to the on-going pandemic, political unrests and climate change disruptions . Today, technology-driven interventions and innovations lead to dynamic cross-linkages, challenging the political, economic, and social models of the 21st century and improving workflow efficiency and productivity in all socio-economic sectors. All stakeholders involved in a country's socio-economic ecosystem, including government organizations, user organizations, civil society organizations, and academia and research organizations, facilitate technology embedment and adoption in varied sustainable economic development action plans. There is no doubt that the role of technology continues to evolve as more and more people recognize and realize its value.

The era of technological progress is characterized by innovations, the rapid application of which causes an abrupt change in society.

The era of technological progress is characterized by innovations, the rapid application of which causes abrupt changes in society. The importance of innovation in the socio-economic growth of a country, particularly in today's digital age, cannot be emphasized enough. Innovation is key to solving the world's most critical problems and, in most cases, brings positive changes from both micro and macro perspectives.

An important tool that enables the advancement of technology innovations is digitalization. In several economic sectors, digitalization has helped the world move from analog to digital processes. The role of data – both spatial and non-spatial and, derived from different sources is adding to this fast-changing technology environment. Thus, in the context of the 'data economy' and the Fourth Industrial Revolution (4IR), data-driven innovations (DDI) are increasingly becoming critical to resolving collective problems most sustainably and efficiently. This has led to improved human capabilities, better utilization of assets and resources and enhanced the capacity of society to act responsibly. Investments in research and development (R&D) activities that are driven by data, lead to technology and market innovations and drive global technology trends, which significantly impact the world economy and society. Data-driven innovations result in economic growth, increased well-being, and socio-economic and environmental sustainability.

While innovation is critical for development, the role of public policies is often underplayed. Public policies encourage innovation, increase government funding for R&D, provide tax credits and benefits to entrepreneurs, and guarantee intellectual property rights quickly. Today, when data has been re-coined as the 'new oil' of economic growth, policymakers worldwide are increasingly recognizing and realizing its potential contribution to socio-economic development, improved efficiency and productivity, and enhanced well-being. Public policies supporting data-driven innovation can enlarge the market size and increase the degree of commercialization and democratization in the market. Today, numerous public policy initiatives in information and communication technology, space technology, and Digital Twin spur innovation for welfare and productivity.



Source: Policy Imperatives for Data Economy Report, WGIC

At the core of the 'data-driven innovation revolution' is geospatial infrastructure – a foundational and enabling pillar of the data ecosystem that encompasses data, technology, policy, and people. Keeping this in mind, the UNGGIM Private Sector Network is submitting this report: ***Geospatial industry advancing sustainable development goals***. The report highlights the role of geospatial infrastructure in 4IR, which lead to geospatial-enabled innovations such as Digital Twin. The report also hightlights on the value-impact of a dynamic geospatial infrastructure in the world's socio-economic sectors, mainly focusing on achieving the United Nations' 2030 agenda for sustainable development. The report, concludes with a set of key recommendations for the critical stakeholders of the geospatial ecosystem to facilitate the diffusion of geospatial infrastructure, that is, data and information and advance geospatial technological progress, globally.

1.1. Data Economy and Data-Driven Innovation

1.1.1 Data Economy

The data economy, comprising both spatial and non-spatial data, is recognized as the most valuable asset to stimulate economic growth, foster research and innovation, and accelerate socio-economic benefits.

The strategic value and the viability of data, and its growing relevance in today's digital age, is being recognized worldwide. In the 21st century, the ***data economy***, comprising both spatial and non-spatial data, is recognized as the most valuable asset to stimulate economic growth, foster research and innovation, and accelerate socio-economic benefits, helping unlock approximately USD 5.4 trillion annually in economic value. Today, the data economy enhances the capabilities of governments, organizations, user departments, and citizens to leverage big data and analytics to derive strategic insights, improve operational efficiencies, develop innovative business models, drive revenue growth, and achieve sustainability of everything.

The concept of the data economy relies on the idea that 'information creates economic value', which is based on harnessing data for decision-making and

Key Characteristics of Data Economy

1	**EXPLOSION** in collection and dissemination of granular level spatial, non-spatial and personal data.
2	**INCREASED** use of value-based situational, contextual, historical, temporal, and spatial context data, metadata and derived data.
3	**INCREASED** data sharing at organizational, enterprise and government levels to derive databased insights to create high returns and contribute to economic growth.
4	**REFORMULATION** of existing economic models, and policy frameworks governing data.
5	**ACCELERATED** use of Artificial Intelligence, Machine Learning and Big Data Analytics to industrialize learning.

Source: Geospatial World Analysis

creating new products and services for higher value impact across socio-economic sectors. Additionally, as government authorities and decision-makers grasp the shifting realities of the decision-making process due to use of data, public policy and innovation too are going to evolve accordingly.

Statistically, data-fueled applications will create an additional value of approximately USD 13 trillion in new global economy activity by 2030. The International Data Corporation's (IDC's) annual DataSphere and StorageSphere reports estimate that in 2020, 64.2 ZB of data was created or replicated, defying the systemic pressure asserted by the Covid-19 pandemic. The report also estimates that global data creation and replication will grow at a CAGR of 23% over the period 2020-2025, owing to Internet of Things (IoT) data, data created in Cloud systems, Edge Computing and geospatial technologies.

From a country perspective, data added upto USD 1.1 trillion to the United States economy in 2018. Additionally, as per the fact sheet of European Data Strategy, the European Commission estimates that the net worth of the European Union's

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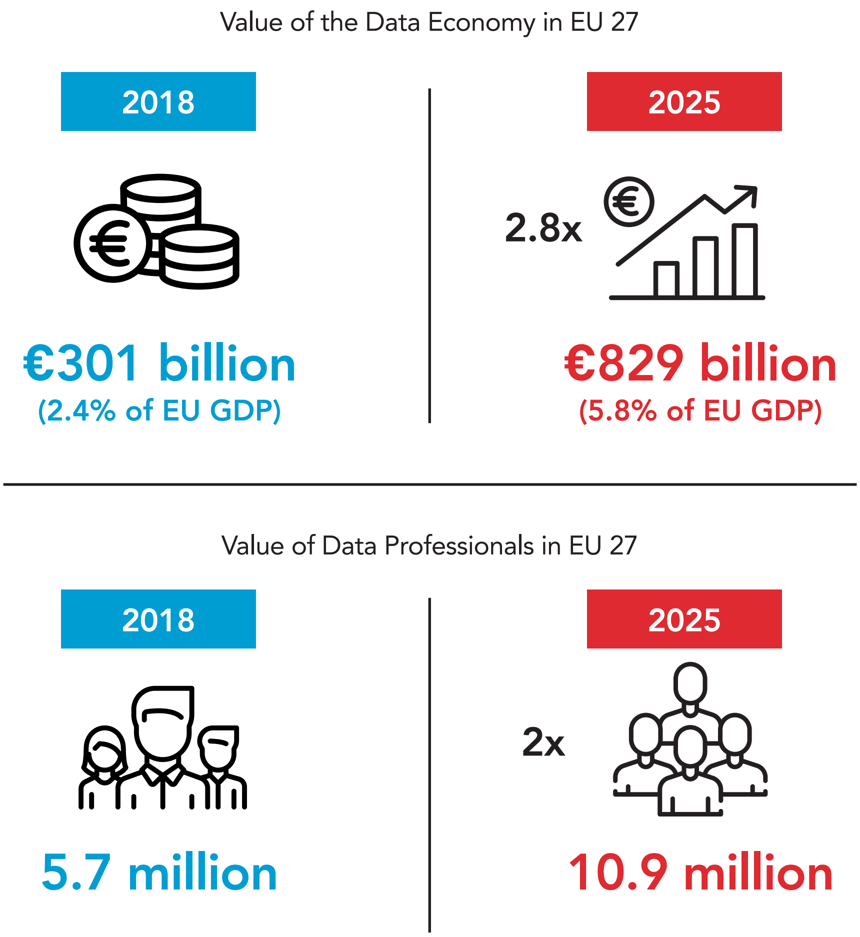
data economy will rise from 2-6% of GDP in the next seven years. The value of the data economy is estimated to rise from EUR 301 billion in 2018 to EUR 829 billion in 2025, while the number of data professionals is going to increase by 2x, that is, from 5.7 million in 2018 to 10.9 million in 2025.

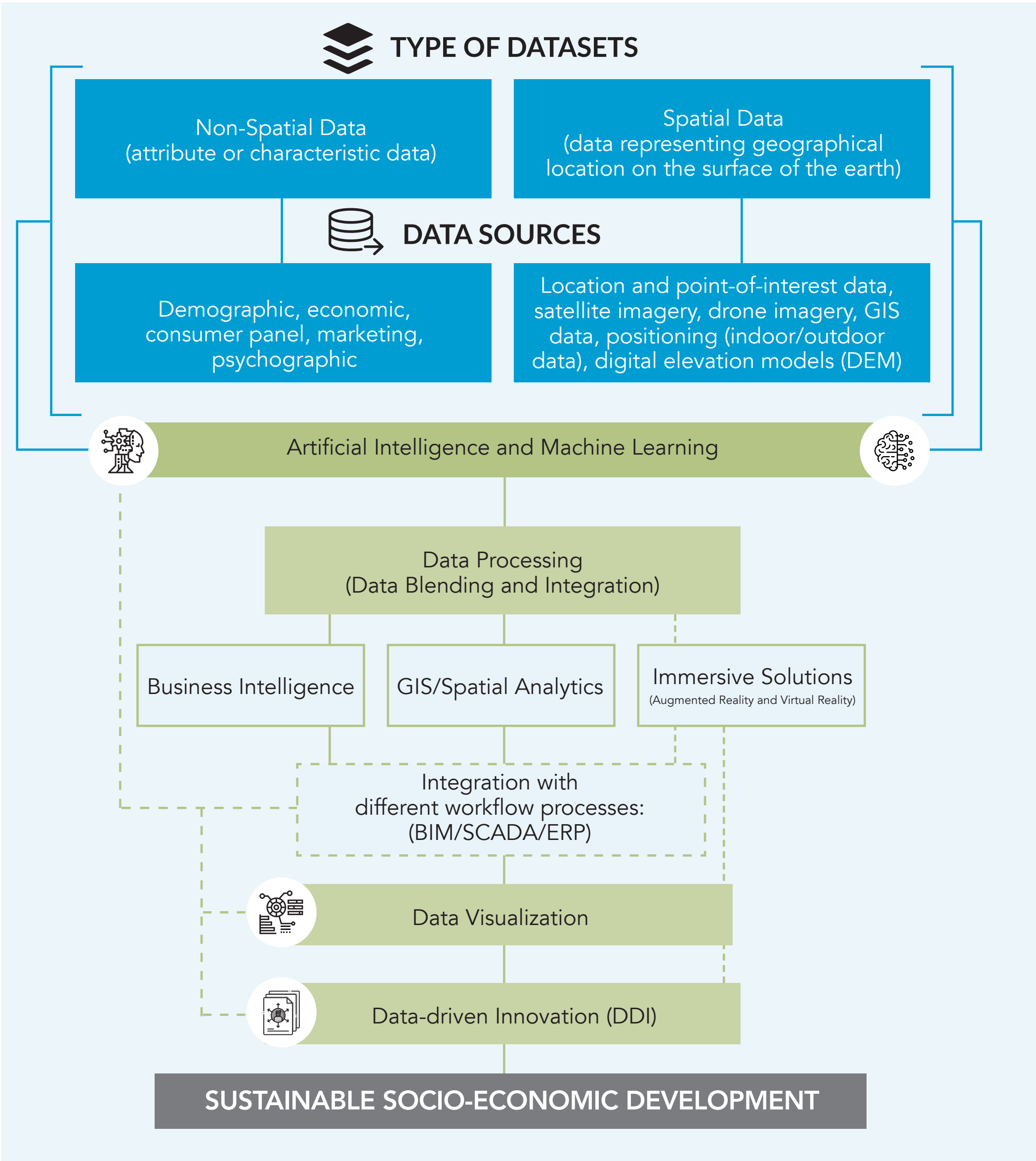


Source: Factsheet - European Data Strategy by European Commission

1.1.2 Data-Driven Innovation

There is no doubt that the data economy will stimulate research and innovation based on data, leading to new innovations, more business opportunities, increased availability of knowledge and capital, that will collectively help solve global challenges. In this context, innovations born out of trends and correlations of different type of datasets (spatial and non-spatial), commonly known as ***data-driven innovations (DDI)*** in the technology space, are critical to solving the development strategies of the 21st century and acting as a catalyst for enhancing growth, innovation and productivity gains.

Data-Driven Innovation for Sustainable Socio-economic Development



Source: Geospatial World Analysis

Currently, there is no limit to the data available worldwide, that is, Big Data, such as, non-spatial data inclusive of data collected from social media sources, audience polls and marketing, and demographic and economic data; and spatial data captured from geospatial tools and technologies and sensor networks. The proper and effective analysis of the interactions, patterns and inconsistencies of Big Data sets by 4IR technologies drives new innovations and dynamic products. In particular, new and emerging technologies such as Blockchain, IoT, Artificial Intelligence (AI) and Machine Learning (ML) provide great opportunities for organizations to innovate and develop solutions to address the various challenges identified in the Sustainable Development Goals (SDGs) and for socio-economic prosperity.

2. THE GEOSPATIAL CONTEXT

The Fourth Industrial Revolution (4IR), a fusion of advances in AI, Cloud, Robotics, IoT Sensors, Blockchain, 3D Printing, Quantum Computing, and other technologies, is blurring the lines between the physical, digital and biological worlds and leading to frontier technology innovations. According to the World Economic Forum (WEF), 4IR is ***"more than just technology-driven change; it is an opportunity for everyone to harness converging technologies to create an inclusive human-centred future."*** At the core of this revolution lies ***Geospatial Infrastructure.***

2.1 Geospatial Infrastructure in Fourth Industrial Revolution

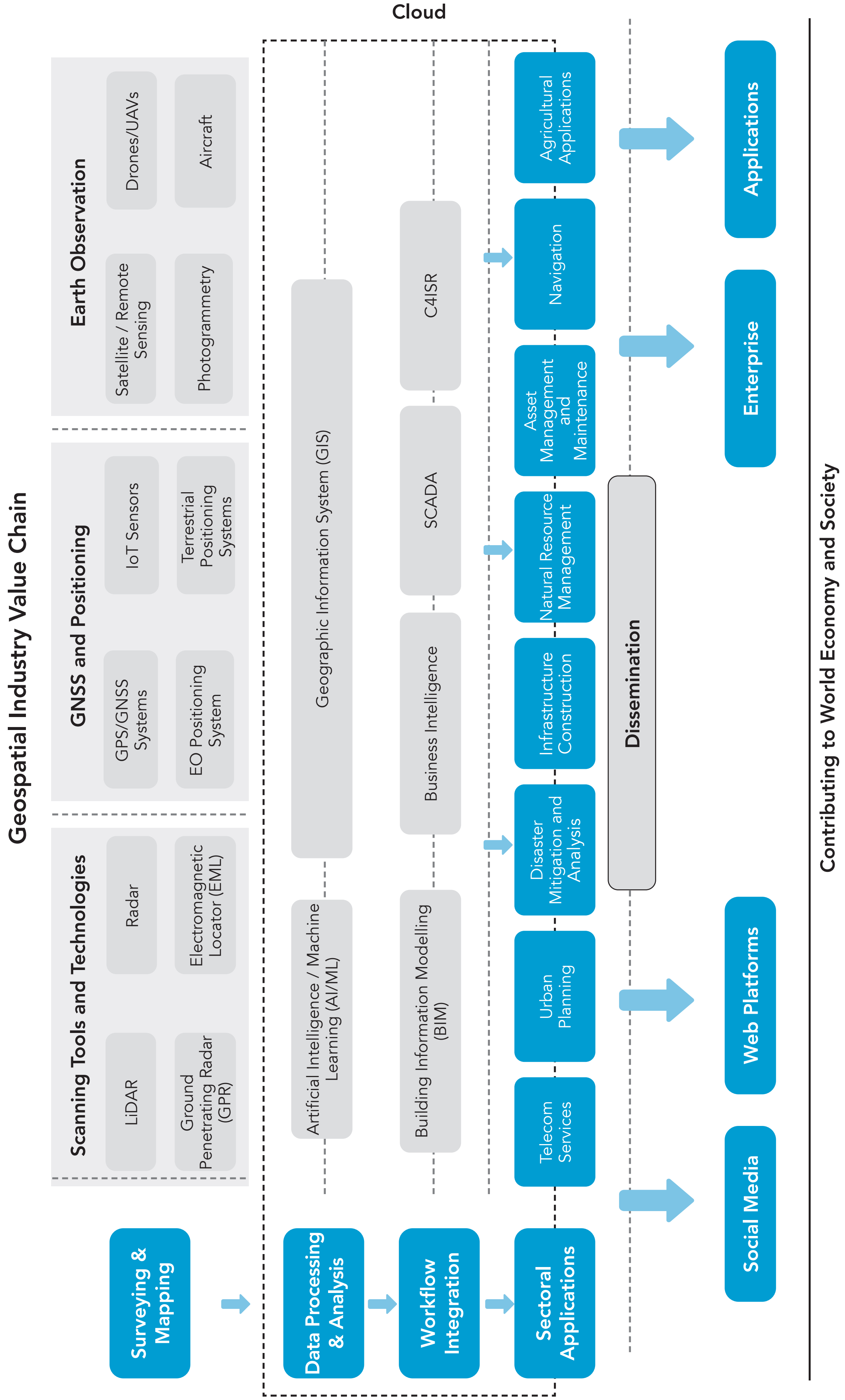
In today's digital context, to make strategic decisions, the cross linkage between non-spatial, spatial and locational dimensions is critical. In the present era of 4IR, geospatial infrastructure is a foundational and enabling pillar of the data ecosystem. The geospatial infrastructure of a country encompasses data, technology, policy, and people – to ensure the smooth provision and use of geospatial data and services to develop a more holistic understanding of the future. Geospatial infrastructure integrates data and information, old and new technologies, people, processes, and social and organizational elements of the much larger digital infrastructure ecosystem, with 'location' as a common reference frame. Additionally, geospatial infrastructure provides the cognition for data and knowledge-driven innovation across government systems and services and other national development initiatives. Thus, geospatial infrastructure is a geospatial nervous system – enabling stakeholders to make the right decisions at the right time for an appropriate and strategic action plan.

From a technology perspective, globally, there are many definitions of geospatial technology. For this report, the definition of geospatial technologies is that provided by Geospatial World, wherein geospatial technology is defined as a complex technology entity of multiple interactive components, inclusive of geospatial data sourced from various technologies and broadly segmented into four key categories – GNSS and Positioning, GIS and Spatial Analytics, Earth Observation (satellite, aerial and street imagery), and Scanning Technologies (LiDAR, RADAR).

Geospatial infrastructure is a geospatial nervous system - enabling stakeholders to make the right decisions at the right time for an appropriate and strategic action plan.

2.1.1 Geospatial Industry Trends and Innovations

As digitalization picks up pace, the geospatial industry too is witnessing a revolution that is transforming the way geospatial technologies evolve. Over the last few years, the geospatial industry has increasingly been propelled by new technology trends in the market that are driving new geospatial development. These technology trends are further accelerating geospatial-enabled innovation processes, advancing geospatial technology innovation beyond multinational corporations and government-funded research labs to small- and medium-size enterprises. These

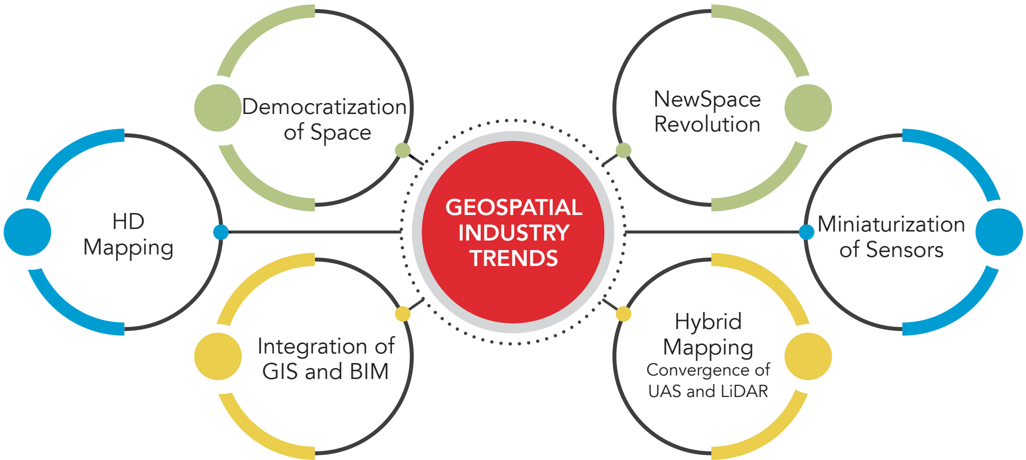


Source: Geospatial World Analysis

trends, as we know today, are having a huge impact, causing big disruptions, and creating opportunities in the geospatial industry. The geospatial industry is thus well-placed to leverage the rapid pace of technology evolution and disruptions, which can be used for socio-economic growth.

2.1.1.1 Geospatial Industry Trends

Geospatial Industry Trends



Source: Geospatial World Analysis

1. Democratization of Space: This is a key emerging trend in the space ecosystem, wherein essentially more people and/or organizations are participating in the space industry. This also means that 'outer space' is not just accessible to developed countries and large multinational organizations but also to developing countries, start-ups, universities, and even high schools. Since funding is now available for research and development, new business models for launching rockets, innovative satellite manufacturing processes, and miniaturization of satellites, setting up a space program is not a challenge anymore and is 'democratized' for a larger stakeholder ecosystem.

2. NewSpace Revolution: The emergence of private industries in the spaceflight industry largely illustrates the NewSpace economy. Specifically, with the emergence of relatively new aerospace companies like SpaceX, Spaceflight, Virgin Galactic, etc., who offer low-cost access to space, the NewSpace industry is attracting a lot of interest and, thus, investment. Additionally, in the Earth Observation space – companies like Capella Space, ICEYE, and Synspective are revolutionizing the Earth Observation ecosystem as a whole.

3. HD Mapping: At the core of technology innovations like autonomous vehicles, smart cities, and urban development, lie high-definition maps. These high-precision navigational maps showcase location at a centimeter scale and provide detailed information such as lane placement, road boundaries, and the severity of curves, among other things. Geospatial data and information are prerequisites for developing such maps and, therefore, the increasing demand for HD Maps is met by using comprehensive geospatial mapping tools such as LiDAR and Remote Sensing.

4. Miniaturization of Sensors: Miniaturization of technology assets is the new 'big thing' driving geospatial industry growth. Today, miniaturized technologies including Sensors, LiDAR, Drones, Wearables and even Satellites are opening new vistas for data collection, while also making geospatial technology more effective, productive, accessible, and popular.

5. Integration of GIS and BIM: The integration of Building Information Modeling (BIM) with GIS is driving the growth of the geospatial industry within the Architecture, Engineering and Construction (AEC) sphere. The AEC sector, which has been the least digitalized of all sectors, is today seeking refined tools, methods and geospatial datasets to take advantage of the upcoming opportunities worldwide in the infrastructure space. The integration of geospatial and BIM for sustainable AEC industry practices is a new emerging trend that is driving geospatial industry growth.

6. Hybrid Mapping Convergence of UAS and LiDAR: The urban development, smart cities, land administration, and disaster management sectors are increasingly demanding optimal solutions that can conceivably simplify geospatial data collection and analysis processes. The increasing demand for LiDAR on Unmanned Aerial Systems (UAS) is to ease scanning of up to centimeter-level precision, fast capture and delivery of high-accuracy aerial imagery and LiDAR data for 3D modelling.

From an innovation perspective, geospatial infrastructure provides for an interconnected platform that integrates geospatial data from different sources, disciplines and formats, enabling new opportunities. A dynamic geospatial infrastructure, complemented by the 4IR revolution, plays a defining role in accelerating geospatial-enabled innovations. In today's digital and data age – geospatial technology/data and information directly or indirectly drive new technology innovation (and vice-versa), while simultaneously leading to business model innovations and changes in consumer behavior.

2.1.1.2 Geospatial-enabled Innovations

A dynamic geospatial infrastructure, complemented by the 4IR revolution, plays a defining role in accelerating geospatial-enabled innovations.

In the digital world we are living in, there are a multitude of geospatial technology innovations, such as, 3D Printing solutions, GeoAI solutions, Autonomous Robotic Systems, Autonomous Vehicles, and Contact Tracing, to name a few. These innovations increase productivity, transform the way we work, bring new and better goods and services to the people to improve their standard of living, and achieve the larger goal of socio-economic development. Although, broadly speaking, the impact of technology innovation is slow, the impact of geospatial-enabled innovations is felt almost instantaneously.

Geospatial-enabled Innovations

Source: Geospatial World Analysis

1. GeoAI Solutions help simulate geospatial data for predictive and prescriptive analytics for informed decision-making, which saves lives and resources to create a more sustainable world. In addition, the use of GeoAI based solutions increases the speed of technology innovation.

2. Geospatially enabled 3D Printing Solutions, which are fundamental to the infrastructure and manufacturing sectors, help minimize wastage, reduce risk and create highly sustainable and light-weight models for construction.

3. Autonomous Robotic Systems are geospatially enabled solutions with GNSS systems for autonomy and remote sensing capabilities (imagery, etc.) for navigation. Due to their remote-sensing capabilities, Robotic Systems enhances and improves GIS data. Most Robotic Systems also use GIS to make decisions and navigate.

4. Augmented Reality and Virtual Reality (AR/VR) are immersive solutions that use geospatial data to shorten the cumbersome processes of the traditional industrial sectors. With respect to sustainable development, these solutions help develop virtual ecological environments and sustainable environment-friendly smart cities and reduce carbon footprint.

5. Self-driving Vehicles or Autonomous Vehicles use geospatial data, which is closely linked to all geospatial technology elements – defining absolute and relative positions, and location and situational awareness.

6. Contact Tracing is one of the newest and most creative geospatial innovations, the importance of which was realized after the outbreak of the COVID pandemic, making it a powerful public health tool. Using location-information and analytics-enabled contract tracing tools, public health officials were able to control the spread of the disease much better than would have been possible with more traditional approaches.

Geospatial infrastructure, enabled by the above-defined geospatial technologies and global technology trends, also serves as the foundation for digital infrastructure and Digital Twin models. This leads to a greater demand for authoritative, accurate, updated, and accessible data platforms. A dynamic geospatial infrastructure brings all stakeholders together while enabling a shift from data to analysis-ready data and applications. This has a substantial impact on reinforcing the development of Digital Twins for the socio-economic sectors of countries.

2.2 Emerging Business Models

The geospatial industry is not only driven by new technologies (as listed in Fig) but are also driven by innovative emerging business models. With 'geo' getting embedded in more and more workflows, the new business models in this industry are disruptive, innovative, and transforming the way the industry grows and expands. Furthermore, with frequent market disruptions, reduced gestation periods, and shorter product/solutions life-spans, the geospatial industry is adopting new business models to stay relevant and derive and manage profit vulnerabilities.

The transformative shifts happening in the geospatial industry are affecting all socio-economic sectors. Industry trends such as the demand for cloud-based and open-interoperable solutions have enhanced the industry's business model options, including the X-as-a-Service model, Coopetition and Partnerships, Consultation business models, to name a few. The disruptions are increasing awareness and the need for geo-coordination. Therefore, they also enhance new consumption-based models from Capex (capital expenditure) to OPEX (operating expenditure) business models to avoid organizational decision bureaucracy associated with large capital expenditures. Furthermore, the industry is willingly taking more risks understanding the consumer preferences/limitations and increasing market competition, thereby leading to new business models in the geospatial industry.

Emerging Business Models

Source: Geospatial World Analysis

EMERGING BUSINESS MODELS -

X-as-a Service Business Model – The X-as-a-Service business model, also commonly known as 'Anything as a Service' business model is a collective term that recognizes that the geospatial industry is increasingly recognizing the value in delivering products, tools and technologies as a service, over a network and as piecemeal products – as per the consumer demands. The model is gradually becoming well-recognized as businesses realize that solutions cannot be provided locally or on-site only, but need to be provided as and when required over a network.

The geospatial industry has transformed itself and developed varied kind of 'As-a-Service' business models to provide complete consumer-centric business models.

- **Infrastructure-as-a-Service: I**nfrastructure-as-a-Service, abbreviated as IaaS, is a building block for Cloud IT. The entire geospatial data can be stored and shared with the stakeholders accordingly. Amazon Web Services is one of the most well-recognized infrastructure-as-a-service provider wherein geospatial data is stored and can be used for application development.
- **Content-as-a-Service:** Geospatial content-as-a-service or CaaS is a licensed data program wherein geospatial data and imagery is collected and updated maps are provided on demand of the users. Such CaaS business models entail – data collection basis consistent specifications and continual refresh schedules. The data available via a CaaS business model is based on the principle of a sharing economy giving everyone access to the same data, democratizing high-quality geospatial data.
- **Platform-as-a-Service:** In this, the geospatial technology providers deliver applications over a network while hosting the user›s hardware and software on its platform or infrastructure. This is believed to be the most disruptive business model that harnesses users› scalable networks, enables ecosystem-value creation, and drives innovation models bringing in an enterprise-wide transformation.
- **Software-as-a-Service:** Software-as-a-Service (SaaS) is a software licensing and delivery model in which software is offered as a service to users on a centrally housed or hosted platform. It is also recognized as an ‹on-demand software.

Coopetition and Partnership: An increasingly large number of geospatial industry players are now entering into strategic partnerships to deliver better and customized solutions to their customers to enter new markets, customer segments and regions.

Subscription / Pay-per-Use: The subscription model is one of the most common business models, a prevalent trend in the industry for the past few years. The primary focus is to encourage the users to subscribe to content, technology, software, or hardware (as required)by essentially paying a small subscription fee. Because the initial investment is less, this business model has proven to capture new markets and expand to new regions effectively.

Consultation: Apart from the subscription model, consultation is a well-established business model which bridges the technological skill and domain expertise gap. Geospatial consultancy involves providing stakeholders with an assessment of their user clientele, identifying the best possible fit available from the vendors and putting together a tailored, ready-to-use system for clients.

Therefore, these emerging business models and technology trends and innovations supplement the development of a National Digital Twin enabled by a dynamic National Geospatial Infrastructure.

2.3 Geospatial Infrastructure And Digital Twin

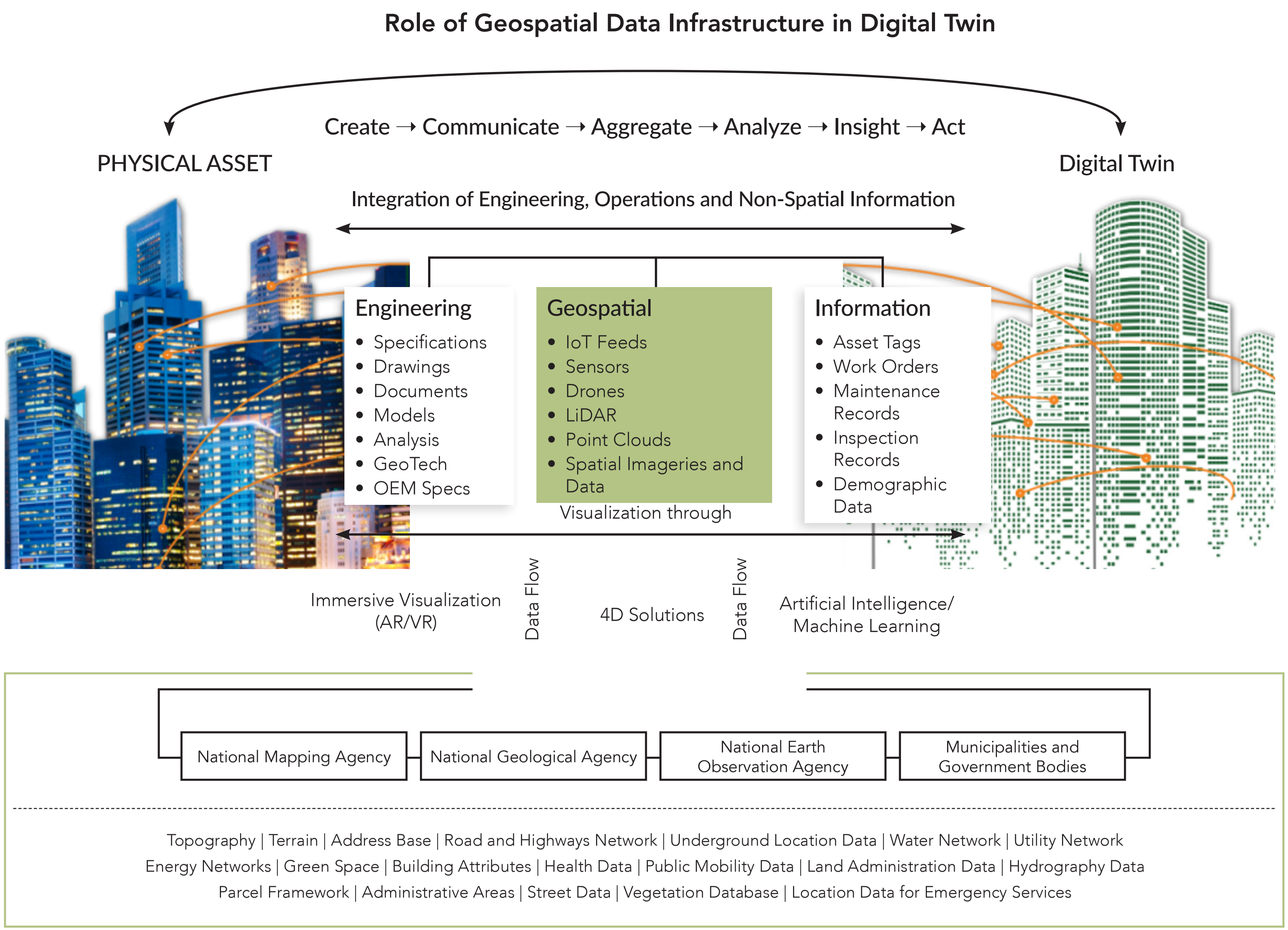
2.3.1 Digital Twin: Definition

The Fourth Industrial Age embraces automation, data interoperability, data exchange, and manufacturing technologies. Digital Twin lies at the core of this new industrial revolution. A Digital Twin is a virtual representation of a physical asset. It can only be developed by a seamless flow of data from the physical asset to its virtual model, and vice-versa. Therefore, the relationship between geospatial infrastructure and Digital Twin is symbiotic in nature. Geospatial infrastructure is a prerequisite to building a Digital Twin ecosystem, to model and simulate changes in a digital world and replicate processes and services. The real-time data connection is enabled by different geospatial technologies and tools, cognitive tools and technologies, and connected sensors (IoT sensor networks), processed by strong digital infrastructure capabilities such as AI to keep the virtual twin as much in sync as possible with the physical twin. The Digital Twin concept, built on a robust and dynamic geospatial infrastructure, thus, cuts across various economic sectors, changing traditional approaches to design in the industrial world and bringing in a more virtual system-based design process. The implementation of Digital Twin creates a myriad opportunity, helping organizations derive valuable insights, predict outcomes, reimagine processes, improve product performance, and enhance operational and strategic decisions.

2.3.2.National Geospatial Infrastructure and National Digital Twin

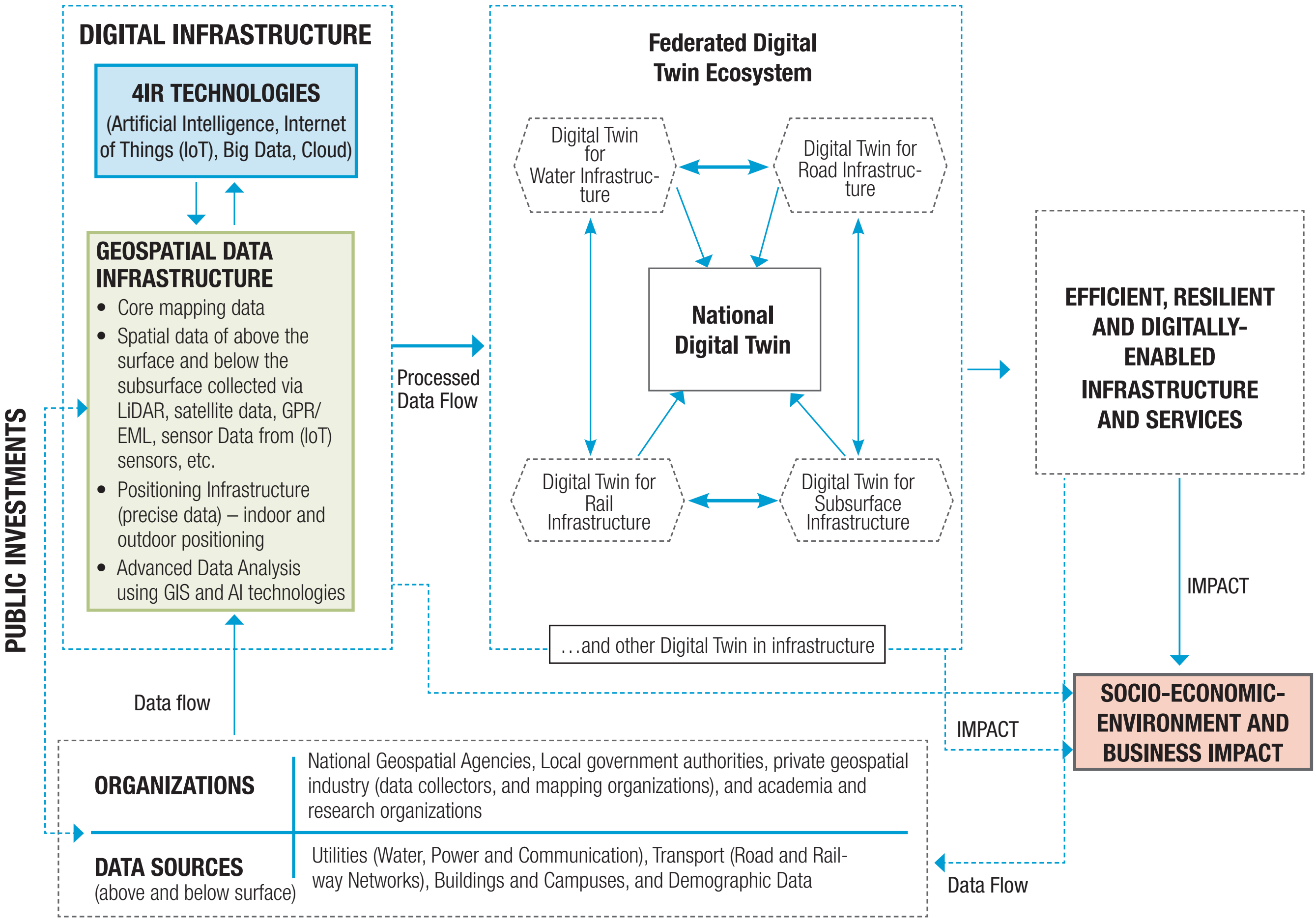
Digital Twin or digital twinning is used for removing uncertainties, errors, and inefficiencies in a multitude of economic sectors ranging from retail, public safety, digital cities (smart cities), healthcare, aerospace, to many others. Since the technology impacts all critical sectors of an economy, globally, countries are developing and embracing a 'National Digital Twin' as a sustainable economic development model.

A National Digital Twin is a federated and connected ecosystem of multiple Digital Twins. Just as geospatial infrastructure is critical for building a Digital Twin of cities



Source: Netherlands Geolocation Economy Report: Geospatial World Analysis

Building a National Digital Twin



Source: Netherlands Geolocation Economy Report: Geospatial World Analysis

and strategic assets, ***the role of a 'national geospatial infrastructure' in building a National Digital Twin is even more crucial.*** A national geospatial infrastructure encompasses a data technology ecosystem inclusive of surveying and mapping capabilities, positioning infrastructure and earth observation infrastructure – along with policies and standards that enable the use of geospatial in a nation. Thus, to build a National Digital Twin, a country needs to leverage all the capabilities of its national geospatial infrastructure, such as a large-scale base map, topography and terrain data, precise positioning data from GNSS systems and IoT Sensors (for health and emergency services), spatial data of underground networks of cables and pipes, map of transport networks and buildings, and spatial and non-spatial database records maintained by municipalities and city departments. In this context, the role of those who maintain the geospatial infrastructure is essential because they are the custodians of high-resolution, accurate, reliable, secure, intelligent, semantic-rich, and continuously updated spatial information necessary to create a dynamic National Digital Twin. Thus, the use of real-time geospatial data supported by 4IR technologies in the National Digital Twin ecosystem increases efficiency, generates high economic value, and facilitates better decision-making for maintaining the social-economic and environment continuum.

The benefits of a National Digital Twin are multifold. As defined by the Centre for Digital Built Britain, a National Digital Twin offers better outcomes for all stakeholders – that is, to society, to the economy, to businesses, and to the environment.

Benefits of National Digital Twin

1

Benefits to Society
- Transport Stakeholder Engagement
- Better Outcomes for the Public
- High-performing Infrastructure and Services

2

Benefits to the Economy
- Increased national productivity
- Efficient measurement of outcomes
- Enhanced information security

3

Benefits to Businesses
- Creation of new markets, new services, new business models & new entrants
- Improved business efficiency and better risk management
- Optimal delivery efficiency and reduction of uncertainty

4

Benefits to the Environment
- Greater resource efficiency
- Promotion of circular economy
- Less disruption and waste

5

Benefit to Individuals
- Citizen Science
- Increasing sustainable mobility

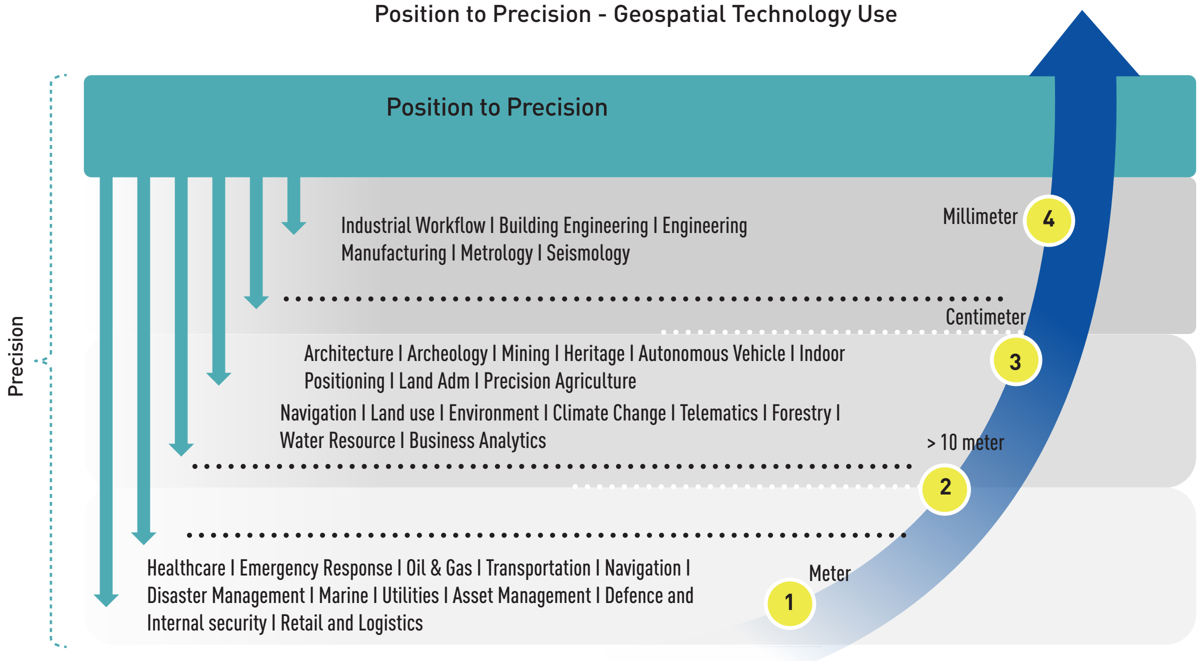
Source:Geospatial World Analysis

3. GEOSPATIAL DATA AND INFORMATION: FUNDAMENTAL TO SOCIO-ECONOMIC SECTOR WORKFLOWS

Geospatial data and information are ubiquitous for the world economy and society. Governments and technology providers are increasingly witnessing greater demand from economic sectors as more and more sectors integrate geospatial solutions into their daily workflows. The adoption of GNSS, location analytics, satellite imagery, scanning tools, and sub-surface mapping tools such as Ground Penetrating Radar and Electromagnetic Locator (GPR/EML) geo-enabled mobile applications for getting the required precision has burgeoned over the last couple of years.

Today, the adoption of geospatial information and technology is not limited to archetypal sectors like defense and intelligence, disaster management, land administration, urban development, and infrastructure, but has extended to sectors such as banking and finance, retail, supply chain and logistics, real-estate, among many others. While traditional sectors that are economically important to a country require data of position and precise accuracy of less than a meter (and in some cases millimeter accuracy), new sectors, such as navigation, business analytics, BFSI (Banking, Financial Services and Insurance), telematics, and tourism require data of position and precision accuracy of 10 meters and above. Therefore, geospatial technologies that are embedded with varied workflows such as Building Information Modeling (BIM) and Business Intelligence, add to the democratization of geospatial technologies.

Position to Precision - Geospatial Technology Use



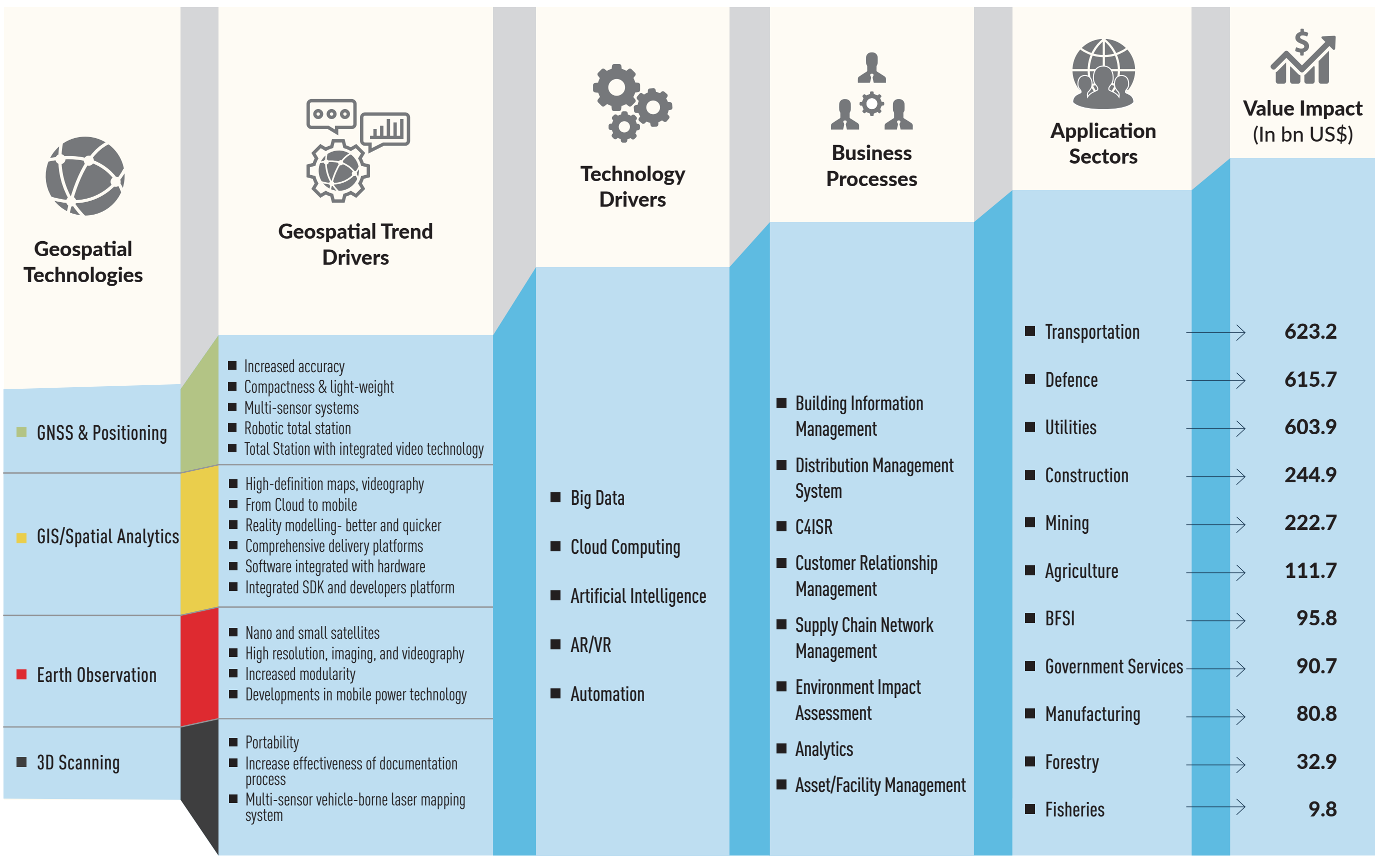
Source: Geospatial World Analysis

3.1 Geospatial Technologies: Creating High-Value Impact

The geospatial industry continues to grow as it is embedded in various business processes such as BIM, C4ISR [Command, Control, Communications, Computers (C4) Intelligence, Surveillance, and Reconnaissance (USR)], Supply Chain Management Networks, Distribution Management Systems, Enterprise Resource-Planning (ERP Systems), and Business Intelligence, for the benefit of different sectors. Increasing investments by government and private sector user segments, expanding digital services, and innovations in geospatial technologies have created new avenues for geospatial applications in recent times. Satellite imageries, GIS/Spatial Analytics, Unmanned Aerial Vehicles (UAVs), GNSS and Positioning, and 3D Scanning are being used vigorously by various industries for geo-referencing, mapping, visualization, and analysis for better decision-making and workflow automation. Thus, by leveraging geospatial information, various sectors are able to use and develop traditional and emerging geospatial applications to improve resource efficiency and productivity, creating high-value impact for economies worldwide.

Today, the geospatial industry has reached that existential moment where being 'niche' is an old cliche and the 'mainstreaming' of geospatial data and technology is accepted as the new normal. The economic impact of using geospatial technologies and applications is often underappreciated even though it extends

Geospatial Technologies: Creating High-Value Impact



Source: Geospatial World Analysis

Geospatial analytics is being used globally across sectors for data-driven informed decision-making, becoming pervasive in day-to-day activities.

beyond the core geospatial industry. Geospatial analytics is being used globally across sectors for data-driven informed decision-making, becoming pervasive in day-to-day activities. For traditional sectors, the value impact of using geospatial technologies enabled by 4IR and business processes is significantly much higher. For instance, in 2018, the use of geospatial technology in the transportation sector created a value impact of USD 623.2 billion, in defense, it created a value impact of USD 615.7 billion, and so on. This, by and large, signifies that while the geospatial industry grew at almost two-fold, the economic impact of the technology was at least ten-fold, playing as an economic enabler. Notably, while economic impact can be calculated, the societal impact, which is difficult to measure, is expected to have far greater importance and value.

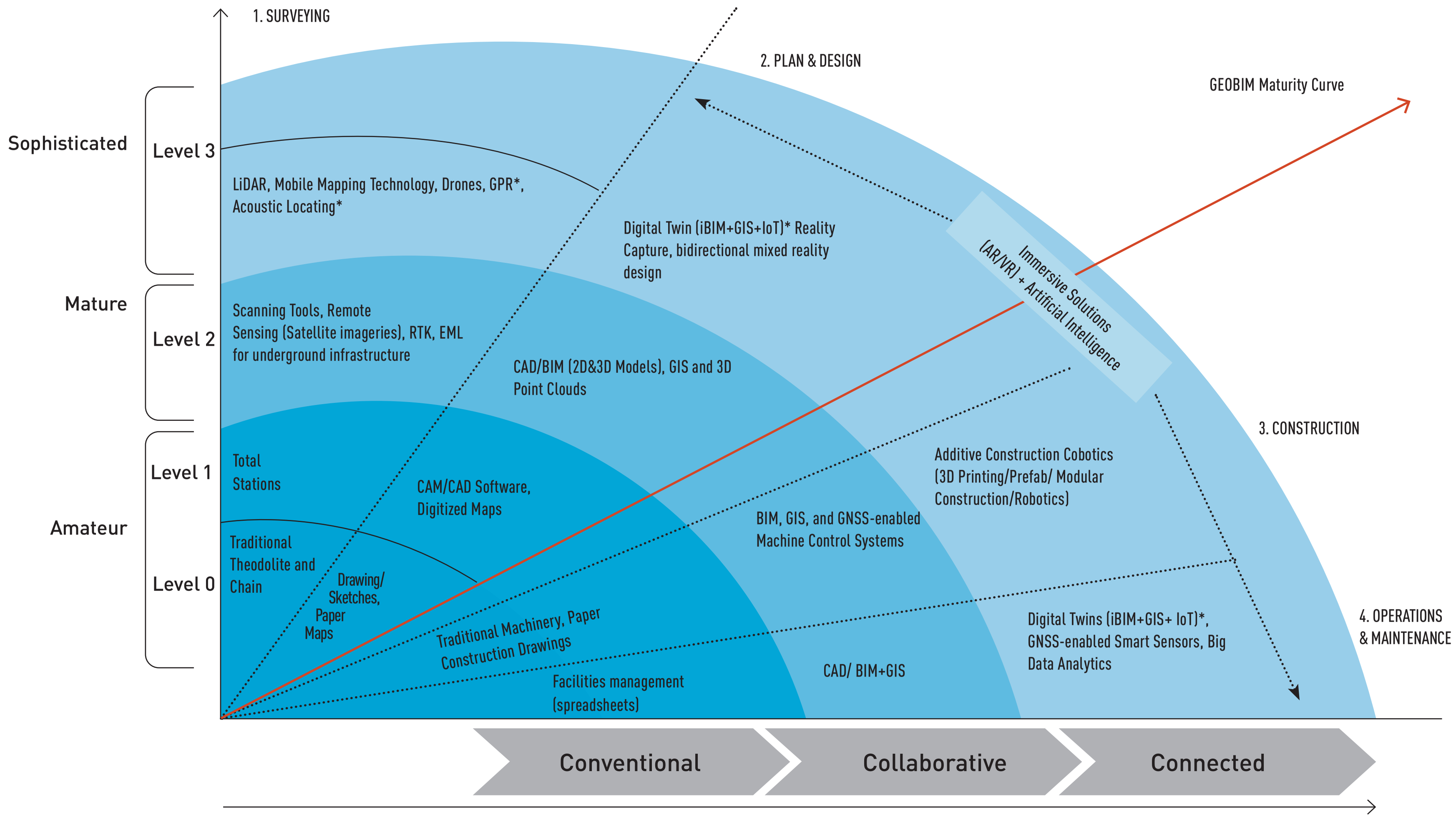
While geospatial technology use is underpinned in almost all sectors, ***seven vital economic sectors that are of national priority for governments worldwide for achieving sustainable development goals have been included in this report.*** The seven sectors are AEC (architecture, engineering and construction) inclusive of sub-surface infrastructure; telecommunications; urban development and smart cities; disaster management; healthcare; renewable energy; and land administration, are key sectors where geospatial technologies are critical and necessary.

3.1.1 Architecture, Engineering and Construction (AEC)

The traditional AEC industry is witnessing a rapid technology disruption that is redefining it. The ever-increasing technology mainstreaming and convergence of digital technologies across the construction lifecycle, driven by 4IR technologies and immersive solutions, is creating a seamless synchronization between geospatial and BIM technologies for hassle-free decision-making and higher productivity levels. The industry has begun to realize the importance of co-existing in a 3D spatial environment – with BIM, immersive solutions, and traditional construction tools leading to better coordination and collaboration. Geospatial and BIM technologies are, thus, transforming the AEC industry to deliver a more sustainable and resilient infrastructure of tomorrow.

The cumulative global market size of the AEC industry is estimated to reach USD 117.59 billion in 2023, growing at a CAGR of 12.69% between 2015 and 2023. The value of geospatial technologies and BIM in the AEC workflow begins with surveying, planning and design, construction, and culminates in operations and maintenance. Over the years, as technology has advanced, the use of geospatial technologies has evolved – from Total Stations to Remote Sensing (satellite imageries), Scanning Tools (LiDAR, Radar), Mobile Mapping technology, Drones/UAVs, among others. Further, the industry has moved towards integrating GIS and BIM and IoT networks to create Digital Twins for the AEC industry in the planning and design and construction phases. The level of adoption of technology defines the GEOBIM maturity. Deploying geospatial solutions in the AEC construction sector, helps increase project resiliency, reduce material usage, and bring workflow efficiency.

Geospatial Technology Embedment in Construction Lifecycle: GEOBIM Maturity Model



* For both above and underground infrastructure

Source: GEOBIM Market in AEC Industry Report: Geospatial World Analysis

Subsurface Infrastructure: The AEC industry is increasingly recognizing the need to map subsurface infrastructure since every project requires excavation, which includes significant investments, costs and risks. The value of Ground Penetrating Radar (GPR), Electromagnetic Location (EML), and BIM technology solutions is increasingly being recognized by stakeholders globally to navigate and geo-locate the subsurface buried utility networks and hidden construction. It is important to note that if subsurface infrastructure is not mapped prior to excavation it leads to significant engineering, environmental and societal risks (deaths from utility explosions, etc.). Hidden subsurface utility networks have historically endangered the lives of many people. For construction owners and excavators, lack of information about the presence, nature and location of subsurface networks often creates a challenging situation. Thus, the use of geospatial technology is paramount to understanding the subsurface and building a 3D map to aid surface and subsurface construction.

Additionally, governments worldwide are devoting significant sums of their infrastructure budgets for subsurface infrastructure mapping. For instance, USA devotes an estimated USD 10 billion to locating underground infrastructure, while the United Kingdom, Netherlands, France, Japan and New Zealand are among a few countries where there are strategic initiatives in place to enable a shared subsurface database.

From a technology standpoint, innovative technology solutions such as advanced sensors, GPR, EML, LiDAR and BIM improve data collection, data storage and dissemination of highly reliable 2D and 3D utility information. Lately, both GPR and EML have gained the attention of leading contractors in the AEC industry for bringing forth an accurate view of construction sites' subsurface in a non-destructive and non-invasive way. While the GPR offers an image of the subsurface infrastructure, EML helps to determine the position and depth of the buried utilities. The use of these technologies improves the safety, productivity and

Source - Geospatial World Analysis

efficiency at excavation sites, whilst simultaneously adding to the quality and usefulness of the dataset itself. Further, the data collected by these sensors is used with BIM to create a real-time 3D map of the subsurface, helping project engineers understand the risks and take informed decisions accordingly. Therefore, the value-impact of using GPR, EML and BIM solutions, and in some cases, LiDAR and Drones, brings significant efficiency and productivity to construction processes.

3.1.2 Telecommunications

The global telecom market size was estimated at USD 1,657.7 billion in 2020 and is expected to grow at a compound annual growth rate of 5.4% from 2021 to 2028 to reach USD 2,467.01 billion by 2028. This staggering growth is driven by wireless and digital technology and through the consumption of readily affordable services like high-speed internet, Augmented Reality (AR), and 5G services. Additionally, the telecommunications sector is the backbone of all information and communication services through the internet, wireless sensors, phones, cables, and satellite networks. With the ongoing 4IR and the buzz about the 5G's massive rollout, the telecom sector is going to drive transformations and equally explore new territories. To keep up with these technology trends, the telecom sector needs to transition from being just a mere utility service provider to a full spectrum service provider. This will require significant investments in new technology infrastructure, know-how, and expertise to stay relevant and maintain consistent growth.

From the perspective of digitalization, geospatial data plays a significant role in helping telecom companies address emerging challenges and pave a roadmap for the future. Geospatial technologies result in intelligent maps created by GIS (using satellite and aerial imagery) for effective decision-making, improve service, and create next-gen enhancements. Geospatial data will thus greatly benefit from the fast speed and connectivity of 5G networks, because geospatial and 5G are interdependent, and both will drastically change the dynamics for smart cities, utilities, and transportation, among other things.

Thus, geospatial technology and data facilitate and enable telecom network planning, risk management, and performance monitoring – reshaping the telecom industry via digital modernization. The use of geospatial data will intensify when organizations have to plan new assets for more complex 5G telecom networks. The telecommunications industry will be one of the most significant users of geospatial technology and data for its maps and visualization and decision-making. Geospatial technology and data will, therefore, enhance telecommunications networks in the times to come.

Geospatial technologies (and data and information) adds value to the telecommunications sector wherein precise geospatial data helps telecommunication players to:

- Identify the best market to develop telecom infrastructure basis population density and segmentation expenditures
- Plan advanced wireless network planning for 5G
- Better infrastructure planning/construction engineering
- Determine optimal placement locations for reliable analysis and modelling of new telecommunication infrastructure
- Optimizes resources and network optimization

3.1.3 Urban Development and Smart Cities

Urban settlements today are facing increased agglomeration and need to self-sustain themselves. Urban settlements are striving to become resilient and livable by addressing heterogeneous conditions and unique challenges faced in the cities. The urban settlements face challenges of unplanned urban sprawl leading to inaccessible service, degradation of social cohesion due to unequal economic opportunities, and improper governance contributing to the haphazard supply of basic infrastructure services and maintenance.

Geospatial technologies and data and their applications are critical for sustainable urban development and the growth of smart cities. Urban transformation and the smart cities' mission have begun focusing on key pillars

Role of Geospatial Technologies in Urban Development and Smart Cities

CHALLENGES	ROLE OF GEOSPATIAL TECHNOLOGY
Basic Infrastructure	• GIS technology helps to collect and analyse the datasets to help lower the wastage of resources. • Internet of Things (IoT) and sensors of different kinds help estimate the amount of the waste production from different areas which help them in the allocation of optimum resources for waste collection and management. • Sensors can be used to recognise the light intensity of streets and provide the exact amount of lighting that is needed to make the streets smart and safe for pedestrians and cyclists.
Affordable Housing	• GIS and remote-sensing applications helps to automate land assessment which helps the administration to identify areas for developing low income housing facilities. • GIS combines large data sets to visualize data enabling land-use consultants to take unsuitable land out of the picture straight away. • GIS tools helps to provide accessibility to public transport, schools, local/town centres, basic physical and social infrastructures, etc.
Density of Urban Areas	• Multi-spectral satellite imagery (from over extended time periods) using cloud-based computational platforms helps to monitor rising urbanization. • Satellite data helps to manually label areas as "built-up" or "not built-up". • Geospatial technologies helps to measure urbanization with a high degree of geographic precision and close to real time. It also helps to design public policy to tackle economic and environmental challenges of urbanization.

Source - Geospatial World Analysis

of city-wide operations based on inclusive accessibility, urban growth, and urban governance. Geospatial technologies resolve growing urbanization challenges by the development of accessible human settlements by improving affordability and providing for affordable housing, sustainable livelihoods for urban employment, and infrastructure governance through the provision of resource-efficient infrastructure systems.

3.1.4 Disaster Management

Geospatial technologies and tools play a pivotal role in a disaster management lifecycle as each disaster is georeferenced by a location. With the numbers of earthquakes, hurricanes, and storms rising globally, there is a need to necessitate geospatial technologies use in disaster management workflows to enhance situational awareness. Geospatial technologies are critical to defining how disaster management agencies predict, measure, monitor, report, manage, mitigate, recover and rehabilitate cities, societies, and economies after a disaster. Further, technology advancements – such as HD cameras, sensor technologies, and 4IR technologies (AI, Big Data, Cloud, and IoT) – help in accurately processing historical and current data to predict, prepare and plan for an impending disaster and in delivering better outcomes.

Benefits of Deploying Geospatial Technology for Disaster Management:

- Interdisciplinary approaches, using geospatial technologies are needed to address disasters management issues an; and identify and develop actionable strategic plans for monitoring programs, risk reduction, restoration, and recovery efforts.
- Spatial information and applications give us the power to visualize, monitor, assess, predict, prepare, and respond to to enhance situational awareness.
- The integration of mapping, GPS, satellite imagery, and interactive GIS helps capitalize on technologies to create better disaster management plans, establish new networks, and develop strategic decision support systems.
- Surveying and mapping tools and GIS techniques facilitate disaster management by producing a model for visualization of the effect of the disaster, mitigating the extent of the disaster, effectively deploying rescue teams and undertaking post-disaster reconstruction and rehabilitation.
- Spatial applications provide an opportunity to national disaster agencies to predict and disseminate early warning information, and help with resource and inventory management, evacuation planning, vulnerability analysis, simulation and modeling, and early damage assessment, among other things.
- Synergistic efforts from multiple technologies, inclusive of 4IR technologies (Big Data, Cloud, IoT, AI/ML), geospatial technologies, enhance spatial information use to depict the geographic extent of the event rapidly.
- Multiple disasters worldwide have necessitated the need for national disaster agencies and supporting organizations to work together with the geospatial industry to adapt spatial technologies and complex analytic procedures to distribute precise, accurate, and real-time information in a timely fashion. Thus, the geospatial opportunity in disaster management has diverse imaging and data sources at its disposal.

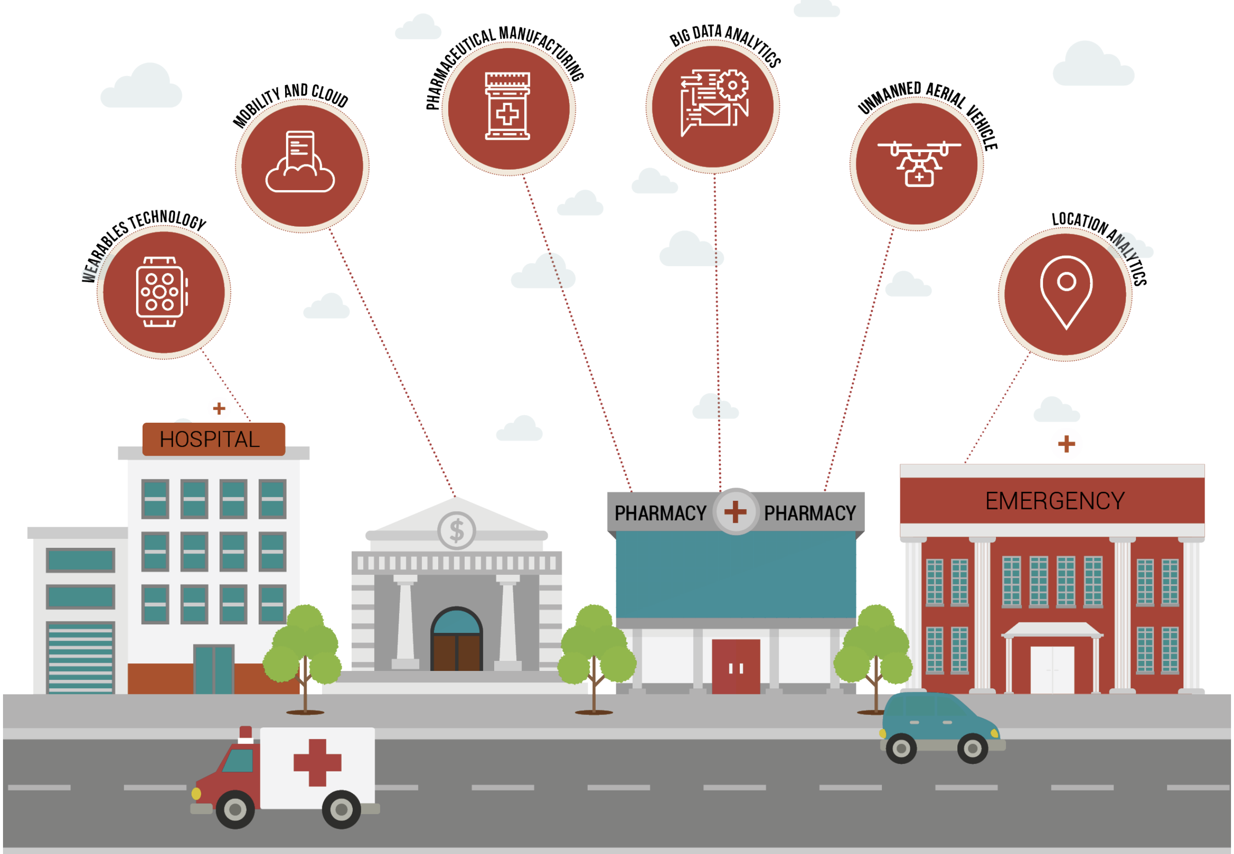
3.1.5 Healthcare

The world is facing a health pandemic of an unparalleled scale; in a matter of months, COVID-19 has crippled health, social and economic infrastructure globally. As humanity collectively braces for the most trying times since World War II, there is a realization that despite tremendous advancements in science and technology, our healthcare facilities are inadequate, especially in the face of an unknown enemy. There is a need for a coordinated global approach using geospatial data and technologies to develop an early detection and response system for disease surveillance, chronic disease prevention, control the spread of the pandemic and immunization.

Disease Surveillance

Early detection is crucial when people are exposed to potentially fatal diseases, and geospatial technologies enable us to detect diseases and respond to them in time. Contextualized data and geographical insights generated from digital maps and location-based technologies such as geofencing, GPS trackers, and sensors can highlight historical and predictive insights into patient behaviors and minute layers of details on the existing system discrepancies and inefficiencies, thus simplifying

Geospatial Technologies and 4IR technologies in Healthcare



Source - Geospatial World Analysis

planning and execution of health resources and programs. This can enable healthcare providers, medical practitioners, and government agencies to prepare for a disease outbreak, thus, enabling the support systems such as healthcare facilities during an outbreak.

Geospatial technologies help:

- Map the spread of infections over time and aid in target interventions.
- Develop GIS-based applications which can map confirmed and active cases, deaths, and recoveries to identify where the disease exists and has occurred.
- Map social vulnerability, age, and other factors to help monitor at-risk groups and regions.
- Map healthcare capabilities – inclusive of facilities, employees, medical resources, equipment, goods and services – to understand and respond to the current and potential impact of diseases.

Chronic Disease Prevention And Control

A close understanding of location awareness ensures appropriate and informed public health responses for chronic disease prevention and control. Having spatial insights on chronic disease expands the ability of public health departments and organizations to scale their efforts and resources at the community, regional and national levels. Geospatial information can be used to examine characteristics such as social, economic, and physical infrastructure of communities, which can aid or inhibit chronic disease prevention and treatment. Through maps and spatial analysis, governments and agencies can see the patterns that emerge across communities and develop programs and policies that address these drivers of chronic disease at multiple geographic levels, supporting prevention initiatives of chronic illnesses.

Geospatial technologies help:

- Map and visualize disease distribution.
- Link intra- and inter-logical connections between health, social services, and natural environment.
- Investigate diseases and plan interventions.
- Improve transparency and accountability.
- Support advocacy through visual maps.
- Promote and deliver health services.

Immunization

Immunization is one of the core components of primary health care, and geospatial technologies play an essential role in aiding immunization initiatives worldwide. When we look at vaccine coverage, there could be many inequities. These arise from differences in place of residence (urban or rural), due to income and education status, the gender of the child, and much more. Geospatial technologies have proven to be significant in addressing these challenges and increasing immunization coverage.

Geospatial technologies help:

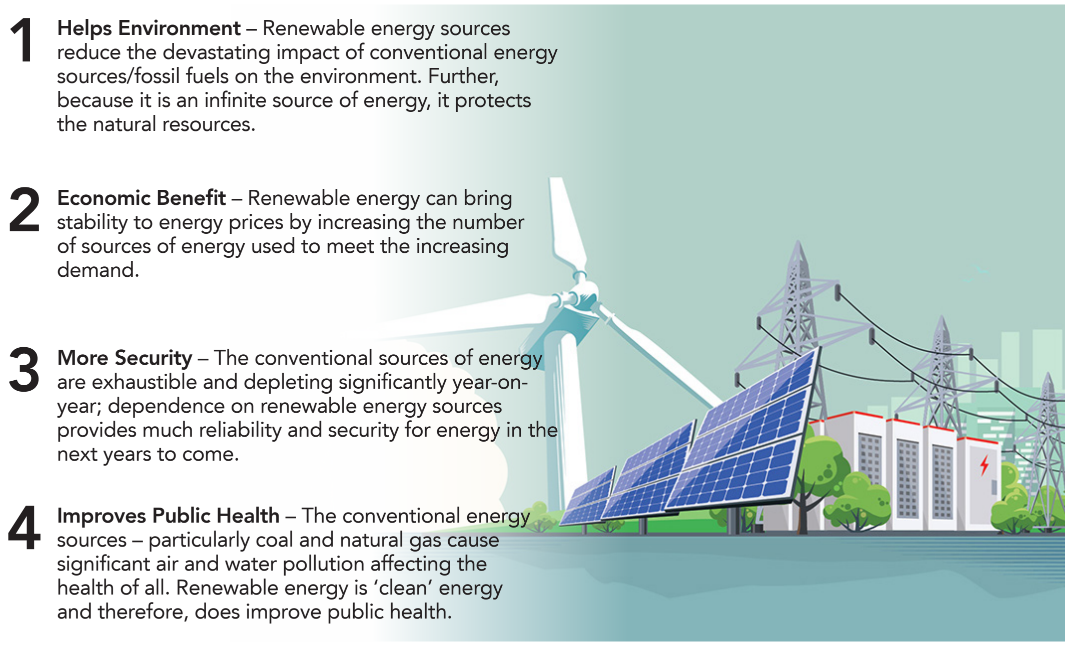
- Ensure that all communities are mapped for immunization and linked with other healthcare system components.
- Support better planning, resource allocation, and targeting of immunization funding and resources.
- Discover and respond to gaps and risks in immunization delivery.
- Improve transparency and accountability.
- Empower grass root level workers through geospatial crowdsourcing.

3.1.6 Renewable Energy

Despite climatic concerns, today, the world still depends on energy sources like crude oil, natural gas and coal – resources that are expensive in the context of sustainability, exhaustible and will get depleted in a few decades. With the 2030 Agenda for Sustainable Development Goals (UN), worldwide, countries are increasingly recognizing the value of transitioning to more renewable energy sources like wind, solar, geothermal and biomass to meet their energy needs. Further, renewable energy is a smarter and more viable choice and is available through much cleaner energy production and transmission mechanisms. It also provides us the opportunity to mitigate greenhouse gas emissions and reduce global warming by protecting natural resources.

As government organizations and policymakers emphasize the use of renewable energy as a preferable energy source going forward, geospatial technology has an important role to play in the process of renewable energy generation. Geospatial

Benefits of Renewable Energy



Source: Geospatial World Analysis

technologies help stakeholders responsible for renewable power generation to analyze and monitor processes, while ensuring that the power generated is delivered efficiently. The use of geospatial tools and technologies is critical to improving the production, transmission, and delivery of renewable energy.

Data collected with the use of geospatial tools and technologies (such as LiDAR, UAV, Remote Sensing technology such as satellites, and with GIS systems) helps planners, policymakers, and energy providers to effectively determine the right location for producing renewable energy. GIS analytics allows for deep analysis of wind potential, solar potential, distance to cities, type of land cover, among other things, to help build location awareness for a renewable energy power plant. Further, to ensure resilient energy consumption, GIS analytics helps to focus and manage these energy sources (distribution and consumption), whilst showcasing the potential for sustainable energy resources to potential users. In addition, some of the geospatial-enabled innovations of today, such as Drones and Robotics, are being utilized by renewable energy providers to improve efficiency at the plant site for mapping and monitoring and reducing overall cost.

3.1.7 Land Administration

The challenges of land administration are global and have social, economic and environmental relevance. Land administration, as defined by the World Bank, is the process of determining, recording and disseminating information about the tenure, value and use of land. It covers all activities concerned with the management of land as a resource, both from an environmental and from an economic perspective. Today, sustainable development demands effective land administration and management. Likewise, effective land administration and management supports sustainable development. An enabling environment created through the development of policies, standards and regulations may lead towards a cooperative data-creation and data-sharing environment for successful land administration.

Land administration is inherently geographical and good geospatial information is needed to manage geographic elements in a digital world for implementing land policies and land management strategies in support of sustainable development and good governance. Such land administration systems need a spatial framework to operate as place or location is a key facilitator in decision-making. The use of geospatial technology and tools in land administration processes can streamline workflow and enforce cadastral procedures in the correct and legal way through efficient job management and integrate geospatial information into the existing system. Therefore, the use of geospatial technologies and tools is critical for consistent and accurate national mapping to enable effective documentation of land rights, for parcel information and, by extension, for improving land valuation and land rating.

Almost all geospatial tools and technologies are useful in the land administration process and provide long-term benefits. For instance, Aerial Mapping is a useful tool that helps in the demarcation and digitization of land boundaries, covering large areas quickly; Roving GPS allows boundary positions to be captured quickly, leading to faster and cheaper establishment of cadastral ground control; and GIS-based applications applied across the entire cadastre workflow help users manage land parcels and standardize modeling support for maintaining data thematic layers such as parcel framework, ownership and taxation, and administrative areas, among other things.

The use of geospatial tools and technologies in the land administration process, thus, improves data quality, creates an integrated workflow for updating a cadastre, reduces duplication of effort, streamlines workflows, and enforces evidence and data-based cadastral procedures legally. Finally, it leads to cost efficiency in land administration processes.

5. GEOSPATIAL FOR SUSTAINABILITY OF EVERYTHING

Society, economy, and the environment are fundamental determinants of sustainability, and technology innovation, particularly geospatial innovation, plays a defining role in building a sustainable and resilient world. Today, sustainability is consistently being redefined by environmentalists and societal champions, geographers, and economists. In this interconnected and interdependent ecosystem of sustainability, the value of geospatial has often been ignored; however, the technology and its innovations continue to be a powerful force in the evolving role of sustainability. Geospatial technologies bring with them a collaborative and coordinated approach, adding efficiency and effectiveness to sustainability programs.

The 2030 Agenda for Sustainable Development Goals (SDGs) says '*the spread of information and communication technology (ICT) and global interconnectedness has great potential to accelerate human progress and bridge the digital divide and develop knowledge societies.*'[1] The SDG framework emphasizes that the data produced through geospatial technologies has tremendous potential to effectively and efficiently monitor sustainable development measures. For governments to formulate strategies, they need to identify where the citizens are and where the roots of their problems lie, and this is where geospatial comes in. Therefore, to truly harness 'data' to meet the 2030 Agenda, there is a need to integrate geospatial data with other available datasets to create visualizations through maps or 3D models; this will help evaluate impact, monitor progress, and improve accountability.

Geospatial approaches and technology (along with allied technologies), thus, play a significant role in delivering long-lasting and meaningful growth to build 'sustainability of everything.

Successful case studies from all over the world illuminate how geospatial data help to meet the SDGs, directly or indirectly. Geospatial data integrated with non-spatial data (demographic data and statistical data) leads to strategic geospatial innovations for visualizing spatial data; for accurate assessment and evaluation of the development impact across the 17 goals consistently; and to improve accountability. In this context, global organizations like UNGGIM and Group of Earth Observation (GEO) play a defining role in propagating geospatial technology in varied sectors for the successful implementation of SDGs.

Geospatial approaches and technology (along with allied technologies), thus, play a significant role in delivering long-lasting and meaningful growth to build 'sustainability of everything'. Global case studies listed in the Annexure highlight the value of geospatial technologies, data and information in SDGs.

SUSTAINABLE DEVELOPMENT GOALS

GEOSPATIAL TECHNOLOGY FOR 2030 AGENDA

1 NO POVERTY

- GIS-based poverty map

Remote Sensing, GIS and Spatial Analytics, mobile phone

2 ZERO HUNGER

- Geospatial data for agriculture yield estimation
- Smart Agriculture

Remote Sensing, GIS and Spatial Analytics, and UAVs/Drones

6 CLEAN WATER AND SANITATION

- Spatial location of water resource and distribution of water pollution
- Locations of points and non-points pollution source

Remote Sensing, GIS and Spatial Analytics, Sensors, and GNSS and Positioning

7 AFFORDABLE AND CLEAN ENERGY

- GIS based mapping for location of energy resources
- Use of drones for oil & gas pipeline monitoring
- Use of remote sensing in finding out optimum location for renewable energy

GIS, UAVs, Satellite

8 DECENT WORK AND ECONOMIC GROWTH

- Change in LULC Maps
- GIS based maps for mapping parking and other facilities for specially abled

Remote Sensing, and GIS and Spatial Analytics

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

- Determining air pollution through remote sensing across different industries

Remote Sensing, GIS and Spatial Analytics

13 CLIMATE ACTION

- Detection on a large-scale impact of climate (CFCs, hazards) on human lives

Remote Sensing, GIS and Spatial Analytics, AI/ML, and IoT

14 LIFE BELOW WATER

- Detection of ocean pollution (oil spills)
- Identification of potential fishing zones, ocean temperature

Remote Sensing, and GIS and Spatial Analytics

3 GOOD HEALTH AND WELL-BEING

- Geospatial analysis for examining healthcare system
- Location of hospitals
- Disease pattern and distribution

Remote Sensing, GIS and Spatial Analytics, and IoT

4 QUALITY EDUCATION

- GIS based maps on online education

GIS and Spatial Analytics

5 GENDER EQUALITY

- GIS based gender mapping on access to financial institutions
- Gender equality and women empowerment through ICT

GIS and Spatial Analytics, and ICT

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

- Earth observation for sustainable infrastructure development

Remote Sensing, GIS and Spatial Analytics, IoT, and AI/ML

10 REDUCED INEQUALITIES

- Night time lights data to map regional inequality
- Detecting spatial pattern of inequality from remote sensing

GIS and Spatial Analytics, and IoT

11 SUSTAINABLE CITIES AND COMMUNITIES

- Global mapping of LULC changes
- Smart City development

Remote Sensing, GIS and Spatial Analytics, UAVs/Drones, LiDAR, IoT, and AI/ML

15 LIFE ON LAND

- Quantifying forest cover
- Deforestation and forest degradation
- Forest biomass

Remote Sensing, GIS and Spatial Analytics, and AI/ML

16 PEACE, JUSTICE AND STRONG INSTITUTIONS

- GIS based temporal maps on homicide rate
- GIS based regional maps on completeness of birth registration

GIS and Spatial Analytics, IoT Sensors, and AI/ML

17 PARTNERSHIPS FOR THE GOALS

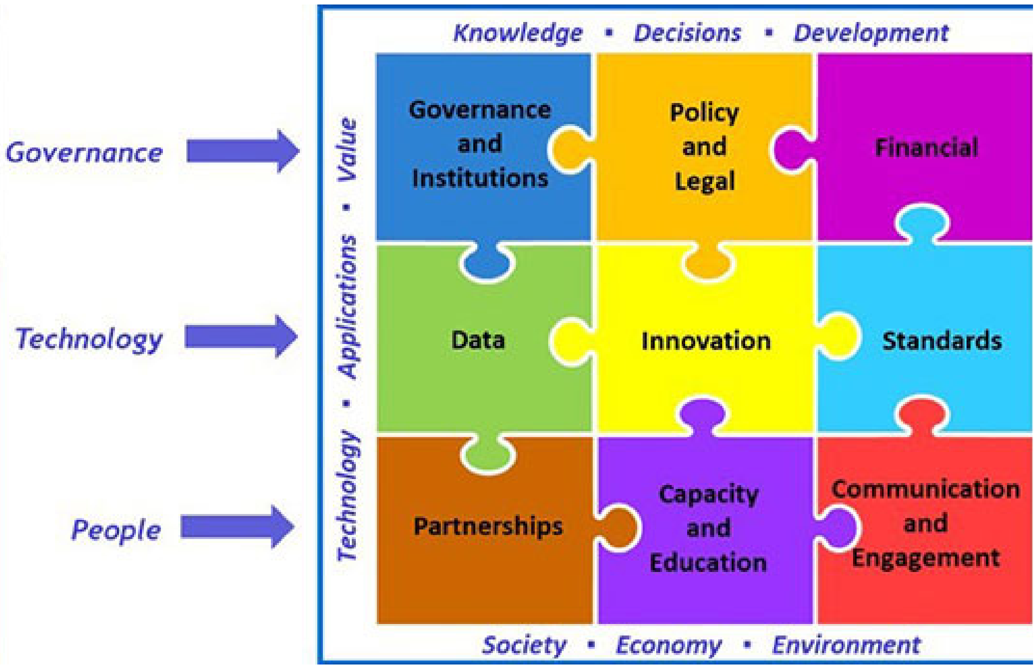
- Mapping government revenue as a share of GDP
- Mapping share of the population using internet

GIS and Spatial Analytics, and AI/ML

6. GEOSPATIAL INFRASTRUCTURE AND GLOBAL STRATEGY AND INITIATIVES

Keeping in mind the importance of geospatial information and its related infrastructure, the United Nations endorsed the Integrated Geospatial Information Framework, developed in collaboration with the World Bank. The Integrated Geospatial Information Framework, also referred to as the UN-IGIF, provides strategic and specific action plans to strengthen national and sub-national arrangements in geospatial infrastructure. The framework provides for practical implementation by UN member states, the World Bank, international organizations, private industry players, academia and research organizations, and non-governmental organizations (NGOs).

Integrated Geospatial Information Framework By United Nations and World Bank



To achieve the overarching vision, UN-IGIF identifies eight goals:

- **Goal 1** – Effective Geospatial Information Management
- **Goal 2** – Increased Capacity, Capability and Knowledge Transfer
- **Goal 3** – Integrated Geospatial Information Systems and Services
- **Goal 4** – Economic Return on Investment
- **Goal 5** – Sustainable Education and Training Programs
- **Goal 6** – International Cooperation and Partnerships Leveraged
- **Goal 7** – Enhanced National Engagement and Communication
- **Goal 8** – Enriched Societal Value and Benefits

The UN-IGIF ultimately aims to improve and strengthen the existing national spatial data infrastructure capabilities and geospatial information capacities globally. Thus, the UN-IGIF is anchored by nine strategic pathways that showcase the different aspects of geospatial maturity across three key factors – governance to data to technology to people. Thus, the UN-IGIF is built on these pathways to develop strategies and policies that drive geospatial innovation, economic contribution, and efficient development of an effective geospatial infrastructure. Further, the nine strategic pathways which have been developed taking into consideration the 2030 Agenda for Sustainable Development and will assist the governments in developing strategic geospatial roadmaps for integrated geospatial information management for evidence-based policies and decisions to bridge the geospatial digital divide. These strategic pathways demonstrate, augment, and build upon existing spatial data infrastructure arrangements, providing a holistic, integrated national information systems-of-systems approach to the geospatial data lifecycle. The strategic pathways guide governments in establishing dynamic geospatial infrastructures and implementing integrated geospatial information systems for sustainable economic, social and environmental development.

Geospatial Knowledge Infrastructure (GKI) is another global initiative that is currently established over a three-year program (Jan 2020 to April 2023) by way of global partnership among national geospatial agencies, geospatial technology providers, and academia and research organizations. GKI provides for the critical geospatial component to knowledge and automation, positioning geospatial,

Geospatial Knowledge Infrastructure (GKI) Elements

Source: Geospatial World Analysis

a general-purpose technology, at the heart of 4IR and knowledge economy. It encompasses data, technology, policy, and people to ensure the smooth provision and use of geospatial intelligence and knowledge in the broader ecosystem.

GKI leverages the many new opportunities enabled by 4IR, accelerating automation and knowledge-on-demand. It supports the United Nations Vision of the 2030 Agenda for Sustainable Development. GKI also advocates for UN-IGIF as the choice for nations to build geospatial infrastructure. GKI is based on six elements that are also in due alignment with UN-IGIF:

- Integrated Policy Framework
- Foundation Data
- Partnerships and Collaboration
- Industry Leadership
- Applications, Analytics and Modeling
- Geospatial Dimension to Digital Infrastructure

Further, GKI integrates a system of systems in which geospatial is part of the wider digital ecosystem. Thus, both UN-IGIF and the GKI framework aim to support governments and industry to deliver sustainable economic, social and environmental benefits to economies worldwide, as part of emerging digital and knowledge ecosystems and infrastructure.

7. STRATEGIES AND RECOMMENDATIONS FOR ADVANCING GEOSPATIAL KNOWLEDGE FOR SUSTAINABLE DEVELOPMENT GOALS

The geospatial industry is making huge strides in technology advancement, application development, and implementation of geospatial technology across varied economic sectors. There is increasing realization that having a dynamic geospatial infrastructure for planning, monitoring, weather prediction, transport, and advertising is important and necessary. Today, economies have recognized the importance of using available geospatial technology and tools for socio-economic and environmental development. Given these technological changes and the increasing availability of data and analytics across the private sector, UNGGIM's Private Sector Network (PSN) has proposed strengthening geospatial infrastructure, developing a national geospatial strategic frameworks, and initiating Public-Private Partnerships (PPPs) for commoditization and commercialization of geospatial technologies.

7.1 Strengthen Geospatial Infrastructure

Geospatial infrastructure, enabled by 4IR, is defined by digitalization, connectivity, and convergence, and is fundamental to achieving the UN's Sustainable Development Goals (SDGs). Geospatial infrastructure serves as a foundation for digital infrastructure (including Digital Twins), facilitating sustainability across sectoral workflows. In this context, there is a need to develop geospatial infrastructure as a service that can be provided to stakeholders – technology players, citizens, and businesses. This will accelerate geospatial innovation and eventually support the objective of sustainable development.

7.1.1 Strengthen Data Infrastructure – To address the socio-economic and environmental challenges of tomorrow, there is a need to develop robust data infrastructure. This will provide real-time accurate and authoritative geospatial data and analytics and intelligence to support a wide range of initiatives from automation to Digital Twin.

ROLE OF PRIVATE SECTOR:

The private sector has the latest technology knowhow to collect, process, analyse and disseminate geospatial data and information. Further, private industry provides updated geospatial information – in 3D model and HD Map formats which is critical to data infrastructure. To strengthen the geospatial data infrastructure at community, national and global levels, high-resolution geospatial data can be sourced from private geospatial industry players (via PPP models). Foundation data agencies (or national geospatial agencies) can consider partner options outside the traditional geospatial sector, capitalizing on 4IR business advances to strengthen availability of data-as-a-content for digital twins, and predictive analytics.

7.1.2 Resilient Positioning Infrastructure – With 'location' critical to all socio-economic activities, there is a need to ensure the development and augmentation of reliable, non-disrupting, precise and assured Positioning, Navigation and Timing (PNT) services worldwide. Understanding the critical role of PNT systems in critical infrastructure, and the vulnerability of GPS to spoofs and attacks, the US and the European GNSS Agency have already started discussing and deliberating new technology innovations in the resilient PNT ecosystem; the same needs to continue with much vigor and policy push. In particular, with the advent of 5G, IoT, Autonomous Vehicles, Indoor Positioning Technologies, and Contact Tracing Applications (for healthcare), there is a definite need to improve consistency and accuracy of positioning infrastructure worldwide. A robust PNT system – terrestrial or space – will enable uniform, equitable and coordinated access to location and situational information for critical infrastructure of today.

ROLE OF PRIVATE SECTOR:

The Positioning Infrastructure of today, is largely dependent upon a collaborative effort of the public and the private sector. GPS vulnerabilities have enhanced the role of the private sector in creating and operating contingency technology solutions, and layers for Positioning, Navigation and Timing (PNT). Today, many of the leading private companies are increasingly making strategic investments in developing resilient PNT systems – both terrestrial and earth-observation based; and are working with the federal governments to maintain the infrastructure and improve it's capabilities.

Additionally, leading geospatial private companies are playing a critical role in establishing Continuously Operating Reference Stations (CORS) network globally, to provide countries with the benefits of modern GNSS technology.

7.1.3 Geospatial Knowledge Platforms and Services – With the advent of 4IR technologies, there is a need to develop Cloud-based and AI-driven Cloud-based geospatial platforms with both real-time and static data, to deliver actionable information, products, and services for different stakeholders. These platforms will lead to scalability of applications, and geospatial innovation, extending socio-economic benefits to nations worldwide.

ROLE OF PRIVATE SECTOR:

The private sector plays a defining role in providing innovative, autonomous, interactive and dynamic knowledge services to the government and the user sectors, thus, playing a leadership role in geospatial knowledge creation. Further, the private sector is responsible for establishing a cross-linkage between geospatial technologies; and it's embedment with other workflow processes to deliver knowledge services across industry sectors. Furthermore, the private sector with its ability to keep pace with the latest technology advancements in the 4IR space, enables data integration, analytics, modelling and applications at a much faster pace.

7.1.4 Setting up Geospatial Standards and Interoperability Frameworks – Geospatial data comes from varied sources, and from within different ecosystems. To ensure the accurate use of geospatial data in workflow processes, there is a need for the public sector to work in close collaboration with the private sector to ensure the development of standards and interoperable frameworks to ensure the geospatial data collected is (re)used seamlessly, without losing its attribute of knowledge. Further, standards are necessary to harmonize technical specifications for developers, business partners and users to optimize the operations, and applications of geospatial data use. Additionally, interoperability frameworks also increases the compatibility of geospatial data and information with different sectoral workflow data such as building information modelling (BIM), business intelligence (BI), etc., thus enhancing the capabilities and capacities of products and services.

ROLE OF PRIVATE SECTOR:

With the rapid pace of technology advancement, there is a need to develop standards and interoperability frameworks which can enhance data analytics and geospatial application development. The Private sector play a critical role in defining the standards and interoperability frameworks necessary to define how Geospatial technologies and standards are seamlessly integrated into web, business and government systems and enterprises.

7.2 BUILDING ENABLING GEOSPATIAL REGULATORY FRAMEWORKS

There is a need to incorporate geospatial technology solutions as a policy/guideline for all economic sectors, strategies, and procurement guidelines at a national level. Additionally, there is a need to encourage the use of geospatial technologies in all sectoral workflows by mandating geospatial technology (and frontier technology) use in nations' project plans. The sectoral project plans should include detailed and elaborate plans encompassing the different roles and responsibilities, activities, and resources (financial and technology) required during sectoral workflows and lifecycle.

It is also important that geospatial technology and data help nations absorb the climate-change shocks and population growth coming their way. Policy mandates aimed at integrating technology in key features of sectoral workflows will enhance the uptake of geospatial technology solutions for sustainable development. Government authorities should mandate smart technologies and open data sharing (real-time information) to optimize existing systems and reduce strain on the available and limited resources. This will help them prepare for worst-case scenarios, improve operational capabilities, and build capacities for sustainable development. Furthermore, to integrate geospatial data and technology in sectoral workflows there is a need to have enabling policies which facilitate the use of standards-based technologies which enable FAIR access to data. A fair access to data empowers analysts to integrate standardized and interoperable information to develop right applications and products to the decision-makers and provide right knowledge to the users.

7.3 Public-Private Partnership

To develop and augment the geospatial infrastructure of tomorrow, there is a need for public-private geospatial collaborations, which are defined by varied business models, choice of contractual relationships, procurement arrangements, and revenue models. The private geospatial industry proposes benefits and rationales of PPP models across three broad areas:

- Financial Benefits
- Technological Flexibility
- Competence Exchange

The three broad areas were defined during a workshop organized by the World Geospatial Industry Council (WGIC), a not-for-profit trade association of commercial geospatial companies representing the entire value-chain of the geospatial ecosystem. The following broad areas are from the report by WGIC, titled 'Public-Private Geospatial Collaboration: Exploring Potential Partnership Models'**:**

- **Financial Benefits:** Globally, governments of many economies are foreseeing a growing governmental indebtedness and a political restraint with respect to the allocation of funds for advancements in new technologies and geospatial infrastructure. In this context, there is an opportunity for PPPs among the public and private sector stakeholders to supplement the gaps in government funding. These financial benefits are achieved at both macro and micro-economic levels. The necessary investments by the private sector in geospatial infrastructure development lead to more private sector responsibility and ownership and provides for an effective framework for mutual understanding of effective financial accountabilities and responsibilities.
- **Technological Flexibility:** It is not a surprise that the private sector is at the forefront of technology adoption and can adapt and adopt new technologies more quickly and effectively than the public sector. While governments worldwide are building in-house capacities and capabilities to adopt new technologies (or facilitate the adoption of new technologies in different economic sectors), the private sector has an advantage over the public sector. Further, the public sector often finds technology advancements happening at a much faster pace and, therefore, a PPP model will provide them with the required flexibility to adopt the appropriate geospatial technology for the right application. A well-defined PPP model enables flexible technology adoption and integration in a multi-disciplinary manner.
- **Competence Exchange:** A PPP model ensures a significant competence exchange wherein both the sectors draw from their respective competencies. A PPP model is the only way to ensure that the private company works in a national priority project. Further, by partnering with the public sector, the private geospatial technology players have an opportunity for increased innovation. The public sector, on the other hand, can draw upon the private sector's novel and multi-channel expertise in service delivery; better access to financial resources; latest technology know-how; deeper management capabilities and skills; focus on return-on-investments; emphasis of time and priority to key objectives, and gain a better understanding of the real-time knowledge of shifts in consumers

and market behavior. Further, the business entities can adjust their strategic action plans and innovate rapidly in a challenging environment, leading to more effective management and delivery of better services beneficial for citizens.

The element of partnership and collaboration between the public and the private sector is important. The partnerships required for geospatial infrastructure development will be different from those of earlier years but will have the three fundamentals as stated above attached to them for potential geospatial collaboration.

Recommendations:

- Long-term national geospatial agency contracts with industry geospatial data suppliers would encourage industry investment, and the government can benefit from downstream technology developments.
- Geospatial infrastructure organizations, i.e., national geospatial agencies, should consider partnerships with organizations capitalizing on 4IR advances instead of only focussing on traditional geospatial organizations.
- Industry seeks to build PPP models which shall share reward as well as risk. One without the other would not be beneficial for either of the parties.

7.3.1 Geospatial Knowledge Co-Creation and Collaborative Innovation The development of geospatial knowledge is a collaborative process and cannot happen in silos. Therefore, there is a need for industry, national geospatial agencies, and academia and research organizations to cooperatively collect, process, exchange, and improve data to co-create information and knowledge that may have similar or unique benefits for each partner stakeholder involved in the collaboration process. This collaborative approach to geospatial knowledge co-creation shall also ensure a reduction in duplicity of fundamental data created.

Recommendations:

- For an innovative knowledge co-creation partnership, the government procurement and tax regulations need to be open and flexible.
- National geospatial agencies and industry (technology and users) should collaborate to identify the best possible way to co-create fundamental geospatial data.
- Government, national geospatial agencies, industry (technology and user), investment companies, and academia should establish geospatial innovation programs providing developers and data scientists with support for commercialization, fundamental geospatial data APIs, and investment opportunities to name a few.

Additionally, the national geospatial agencies and industry (technology and users) need to collaborate for innovating new products and services focusing on the 4IR. The collaboration can extend beyond technology innovation to develop new business models, support geospatial start-ups and micro-businesses. Such collaborations could result in significant breakthroughs in geospatial infrastructure development and lead to partnerships beyond international boundaries.

7.3.2 Citizen Partnership It is well-known that in today's age of 'social media' and 'smartphones', citizens are effectively one of the major producers and contributors of location data and information. They are the most effective geo-location data source for businesses like retail, marketing, and advertising, restaurants, among many other. Therefore, while citizens engage unconsciously in geo-location activities, there is a need to directly engage and partner with citizens to develop the dynamic geospatial infrastructure of tomorrow.

Recommendations:
Government and national geospatial agencies should create an enabling environment for citizens to contribute to the national geospatial data via their smart phones and social media tools, whilst simultaneously ensuring personal data privacy.

PPP CONTRACTUAL RELATIONSHIPS AND BUSINESS MODELS

Business Model	Description
Design and Build (DB)	Where the private sector designs and builds infrastructure to meet public sector performance specifications, often for a fixed price, or a turnkey basis, so the risk of cost overruns is transferred to the private sector. (Some do not consider DB's to be within the spectrum of PPPs and consider them as public works contracts.)
Operation and Upkeep Contract (O & M)	Where a private operator, under contract, operates a publicly owned asset for a specified term. Ownership of the asset remains with the public entity and the specific instrument often takes the form of a service contract.
Operating License	Where a private operator receives a license or rights to operate a public service, usually for a specified term. For the geospatial community, these types of arrangements are sometimes utilised to operate such governmental assets such as earth observation ground receiving stations, and to provide the opportunity for private sector providers to establish and develop their own ground stations.
Design-Build-Maintain (DBM)	In this category there are a series of variations on the model, which include extensions of responsibilities for operations (DBO) and operations and maintenance (DBMO). This family of P3 models allows for a private entity to design and build (and perhaps maintain and/or operate) a new facility under a long- term lease, with a clear operational ambit. At the end of the lease, the private entity usually transfers the facility to the public sector, ostensibly in a well-maintained state, while ensuring profitability from the nature of a stable long-term contract.
Build-Lease-Operate-Transfer (BLOT)	A private entity receives a franchise to finance, design, build and operate a leased facility (and to charge user fees) for a defined period (longer-term), against payment of a rent.
Buy-Build-Operate (BBO):	Transfer of a public asset to a private or quasi-public entity usually under contract that specifies the assets are to be upgraded and operated for a specified period of time. Public control is exercised through a contract at transfer. (e.g., transfer of Crown or government-owned lands for development)
Build-Operate-Transfer (BOT):	The private sector designs, finances and constructs a new facility under a long-term Concession Contract and operates the facility during the term of the Concession, after which ownership is transferred back to the public sector if not already transferred upon completion of the facility. In fact, such a form covers BOOT and BLOT with the sole difference being the ownership of the facility.
Build-Own-Operate-Transfer (BOOT):	A private entity receives a franchise to finance, design, build and operate a facility (and to charge user fees) for a specified period, after which ownership is transferred back to the public sector.
Build-Own-Operate (BOO):	The private sector finances, builds, owns, and operates a facility or service in perpetuity. The public constraints are stated in the original agreement and through on-going regulatory authority oversight function.
Rehabilitate-Operate - Transfer (ROT)	Identical in structure to the BOT but instead the private sector takes on the responsibility to rehabilitate, upgrade, or extend existing assets.
Concession	The concession model is generally used to permit the design, rehabilitation, extension, building, financing, or operations of a set of services to users. It is generally funded through a governmental subsidy: or in some cases a fee is paid to government; and user-pay almost always forms a critical element of the model.
Private Finance Initiative (PFI)	This approach, first piloted by the United Kingdom, focuses on government contracting private firms to complete and manage public projects. This model does not involve the direct delivery of services to citizens or clients and does add an element of private finance. It has also been criticized for taking government debt off of national balances, thereby hiding national debt.

Source: WGIC Policy Report – 2021-22
Public- Private Geospatial Collaborations – Exploring Potential Partnership Models

8. WAY FORWARD

In conclusion, the way forward for the public and private sector to advance the use of geospatial technologies and to accelerate geospatial innovation, is to work in collaboration and coordination to develop an ecosystem-of-ecosystem approach to achieve the sustainable development goals as outlined by the United Nations.

A dynamic geospatial infrastructure complemented by 4IR is imperative for accelerating geospatial innovations to achieve the SDGs. Robotics, Autonomous Vehicles, AI, Immersive Solutions, all together are transforming the way we work, improving the standard of living of stakeholders to achieve the larger goal of socio-economic development. Further, as geospatial technologies are embedded in various business process such as BIM, C4ISR, to name a few, various sectors are able to use and develop traditional and emerging geospatial applications to improve resource efficiency and productivity, creating high-value impact for economies worldwide and achieve sustainability of everything.

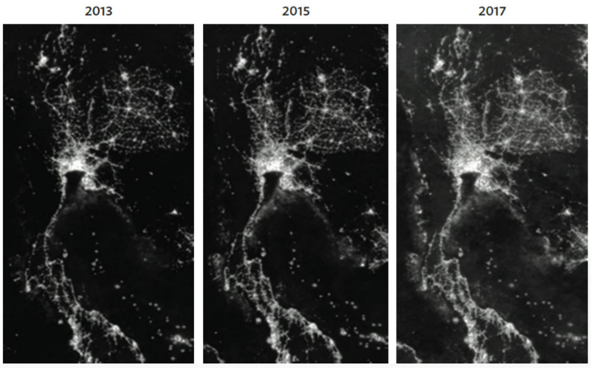
To take advantage of the benefits and impact of geospatial infrastructure, it is recommended that the stakeholders of the geospatial ecosystem strengthen geospatial infrastructure, facilitate the diffusion of geospatial data and information in workflow processes, and develop mechanisms for public and private sectors to collaborate and coordinate with each other to enhance geospatial technological innovations and use globally.

CASE STUDIES

Project Title:

Mapping the spatial distribution of poverty using satellite imagery in Thailand

SDG GOAL 1 No Poverty



Geospatial Technology Used:

Satellite Imagery, Data Integration and AI

Project Brief:

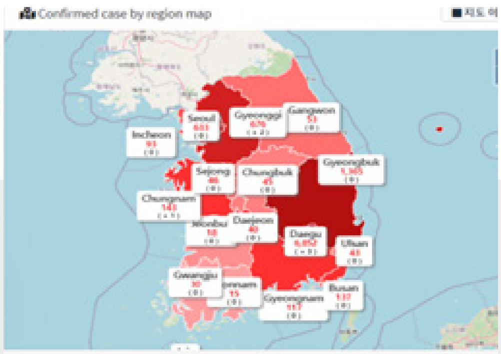
Data on night light intensity were taken from the Visible Infrared Imaging Radiometer Suite (VIIRS).

- To align with the goal of providing Thai poverty statistics pertaining to specific years, custom year composites were generated from published monthly composite images published by VIIRS.
- In minimizing the effect of outliers, the median of monthly values was calculated. Further data processing was done to ensure consistency of the resolution of night light data with the daytime satellite imagery in preparation for the CNN modelling (ADB 2020)
- The satellite images on night lights shows the considerable increase of the areas having access to the electricity from the year 2013 to 2017, from which it can be inferred that the poverty has reduced considerably during the mentioned time period.

Project Title:

Tracking the spread of COVID-19, South Korea

SDG GOAL 3 Good Health & Well Being



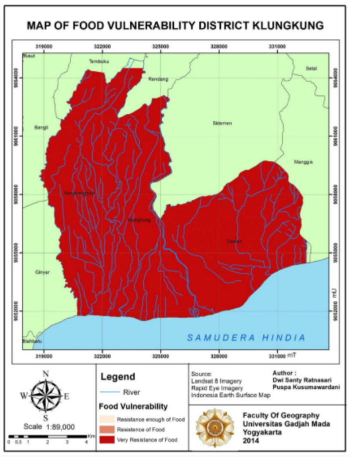
s) - a practical example of geospatial-based COVID-19 response (image:

Geospatial Technology Used:

GIS & GPS

Project Brief

- Data from GPS tracking of phones and cars, credit card transactions, travel histories, and CCTV footage have been analyzed to identify high-priority cases and track infected individuals.
- Strong legal and regulatory framework in Korea enabled integration of spatial data.
- At a central level, the Korean National Spatial Data Infrastructure Portal ensured collaboration among the Ministry of Land, Infrastructure and Transport; the Ministry of Information and Communication; the Korea Centers for Disease Control and Prevention; the National Police Agency; telecommunication companies; and 22 credit card vendors.
- By interlinking databases, they combined national health insurance information, immigration, and customs databases to identify potential disease areas and notify the public – if your neighbor tested positive, you were alerted via SMS within 24 hours.



Project Title:

Spatial modelling for food vulnerability using remote sensing data and GIS, Klungkung Regency, Bali

SDG GOAL 2 Zero Hunger

Geospatial Technology Used:

Remote Sensing and GIS

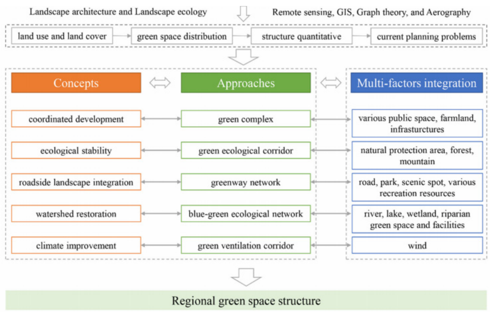
Project Brief:

- Remote sensing can help to assess food insecurity through a spatially variable soil critical level, the rate of erosion, and the potential for PUSO (crop failure).
- With remote sensing technology, the analyst will know the locations that are vulnerable for experiencing food insecurity, and it will help the local government to distribute the food needs for the community based on the analysis.
- The mapping of food insecurity is very helpful for managing equitable distribution of food to the local community needs.
- Food vulnerability can be modelled by using GIS and remote sensing is which used as an input to food vulnerability parameter detection.
- There is no high risk of food insecurity area in Klungkung.
- Klungkung is dominated by area of degraded land, but there is no food vulnerability area in Klungkung because every parameter that caused food vulnerablity has low weight.
- Food vulnerability is influenced by precipitation anomaly, vegetation cover, degradation land, and harvest failure risk.

Project Title

Conceptual Planning of Urban–Rural Green Space from a Multidimensional Perspective: A Case Study of Zhengzhou, China

SDG GOAL 11 Sustainable Cities and Communities



Geospatial Technology Used:

Remote Sensing, GIS, graph theory, and aerography

Data Collected

10-m resolution global land cover image of 2017, 12-m digital elevation model (DEM) image, Landsat 8 (Level 1T, 2017–4–28, 30-m resolution) image, Road–river data, Forest data, urban planning and construction data.

Project Brief:

- The study proposes an optimized framework for green-space structure planning with a multidimensional approach using various technical and analytical techniques.
- Five green-space structures planned in the study were- green complex, green ecological corridor, greenway network, blue- green ecological network and green ventilation corridor.
- This integrated framework offers an opportunity for achieving coordinated development, ecological stability, roadside landscape integration, watershed restoration, and climate improvement and was tested over Zhengzhou region of China.

Project Title

Impact Assessment Analysis of Sea Level Rise in Denmark: A Case Study of Falster Island, Guldborgsund

SDG GOAL 13 Climate Action

Proposed workflow to derive statistics for various SLR scenarios.

Geospatial Technology Used:

Remote Sensing, GIS

Data Collected

High resolution Digital Elevation data by LiDAR Scanning, Sea Level Data, municipal framework

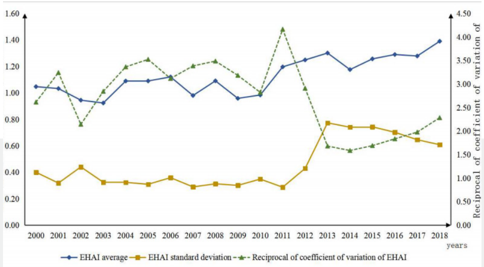
Project Brief:

- The study aims at including more sectors of the economy and stakeholders of the surrounding region to mitigate the future Sea Level Rise (SLR) instead of using localized temporary remedies.
- The workflow was developed to analyze the impacts of sea level rise in the coastal municipalities of Guldborgsund, Denmark
- An estimated 98.6% of the structures in the region are estimated to be flooded in a 2100 scenario with 99% of the road network coverage as well.
- The study empowers other communities at risk of sea level rise to plan their adaptation using geospatial analysis and climate change projection data.

Project Title

Ecosystem Health Assessment of Shennongjia National Park, China

SDG GOAL 15 Life on Land



Changes in the EHAI statistics of Shennongjia National Park each year.

Geospatial Technology Used:

Remote Sensing, GIS

Data Collected

Normalized Difference Vegetation Index (NDVI), land use data, Leaf Area Index (LAI), 16-m and 2-m resolution GF-1 satellite images

Project Brief

- In this study, Vitality Organization Resilience (VOR) model was used for the assessment of ecosystem health.
- Parameters such as LAI, LUI, FPAR were retrieved as inputs to the VOR model in order to calculate Ecosystem Health Assessment Index (EHAI)
- The rate of improvement of the ecosystem's health level from 2016 to 2018 was observed to be 2.5-times that of the overall rate.
- The ecosystem health level of non-nature protection areas was found to be superior to that of nature reserves from 2016 to 2018 in the study.

Project Name:

City Resilience from natural disasters with GIS[1]

SDG GOAL 11 Sustainable Cities and Communities

Mission Statement:

To implement GIS enterprise-wide and put a strong focus on standards, centralization and ensure no silos of information exists. Building enabling infrastructure by embracing GIS to make cities more resilient.

Geospatial Technology Used:

GIS

Project Brief:

- A severe storm in June 2013 downed 1,800 of the city's street trees.
- The city professionals used an ArcGIS based app called MapIt on mobile devices to develop an inventory of the fallen trees which enables the removal of the tree debris, removal of the stumps, plans of reimbursements and replantation of trees.
- sing MapIt, operation data, or location data in this case is immediately integrated with the layers using ArcGIS on mobile devices.
- The long-term benefit is that it streamlines data collection process and enabled collaboration, communication and analysis on the basis of the needs and requirements of the users.
- The use of GIS helped the city remove hazardous fallen trees, repair infrastructure damage (near fallen trees), and recover funds. The purpose of the application is to enhance the city's resiliency and save the city's money.

Building Resiliency with GIS: https://www.esri.com/about/newsroom/arcuser/building-resiliency-with-gis/

ABBREVIATIONS

AR – Augmented Reality

AECAR – Architecture, Engineering and Construction

AIAR – Artificial Intelligence

BFSIAR – Banking, Financial Services and Insurance

BIMAR – Building Information Modelling

C4ISRAR – Command, Control, Communications, Computers (C4) Intelligence, Surveillance and Reconnaissance

DDIAR – Data-driven Innovation

EMLAR – Electromagnetic Locator

ERPAR – Enterprise Resource-Planning

4IRAR – Fourth Industrial Revolution

GNSSAR – Global navigation satellite system

GPRAR – Ground Penetrating Radar

GDPAR – Gross Domestic Product

GPSAR – Global Positioning System

GISAR – Geographic Information System

IDCAR – Data Corporation

IoTAR – Internet of Things

MLAR – Machine Learning

PSNAR – Private Sector Network

PPPAR – Public-Private Partnership

PNTAR – Positioning, Navigation and Timing

R& DAR – Research and Development

SDGsAR – Sustainable Development Goals

UAVsAR – Unmanned Aerial Vehicles (UAVs)

UNAR – United Nations

UN-IGIFAR – United Nations Integrated Geospatial Information Framework

VRAR – Virtual Reality

WEFAR – World Economic Forum

WGICAR – World Geospatial Industry Council

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