Leveraging GeoAI:

A Strategic Approach for Utility Companies

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01 Introduction

Introduction

The primary objective of utility companies is to effectively plan and manage their infrastructure to ensure reliable delivery of essential services like water, electricity, natural gas and telecommunication to its customers. Geospatial data accurately maps utilities on the surface of the earth, along with its technical and physical parameters. Therefore, it is critical for effective infrastructure management, enabling precise supervision of assets such as power lines, pipelines, and telecom towers within the electricity, water, gas and telecommunication sectors. It helps in decision making by assisting in the optimisation of network configurations, identifying upgrading needs and accelerating fault detection and maintenance processes.

Geospatial and AI market growth: A rapid transformation

Global geospatial market: Valued at **$560.18B in 2024**, projected to hit **$1T by 2028** (CAGR **15.9%**).

Key contributor: The utilities sector (electricity, water, gas) holds **18% market share**.

Middle East geospatial market: Expected to grow from **$1.16B (2024) to $1.71B (2029)** (CAGR **8.15%**), driven by smart grids, meters, and asset management.

Global AI market: Estimated at **$196.63B (2023)**, set to soar to **$1.81T by 2030** (CAGR **36.6%**).

Utilities & energy AI market: From **$15.45B (2024) to $75.53B (2034)**.

Middle East AI market: Growing from **$11.92B (2023) to $166.33B (2030)**, fueled by national AI strategies and sector adoption.

The accelerating adoption of geospatial and AI technologies highlights their expanding role across industries, particularly in utilities and energy.

This is the ideal moment to embrace and leverage Geospatial Artificial Intelligence (GeoAI) which is an integration of Geospatial data and analysis with AI techniques and technologies for extracting meaningful insights from the data. The **Geospatial AI market in Middle East and North Africa** recorded a value of **US$57.3mn in 2023** and is anticipated to reach approximately **$222.8mn by 2031,** growing at a **CAGR of 18.5%** during the forecast period **2024-2031.**[6] This indicates the transformative possibility it holds for the entire region.

In the next few sections we will focus on understanding different components of GeoAI, different use cases, challenges in implementing GeoAI and future trends for the regional utilities sector in Middle East.

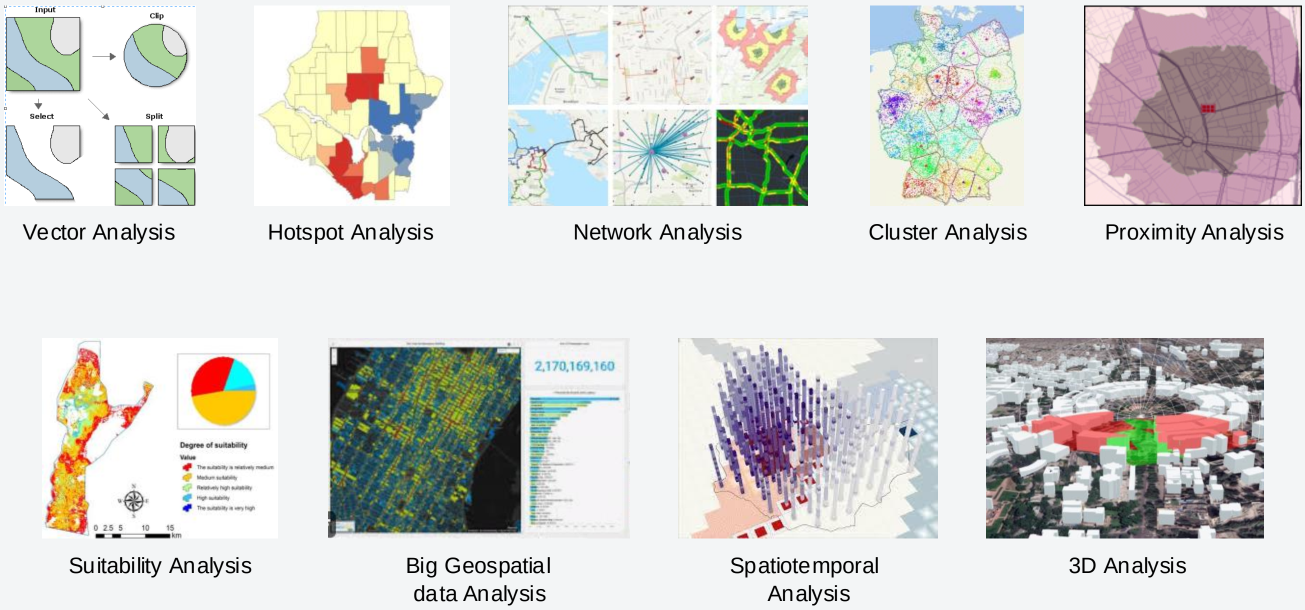
02

Convergence of geospatial analytics with AI

Convergence of geospatial analytics with AI

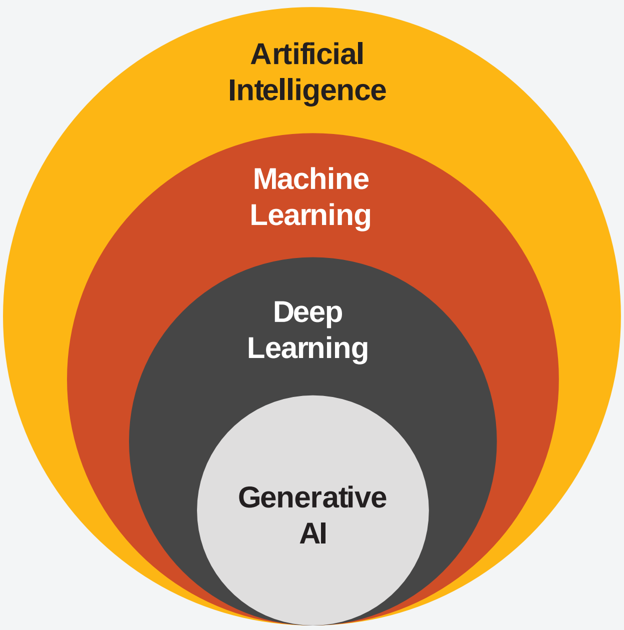
Geospatial analytics is the science of analysing geographical and spatial data to identify patterns, trends and relationships between different assets, people or places. It integrates remote sensing, Geographic Information System (GIS), Global Position System (GPS) and big data to analyse location-based information across multiple dimensions to produce outputs in the form of maps, graphs, statistics and cartograms.

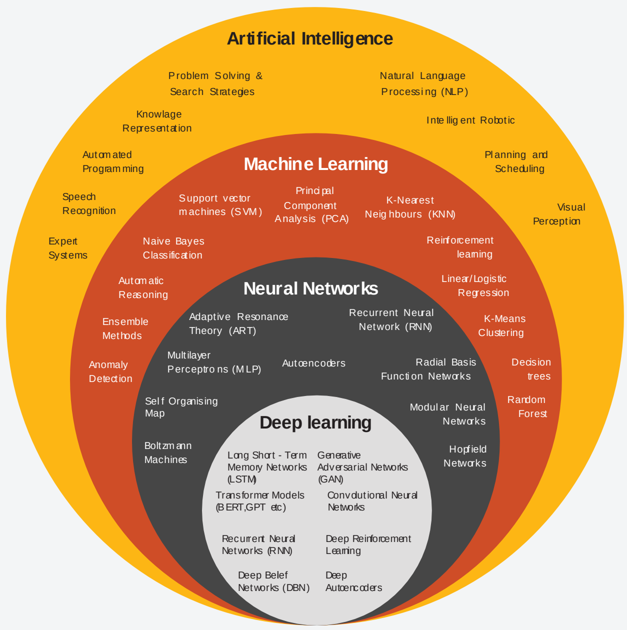
Figure 1: Geospatial Analytics



Artificial Intelligence (AI) is the science and engineering of making intelligent machines that can simulate human learning, comprehension, problem solving, decision making, creativity and autonomy. Machine Learning (ML) is a subset of AI which involves creating models by training an algorithm to learn patterns, make predictions or decision based on data without being explicitly programmed. Deep Learning is a subset of machine learning that uses multilayered neural networks, that is inspired by how the human brain operates to take complex decisions. Generative AI (GenAI) is a subset of Deep Learning which can produce new content like text, imagery, audio, and synthetic data based on the inputs from humans in the form of natural language prompts.

Figure 2: Artificial Intelligence

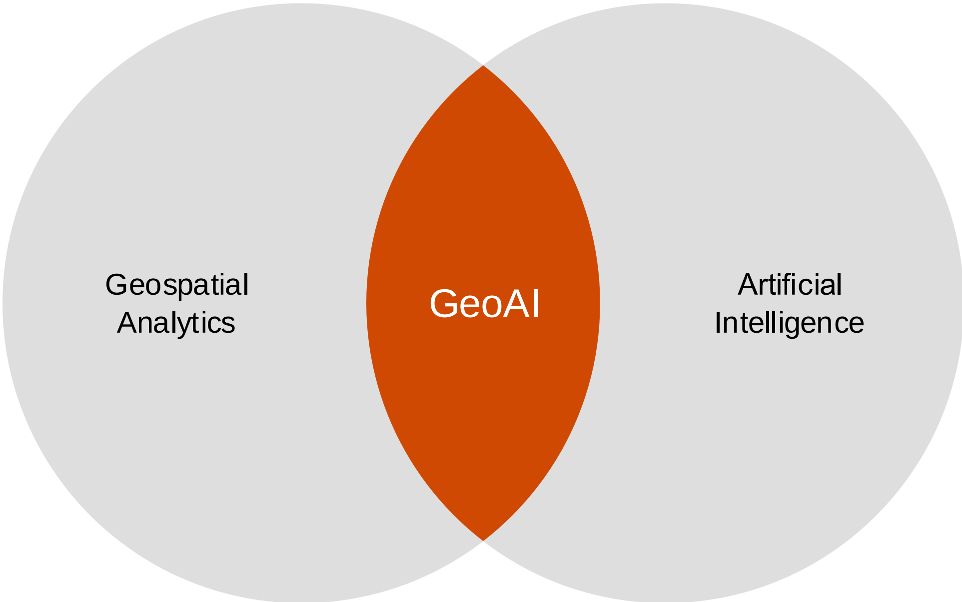




GeoAI is an amalgamation of geospatial data, science, and technology with AI to extract meaningful insights and solve spatial problems.

If we consider AI as the development of machines that can think and reason like humans, GeoAI represents an intersection of AI and geography in developing advanced systems that make use of geospatial big data to perform spatial reasoning and location-based analysis, much like humans.

Figure 3: Geospatial Artificial Intelligence (GeoAI)



While each of these technologies has unique strengths, limitations and applications, it is crucial to understand how they can be effectively leveraged to address business challenges in the utility sector. The table below provides a comparative overview of key parameters and guidance on selecting the appropriate technology.

Parameter	Geospatial Analytics	Artificial Intelligence (AI)	Geospatial Artificial Intelligence (GeoAI)
Focus	Understanding spatial relationships, patterns, and trends	Solving general problems using intelligent algorithms and techniques across domains	Solving geospatial problems using AI/ML techniques
Primary data types	Spatial data (vector, raster) and non-spatial attributes	Any type of data: text, images, video, numerical, categorical, etc	Spatial and temporal data with AI-ready formats
Key techniques	Spatial statistics, geospatial modelling, cartography	Machine learning, deep learning, natural language processing, computer vision	Deep learning, machine learning, computer vision applied to spatial data
Outputs	Maps, spatial models, reports and dashboards	Predictions, classifications, recommendations, decision support systems	Predictive spatial models, automated feature extraction, intelligent insights
Automation	Limited; manual intervention is needed	Fully automated, depending on the system's design and complexity	High automation through AI/ML models and neural networks
Scalability	Moderate; dependent on geospatial data tools and processing	Highly scalable using cloud and distributed computing environments	High; leverages AI-driven scalability with cloud and distributed computing
Complexity	Relatively simpler; focuses on spatial data analysis workflows	Varies; can range from simple algorithms to overly complex neural networks	More complex due to integration of AI/ML with geospatial data
Usage example	Optimising power line routes	AI Chatbot for citizens for outage reporting	Predictive maintenance of power lines using drone imagery

Geospatial analytics gains significant power when enhanced by AI-driven capabilities, such as object detection from imagery, automation, scalability for large datasets, improved accuracy, faster processing and immersive technology.

GeoAI combines predictive, prescriptive insights with geospatial data from drones, satellite imagery and helps to solve the problem in spatial context. It also helps to automate geospatial analytics to make them autonomous and work with minimum human supervision. GeoAI brings the geographic context to solve real world problems using multiple AI techniques object detection, spatial optimisation, natural language processing, integration with multiple data sources, etc.

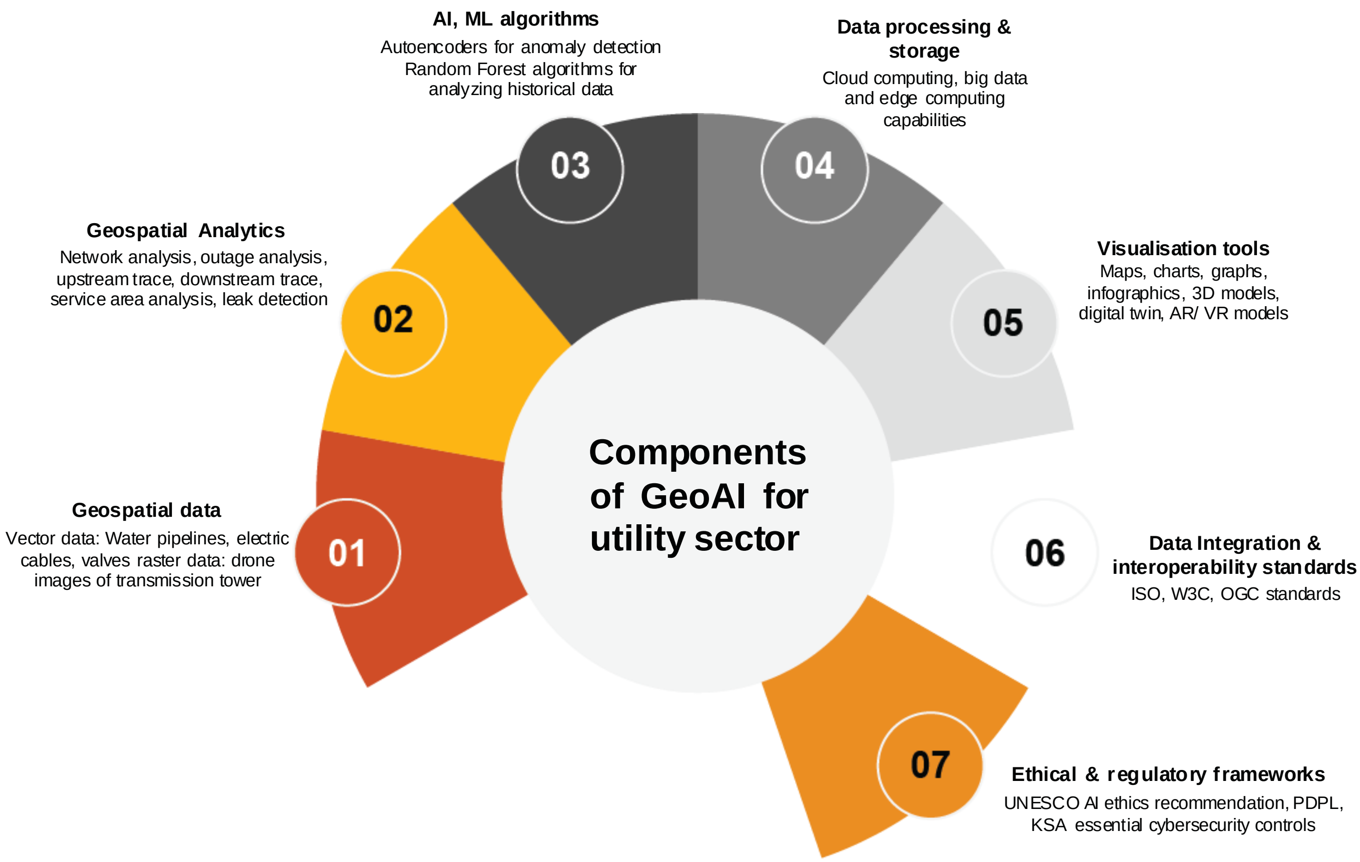
GeoAI applications span across sectors such as urban planning (smart city development), utilities (pipeline monitoring), agriculture (precision farming), transportation (traffic management), environmental conservation (climate change modelling), and public health (epidemic tracking), enabling data-driven decision-making and enhanced operational efficiency. However, the focus of this paper will be applications of GeoAI for utility sector, including electricity, water, gas and telecommunication.

03 Components of GeoAI for the utility sector

Components of GeoAI for the utility sector

The recipe for developing, implementing an effective and robust GeoAI solution for utility sector should include all the key ingredients like geospatial data, geospatial analytics, AI, ML algorithms, data processing, storage, visualisation tools, data integration, interoperability standards and ethical regulatory frameworks.

Figure 4: Components of GeoAI for the utility sector



The table below shows how each component can be supported by industry standard open source or proprietary tools/ platforms.

Component	Supported tools and platforms
Geospatial data	Raster data can be created from different types of sensors like Satellite, Drone, Aerial, etc. Vector data can be created by digitizing raster data or by taking measurements of earth's surface or assets through different surveying techniques like total station, GPS, LiDAR, etc.
Geospatial analytics	Open-source platforms: QGIS, GRASS GIS, PostGIS GeoServer, SAGA GIS, R with spatial packages Proprietary platform: Esri ArcGIS, Hexagon Geomedia, ERDAS IMAGINE, Bentley Maps, etc.
AI, ML, Deep Learning algorithms, techniques	Open-source platforms: TensorFlow, PyTorch, Apache Spark MLlib, Scikit-Learn. Proprietary platform: Google Vertex AI, AWS SageMaker, Azure AI, IBM Watson, OpenAI GPT (ChatGPT), NVIDIA Jetson, etc.
Data Processing and Storage	Open-source platforms: OpenStack, CloudStack, Eucalyptus, Open Horizon, EdgeX Foundry, etc. Proprietary platform: Amazon Web Services (AWS), Microsoft Azure, Google Cloud Platform (GCP), IBM Cloud, Oracle Cloud, NVIDIA Jetson, Microsoft Percept, etc.
Visualisation tools	Open-source platforms: QGIS, GRASS GIS, PostGIS GeoServer, SAGA GIS, R with spatial packages, Cesium, Unity, Google Earth, etc. Proprietary platform: Esri ArcGIS, Hexagon Geomedia, ERDAS IMAGINE, Bentley Maps, PowerBI, Tableau, Microsoft HoloLens, etc.
Data integration and interoperability standards	Data Integrations is supported by the above Enterprise applications in Open-source and Proprietary platforms. Interoperability standards are followed by most of the industry standards platforms include International Organization for Standardization (ISO), World Wide Web Consortium (W3C) and Open Geospatial Consortium (OGC) standards
Ethical and regulatory frameworks	International regulations which deals Global Ethical and Regulatory Frameworks include Organisation for Economic Co-operation and Development (OECD) AI Principles, UNESCO AI Ethics Recommendation Data protection and Privacy laws: General Data Protection Regulation (GDPR), Personal Data Protection Law (PDPL) Cyber laws: National Institute of Standards and Technology (NIST) Cybersecurity Framework, KSA Essential Cybersecurity Controls (ECC)

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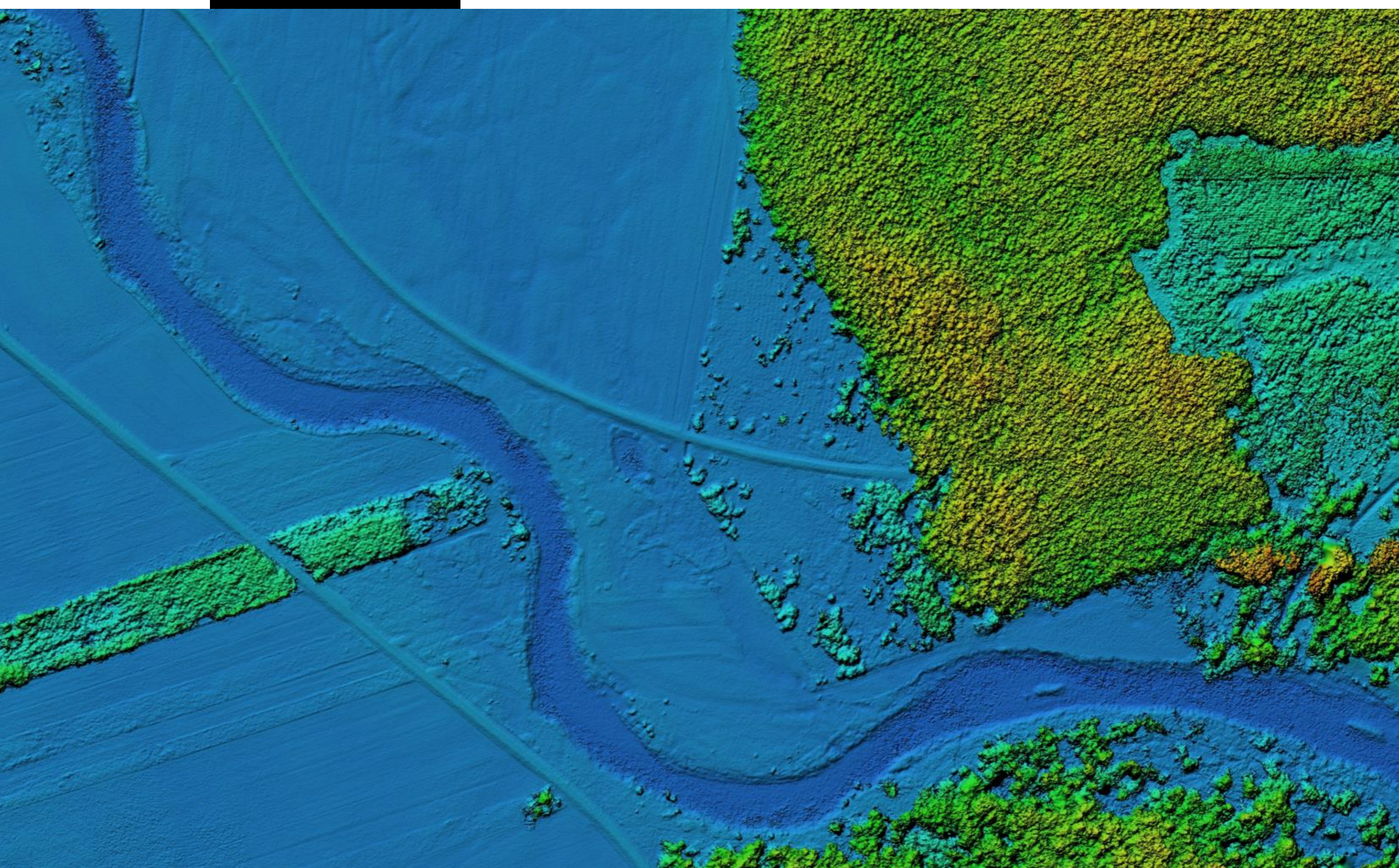
GeoAI use cases in utility sector



GeoAI use cases in the utility sector

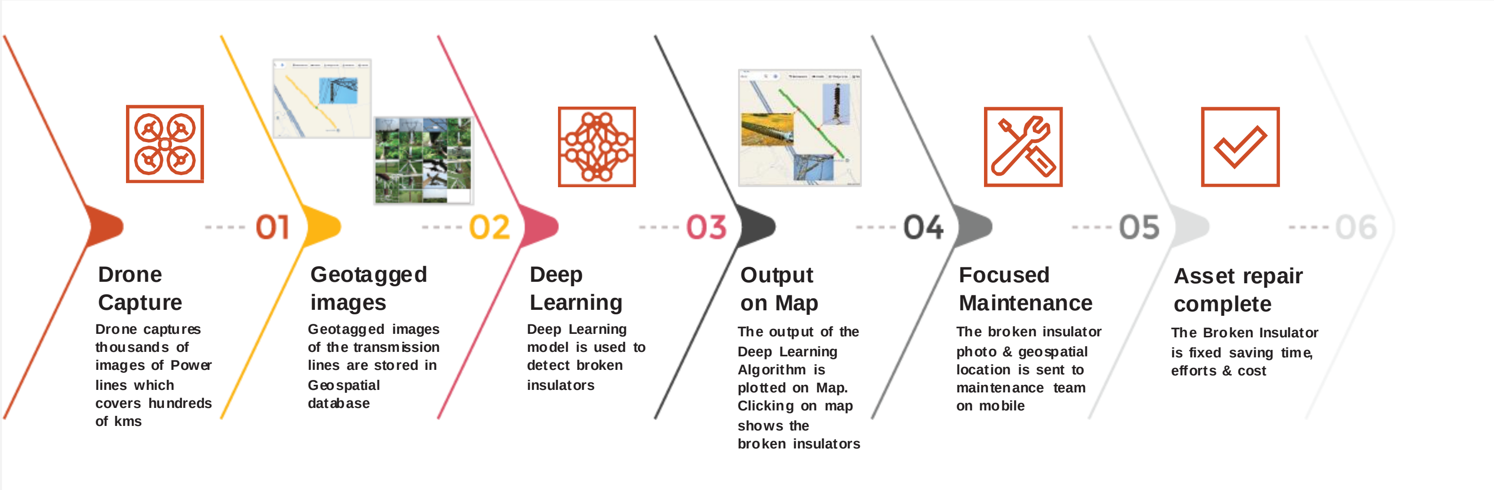
The proliferation of GeoAI in Middle East for the utility sector has been primarily driven by region's urgent requirements for sustainable development, efficient resource management and technological modernisation. GeoAI is increasingly recognised as key enabler in addressing critical challenges across utility sectors while aligning with regional aspirations for sustainable economies and smart cities.

Following are some of the applications of GeoAI in the utility sector:

Use cases	Utility sectors	Technology components	Benefits
Predictive maintenance and Fault detection	Electricity, water, gas, telecommunication	Drones, ML, spatial analytics	Reduced downtime, cost savings, asset lifespan extensionextension
Load forecasting and demand response	Electricity	Smart grid, smart meter, geostatistics, ML	Demand prediction, energy efficiency, peak load management
Energy distribution optimisation	Electricity	Smart grid, smart meter, network planning, ML	Grid reliability, energy loss reduction, optimised supply
Emergency response and damage assessment	Electricity, water, gas, telecommunication	Satellite imagery, drone, change detection, network trace	Faster restoration, real-time insights, reduced service impact
Leak detection and prevention	Water	IoT, satellite, drone, pressure sensors, spatial analysis	Water/gas loss reduction, cost savings, risk mitigation
Route optimisation for new pipelines	Water	Raster analytics, network planning, vector analytics	Cost-effective planning, environmental sustainability
Asset monitoring using digital twin	Electricity, water, gas, telecommunication	IoT, remote sensing, ML, geospatial analytics	Real-time insights, proactive maintenance, operational efficiency
Water demand forecasting	Water	Water meters , geospatial, geostatistical analytics	Resource optimisation, waste reduction, supply reliability
Non-revenue water management	Water	Water meters, pressure sensors, network modelling, drone, spatial analysis	Revenue increase, water loss reduction, conservation
Gas leak detection and monitoring	Gas	Satellite and drone imagery, IoT sensors, ML, location analytics	Safety enhancement, environmental protection, regulatory compliance
Security and intrusion detection	Gas	Video analytics, drone imagery, thermal imagery, ML, location analytics	Infrastructure protection, regulatory compliance, operational safety
5G network planning	Telecommunication	Network planner, geospatial analytics	Accelerates rollout, reduces deployment costs, and ensures optimal coverage and connectivity.
SIM card fraud detection	Telecommunication	Telecom database, AI, location analytics	Enhances security by preventing revenue loss and ensuring customer trust.
Network traffic optimisation	Telecommunication	Network traffic database, ML, geospatial analytics	Prevents congestion, improves service quality, and optimises bandwidth usage.
Route optimisation for field teams	Telecommunication	Route optimisation, Geospatial analytics, field apps data	Reduces travel time and costs, increases efficiency, and improves service delivery.
Targeted marketing	Telecommunication	Customer network data, marketing database	Improves customer engagement, increases revenue, and enhances marketing ROI.
Coverage gap analysis	Telecommunication	Network coverage and tower data, geospatial analytics	Guides infrastructure expansion to maximise user reach and minimise service gaps.

Case study: **Detecting broken insulators on power lines using GeoAI**

Electric transmission and distribution companies manage power lines that usually span across large areas, usually thousands of kilometers. It is often a daunting task for the maintenance team to identify manually broken insulators by visual inspection. With the use of drones that capture images of the power lines, the laborious task of visual inspection is completed. The figure below shows a workflow of using GeoAI tools to automate the process of identifying locations of the broken insulator with evidence.



In the first step the drone captures thousands of images of the power lines. Drones can reach and cover areas of transmission lines which are not accessible by roadways for the maintenance team.

In the second step, thousands of geotagged images are stored in the geospatial database with locational information. The user can click on any location on the map and view the images of the power lines at that location. This helps to overcome the challenge of manually viewing all images and accurately identify broken insulators.

In the third step, deep learning algorithms which are trained on images of broken insulators, flashed insulators and similar scenarios can detect the anomaly from thousands of images in few minutes, thus saving huge time, efforts and cost while being accurate.

In the fourth step, deep learning algorithms highlight broken insulators with different colours by plotting them on map for easy identification. The user can click on the map and verify the image of the broken insulators.

In the final step, the map locations with photos are sent to the maintenance field crew on their mobile phones. This not only enables them to accurately reach the location of repair but also ensures that they carry appropriate tools and replacement devices for complete the job.

This workflow helps the power utilities team to accurately identify exact locations of the broken insulators for focused maintenance which saves time, effort and costs.

Following are some of the success stories demonstrating how different utility companies have implemented GeoAI.

One of the major gas network operators in Europe used a combination of optical and radar satellite imagery for monitoring over 160km of high-pressure gas pipeline, which is routed through forests, fields as well as through built-up areas. Various GeoAI tools were employed for time series analysis, change detection and other spatial analyses, revealing ground deformations in pipeline areas. These deformations were classified into categories ranging from greater than 2 cm/year to less than 10 cm/year.

Vegetation exposure to pipelines were classified from 3m to less than <10m based on the proximity of the vegetation to the pipelines. The use of GeoAI tools saved them operation maintenance cost, time and provided them insights on their pipeline which were suspectable to risk by ground deformation and vegetation in timely manner. They were able to take corrective actions on identified focused areas.[7]

A **leading telecommunication** in Middle East faced challenges in optimising their network performance which included identifying weak signal zones, managing network traffic during peak events like concerts or sports matches, planning efficient 5G deployment across diverse urban and rural landscapes. The company implemented different GeoAI use cases like Call routing optimisation which deployed ML algorithms to direct calls through the least congested routes, ensuring uninterrupted communication. Real time spatial analytics were used during sports events, music concerts to monitor user density and adjust network resources in real time to maintain optimal performance.

By deploying different GeoAI tools the company saw a **25% reduction in deployment costs** through better network planning. They also observed a **20% increase in mobile internet speeds** which resulted in improving services and resulted in user satisfaction. The company also observed faster response times to outages and disruptions, reducing service downtime.[8]

05 Challenges in GeoAI Implementation for utilities

Challenges in GeoAI implementation for utilities

Implementing GeoAI solution for utility providers offers the possibility of increasing efficiency, availing resources appropriately, and improving the level of intelligence in the use of available geo-spatial data. However, the approach for achieving these goals is fraught with different challenges. These include controlling large and dispersed datasets, assimilating GeoAI solutions with existing ones and high initial implementation costs. More so, utilities are dealing with internal conflicts, shortage of AI skills and is exposed to heavy regulations. Other grey areas, namely AI model bias and invasion of privacy also add complications. Meeting these challenges will require defining clear strategies that allow for phased implementation of the changes, clear communication of the changes, ease of expansion as well as collaboration between the technology providers and the users.

01 Data challenges

- **Quality and accuracy**: Many utility providers lack up-to-date data; completeness of the data is also an issue along with fragmented data.
- **Integration**: Consolidating data from disparate sources like IoT, geospatial systems, Asset management, CRM, ERP and other legacy systems is a challenge due to absence of standardised data models.
- **Volume management**: The volume of data from remote sensing sources like drones, satellites, field survey, IOT is growing continuously and processing and managing the data effectively is challenging.

02 Technology and infrastructure

- **Legacy system:** It is difficult to integrate with legacy systems due to lack of interoperability.
- **Initial investments:** Implementation of GeoAI system my require initial investments or technology refresh which can add additional costs to existing IT budget.
- **Scalability:** The utility grids expand it is essential to maintain the scalability of GeoAI solutions and associated tech stack.

03 Organisational barrier

- **Resistance to change:** Employees may resist AI adoption due to unfamiliarity of the technology and fear of job replacement.
- **Lack of expertise:** The utility companies may not have experts in Geospatial and AI technology in house, which makes they rely on external vendors.
- **Workflow disruptions:** Mundane tasks which can be automated using AI may temporarily disrupts the existing workflow creating confusion among the staff.

04 Regulatory and security concerns

- **Data privacy:** It is necessary to be cautious about privacy concerns when collecting consumer data and using it for analytical purposes.
- **Cybersecurity risk:** Since GeoAI system are integrated to critical utility infrastructure they may be vulnerable to cyberattacks and hence required effective security measures.
- **Regulatory compliance:** It is important to ensure that GeoAI systems meet the local and international standards, which may vary in some parts of the world.

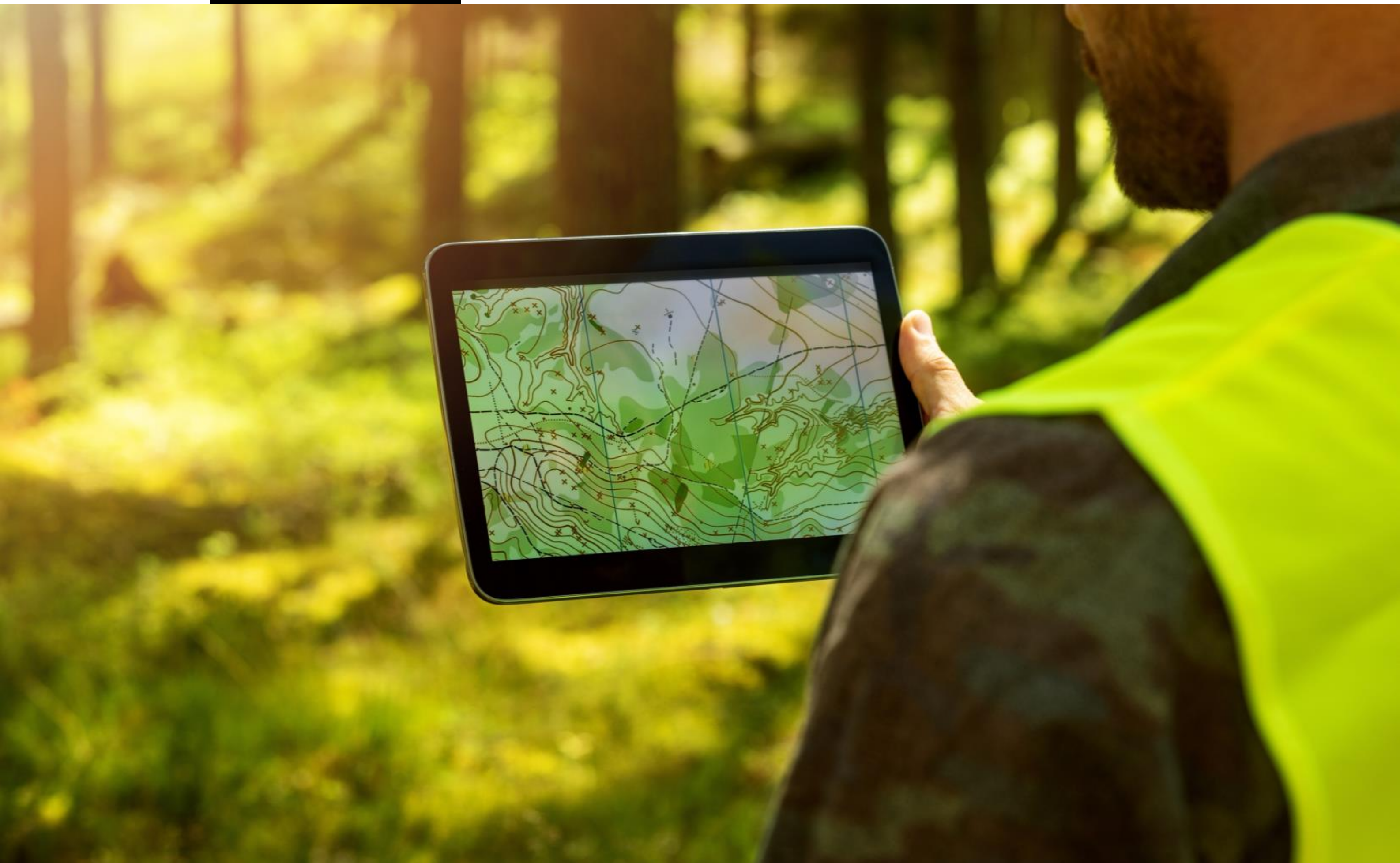
05 Interpretability of AI models

- **Complexity:** Advanced GeoAI models are usually based on deep learning and sometimes it is difficult to explain their decisions making them act like “black box”.
- **Accountability:** Lack of interpretability can lead to operational risks and reduced trust among stakeholders, especially in safety-critical applications. Hence it is important to use Employing Explainable AI (XAI) and using interpretable models, when possible, to address these concerns.

06 Ethical Implications

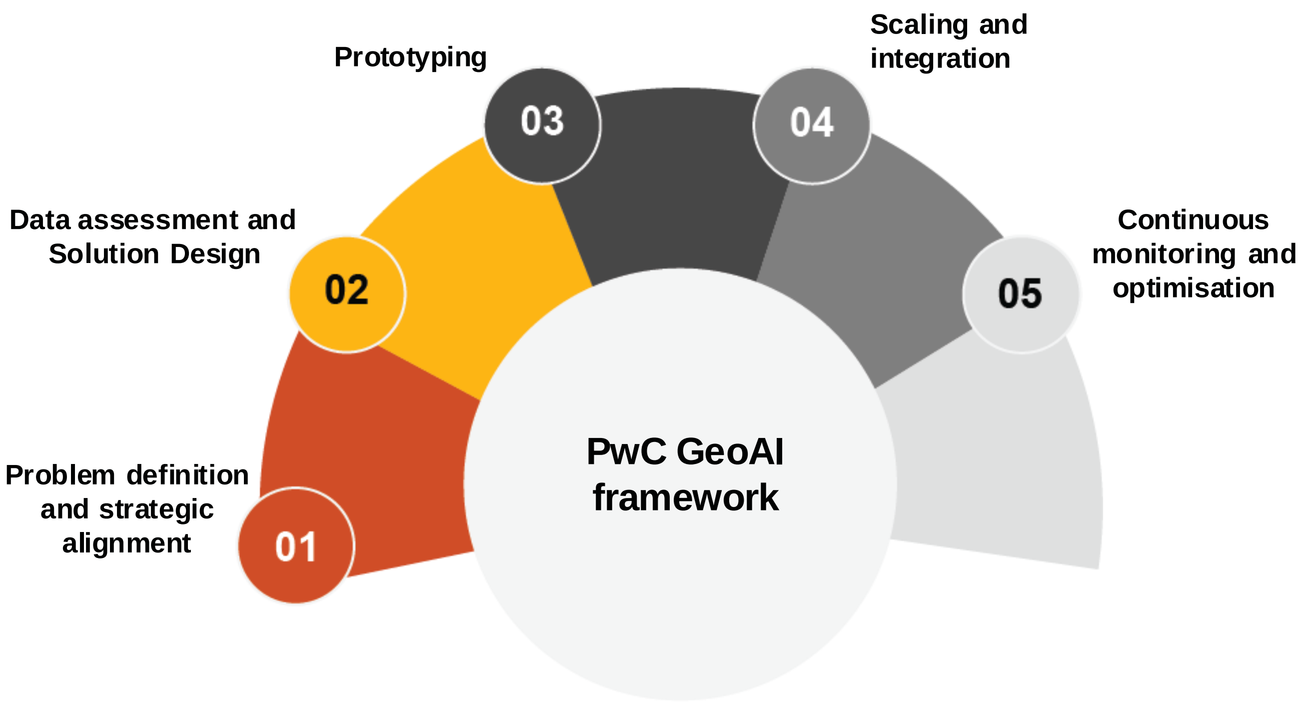
- **Bias:** The training sets used in AI may contain different types of biases like geographical, selection, coverage, reporting, algorithmic, etc. It is important to consider localisation aspects and other relevant aspects for targeted implementation when considering training datasets
- **Job replacement:** Automation of survey, field inspections may result in workforce reduction which is likely to raise concerns among the workforces.
- **Fairness:** It is important to distribute the benefits derived from AI derived insights e.g. uninterrupted power supply in rural and urban areas remains a challenge.

06 Empowering utilities through GeoAI



Empowering utilities through GeoAI

Utility company should embrace the GeoAI by combining their existing Geospatial platforms with AI to optimise their operations, improve customer experiences, lower costs, and foster sustainability. To embark on the journey of implementing GeoAI solution, utility companies can follow PwC's GeoAI framework:



Problem definition and strategic alignment

1. Identify core challenges

- Identify core business challenges.
- Classify them into different categories of planning, operations, maintenance, regulatory.

2. Align with business goals

- Align GeoAI initiatives with organisation strategic goals and objectives.
- Align GeoAI initiatives with different stakeholders in the value chain.

3. Maturity level assessment

- Current state assessment in four aspects: people, process, data and technology.
- Benchmarking your maturity against peers.
- Identify gaps and areas for improvement to align with best practices.
- Outline steps for advancing to the next maturity stage.

Data assessment and solution design

1. Evaluate data readiness

- Conduct data maturity assessment to analyse the geometric coherence, topology validation, spatial accuracy, completeness, consistency, currency and usability of existing geospatial data.
- Conduct assessment of data governance for analysing data collection, storage, sharing, regulatory and ethical practices.

2. Solution design

- Propose technical architecture for implementation of GeoAI applications.
- Propose GeoAI use cases, tools, analytics addressing the business requirements.

Prototyping

1. Define objectives and scope

- Define objectives and scope of prototyping the GeoAI application.
- Propose success criteria for implementation of prototype models.

2. Develop and implement a prototype

- Design GeoAI models that integrate geospatial data, for specific use cases.
- Develop and implement minimum viable product focusing on high impact use cases.

3. Test and validate

- Conduct rigorous testing with real-world data to validate accuracy, performance, and scalability.
- Collect feedback from stakeholders and end-users to refine the application.
- Measure the success of the prototype and provide feedback.

Enterprise Implementation and Integration

1. Enterprise-wide roll-out

- Based on the feedback of prototype, modify the design considerations and update the technical architecture for implementation.
- Design enterprise integrations services of GeoAI applications with existing IT systems.

2. Change management

- Design Change Management plan focusing on awareness, desire, knowledge, ability, and reinforcement for seamless adoption.
- Involve all stakeholders during the implementation of the GeoAI applications.

Continuous monitoring and optimisation

1. Operating model

- Prepare an operating model for the organisation focusing on different aspects like governance structure, responsibility matrix, standards operating procedures, KPIs, risk management, training plan.

2. Optimisation

- Optimise the processes, models, tools based on feedback received from different stakeholders

GeoAI can be the game-changing innovation that could lead the utilities industry to insights-driven, better decisions toward smarter operations and superior customer experiences. Utility companies can manage infrastructure proactively, optimise resource allocation, and improve reliability by harnessing the power of geospatial data combined with AI. With continued industry challenges on the rise, GeoAI will ultimately enable utilities to stay ahead of not only emerging demands but also forge a more sustainable, resilient, and customer-centric future.

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