Mapping a Better Future

The Fusion of GIS and Advanced Tech

Geospatial data serves as a foundation for decision-making processes in numerous fields, including environmental management, urban planning, disaster response, business analysis, and healthcare. By leveraging geospatial data, we can tackle complex challenges such as climate change, sustainability, and social inequity, and identify actionable solutions. Esri's ArcGIS Living Atlas of the World is the foremost collection of geographic information from around the globe. It includes maps, apps, and data layers. With an intent to enable Indian users to make more informed decisions, Esri India in collaboration with various government and private data providers, has published authoritative geospatial maps and datasets as 'Indo ArcGIS Living Atlas of India'. Indo ArcGIS Living Atlas of India is a collection of curated geographic content, including ready-to-use base maps, maps, layers, apps, and tools. This is a dynamically growing dataset repository of India. Currently, there are 1000+ data layers of Indian geospatial content.

GIS provides a platform to store, manage, and analyze geospatial data to help make informed decisions in a variety of fields. Today, organizations are increasingly adopting GIS

NMCG Empowered to Clean River Ganga and Its Tributaries with PRAYAG using ArcGIS

Namami Gange is running PRAYAG (Platform for Real-time Analysis of Yamuna, Ganga & their Tributaries) for Monitoring, review, and accountability measures. PRAYAG is a collaborative Platform to access Information, Data Maps, Apps & Dashboards for Ganga Basin. The significance of PRAYAG had brought a paradigm shift in the visualization of all crucial spatial and non-spatial information of the Ganga basin to adopt accurate & transparent decisions.

The various interventions under Namami Gange have resulted in significant improvements in the water quality of river Ganga. As a result of multi-sectoral interventions, the comparison of median data of water quality parameters viz. Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Fecal Coliforms (FC) of years 2014 and 2023 (Jan to Sept), DO median has improved at 32 locations, BOD median has improved at 43 locations and the FC median has improved at 25 locations respectively. The stretch of River Ganga from its origin up till Haridwar has reached Class A, i.e. highest standard of water quality. Based on the water quality assessment by CPCB in 5 Ganga main stem states in 2023 (January to September), the observed water quality indicates that the median value of Dissolved Oxygen which is an indicator of river health has been found to be above the minimum acceptable limits notified for primary bathing water quality criteria and satisfactory to support the ecosystem of river for almost entire stretch of River Ganga. The median value of Biochemical Oxygen Demand (BOD) has been found less than the maximum acceptable limits of 3mg/L except a marginal exceedance (BOD: 3.2 to 4.5 mg/L) in 2 locations.

The GIS-based Web Centric Water Quality dashboard helps in visualizing the status of River Ganga Water Quality by means of "Monitoring Station wise Water quality Indicator" dashboard. It shows the water quality as reported through monitoring stations at various locations along the river Ganga. This dashboard, as its first phase; is an attempt to create a web-centric GIS-based scientific Water Quality Application by using 7 years' data (2014 to 2021) with 4 parameters DO, BOD, FC, and pH. The data from seven years were processed in a percentile-based method (90, 50 and 10 Percentile) and compliance criteria applied for individual parameters separately. The data can be filtered on the basis of States, Districts, Monitoring Stations, Station Codes, Years, etc. The portal allows users to extrapolate and make sense of trends to better identify decisions in "Nirmal Ganga".

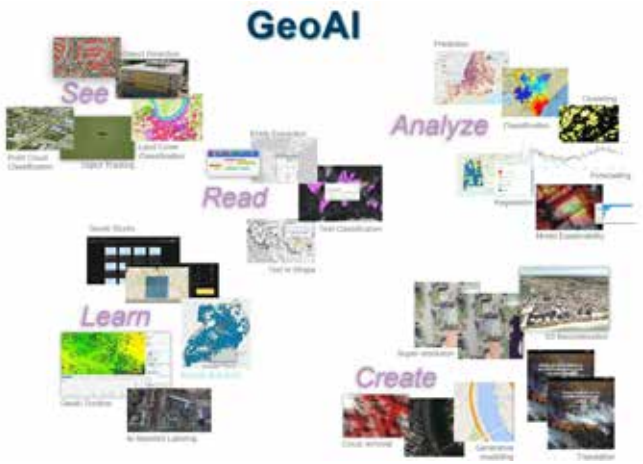
to enhance various aspects of their operations. Whether it's advancing infrastructure development or ensuring the responsible use of utilities, communities are transforming through a geographic approach. GIS is fostering innovations in all fields from infrastructure development to utility management to water resource management to climate action. GIS is already the core foundation of various environmental, disaster resilience, and natural resources management programs like AMRUT, the National Water Mission, and Clean Ganga among others. GIS-driven solutions, powered with vulnerability maps, apps, and data have the potential to help us better understand the sectoral impacts of climate change and build a more resilient future.

GIS is helping us to solve crucial social and business challenges more effectively with its integration with new-age technologies like artificial intelligence (AI), machine learning (ML), deep learning (DL), Internet of Things (IoT), augmented reality (AR), virtual reality (VR), Big Data, Digital Twin, etc.

GeoAI: Setting Grounds for a Sustainable Future

The integration of artificial intelligence and location intelligence has given rise to a revolutionary field: geospatial artificial intelligence (GeoAI). GeoAI merges AI with geospatial data and technology to accelerate workflows, unveil valuable insights, and address spatial challenges with unprecedented speed and accuracy. Monitoring and analyzing events in real-time GeoAI enhances situational awareness and enables more informed decision-making and more effective and equitable outcomes across sectors.

GeoAI is embedded throughout ArcGIS across a wide variety of geoprocessing and exploratory analysis tools. Machine learning algorithms in ArcGIS are used in the analysis of spatial data to perform clustering, prediction (classification and regression), and spatiotemporal forecasting. Deep learning is used in ArcGIS to generate geospatial information from sensor data (including imagery and point clouds) using techniques and tools for pixel classification and image segmentation, detecting objects and extracting features, object tracking, change detection, and image simulation. Deep learning is also used to generate geospatial data from unstructured text using a variety of natural language processing (NLP) techniques. Deep learning can also be used for the analysis of spatial data to make predictions and forecasts. **Many of our most challenging problems require bringing together GeoAI and other powerful spatial analysis techniques to both understand and effectively address these challenges.**



State and local government

By leveraging GeoAI, governments can model the impacts of urban development, understand the availability of resources to the population, forecast road and infrastructure deterioration, and identify land-use change (such as new buildings) to proactively take action.GeoAI has the potential to transform e-governance by leveraging digital technologies to improve government processes and service delivery. Integrating GeoAI into e-governance has the potential to transform how public authorities make decisions, allocate resources, and deliver services. By leveraging GeoAI, governments can analyze spatial data to reveal patterns, trends, and relationships that were once difficult or time-consuming to uncover. These insights facilitate evidence-based decision-making, resulting in more effective and targeted policies and services for citizens. The widespread availability of location-based data and advances in sensor technologies have elevated GeoAI as a key element in effective governance. By combining geographic information with AI-driven analytics, GeoAI offers a deeper understanding of spatial relationships, aiding governments in making informed decisions on various issues such as urban planning, infrastructure development, disaster management, and public health.By leveraging GeoAI, governments can model the impacts of urban development, understand the availability of resources to the population, forecast road and infrastructure deterioration, and identify land-use change (such as new buildings) to proactively take action.GeoAI has the potential to transform e-governance

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Integrating GeoAI into e-governance can enhance service delivery, increase transparency, and improve citizen engagement. Additionally, it allows for the identification of patterns and trends in spatial data, leading to more effective resource allocation and targeted interventions. GeoAI also supports predictive analytics, where algorithms use historical spatial data to forecast future trends and patterns.

National mapping agencies

GeoAI has enhanced traditional geospatial analysis and mapping, altering the methods for understanding and managing complex human–natural systems. The technology is enhancing the responsiveness, productivity, and speed of product delivery for national mapping agencies. Through automation, these organizations are scaling their internal capacities and production workflows. A national mapping department can quickly update a nation's GIS in hours, not months or days.

Earth observation spans multiple domains: air, land, and sea. One unifying technology is needed for mapping large geographic datasets in national domains. It requires a platform that is highly adaptable to support aviation, topographic mapping, and disaster response, as well as maritime charting of the ocean's bathymetry, water column, and littoral zones. Esri's ArcGIS platform utilizes GeoAI for object detection and classification from both point clouds and raster surfaces derived from remotely sensed data.

Globally, National Mapping Department and Program managers are in an exciting transition time for the implementation and scaling of GeoAI workflows within their organization. By leveraging GeoAI Geospatial organizations can quickly update the currency of a nation's foundation baseline imagery, elevation, and geospatial vector information over large geographic regions and deliver the ability of providing decision making information faster and more accurately. GeoAI with ArcGIS Production Mapping and ArcGIS Defense Mapping are the future of accelerated information production for National Mapping.

An important part of the evolution is moving beyond the desktop into enterprise environment that fosters the success of human and machine teams. These enterprise systems can leverage technology like ArcGIS Notebook Server to ensure security and proper access to shareable AI models across the organization.

Defense and intelligence

GeoAI is speeding up how organizations extract information, identify patterns, and determine changes in big data. An intelligence organization can support its activity-based intelligence efforts by automating how it analyzes information related to events, entities, surveillance video, and remotely sensed data.

Spatial machine learning algorithms and deep learning techniques have become highly advanced, thanks to unprecedented computing power. Utilizing these technologies on extensive collections of imagery or geospatial data can significantly enhance the intelligence production cycle. Applications include automatic change detection, socio-economic analysis, maritime safety, and the analysis of space and cyber events, among others.

Public Safety

GeoAI is improving public safety as it relates to traffic accidents, emergency response, and disaster management. Organizations are making communities safer by predicting where accidents are likely to occur and optimizing emergency response times. After natural disasters, assessing damage quickly is crucial for effective recovery and aid. Custom deep learning models can be trained on historical imagery to identify damaged structures from recent events. These models enable rapid damage assessment, helping responders allocate resources more efficiently and allowing insurance companies to process claims faster. With automated assessments, disaster response teams can make data-driven decisions on priority areas for aid and rebuilding.

BFSI

GeoAI empowers financial institutions by incorporating AI-driven geospatial workflows to enhance ESG (Environmental, Social, and Governance) analysis, risk assessment, and asset management. Through predictive analytics, it evaluates the influence of location-based factors on investments, aiding in the identification of market trends and the optimization of strategies. This integration promotes sustainable finance innovation and supports banks in supervisory functions, ultimately fostering a more resilient and informed financial ecosystem.

AEC

AI and GeoAI are revolutionizing how we plan, manage, and safeguard our cities. By harnessing the power of these technologies, we can build urban centers that are not only sustainable but also capable of withstanding the challenges of tomorrow. As these technologies continue to evolve, we can expect even more innovative applications that will enhance the quality of life for all city dwellers.

GeoAI is transforming the architecture, engineering, and construction (AEC) industry with its ability to extract information from imagery, which feeds a digital twin. This data allows decision-makers to improve project management, identify potential risks, and optimize building performance. As a result, architecture firms can design energy-efficient buildings. **GeoAI can analyze energy consumption patterns across different city districts. This allows for the strategic placement of renewable energy sources and optimized energy grids, promoting sustainability and reducing reliance on fossil fuels.**

Informal settlements, which are often dynamic, may not be accurately represented in census data, leading to outdated population estimates. Fine-tuning existing deep learning models to detect building footprints in informal settlements can help local governments maintain accurate population counts. By training a model with local aerial imagery and adjusting it to specific geographic parameters, governments can estimate populations more accurately and allocate resources for essential services effectively.A technology that's increasingly enabling the AEC sector to perform better is Digital Twin Technology. Digital twins are virtual representations of the real world including physical objects, processes, relationships, and behaviors. For the AEC industry, a digital twin is in the form of a built asset. Take, for example, an office building and its digital twin. At the end of design and construction, there is an exact, digital replica of the entire building, from the roof to the HVAC system and MEP. The actual, physical building is mirrored as a 'twin' in a digital, dynamic format. Unlike a digital model or a simulation, a digital twin isn't static. Just as the final, completed office building changes with use, so does the digital twin. It is responsive and continues to evolve as more data is supplied to it, such as data from artificial intelligence, sensors, or the Internet of Things. That means it can also simulate and predict informed decisions based on real-world conditions of the building.

With advancements in 3D modeling and simulations, Digital Twins are increasingly assuming greater significance in the AEC workflows. The proliferation of IoT sensors and devices is providing accurate insights for enhanced location awareness and response. Smart applications streaming real-time insights into ArcGIS enable seamless monitoring and administration of the construction processes, facility

management, and environmental monitoring. Opportunely, there is an array of GIS products that are being utilized for digital twin deployment, including ArcGIS Urban, ArcGIS Indoors, ArcGIS CityEngine, ArcGIS Velocity, and ArcGIS Reality.

ArcGIS technology is the foundation for digital twins, providing solutions to achieve an organization's vision and its transformation objectives. Digital twins are abstracting and modeling everything. They offer a means to improve business processes, reduce risk, optimize operational efficiencies, and enhance decision-making with automation to predict future outcomes.

Business

GeoAI is accelerating smart business decisions as well, delivering insight and predictions that drive better market planning, site selection, supply chain efficiency, and customer intelligence. With these insights, a business can respond to customer behavior and determine whether a new market area is viable based on pattern and predictive analysis of market characteristics.

Managing global logistics in real-time

FedEx's global logistics operation relies on extreme precision. To keep planes and deliveries on time, FedEx uses sophisticated enterprise GIS to track its fleet. That GIS is augmented with AI's predictive capabilities to identify when a plane would need parts or maintenance, making a complex supply chain even more efficient and on schedule.

An emerging step in retail evolution is **'halo forecasting'**– a sophisticated approach that merges location data, transaction history, consumer profiles, and AI to predict sales across both physical and digital channels.

McKinsey estimates that halo forecasting can boost a store's sales by 20 to 30 percent. However, retail executives need precise predictions to capitalize on this phenomenon. Halo forecasting offers exactly that by blending AI, big data analysis, and location intelligence to project the financial impact of the halo effect with remarkable accuracy.

Halo forecasting surpasses traditional methods by analyzing vast amounts of data and accounting for numerous variables that influence sales. Unlike spreadsheets, which struggle with large data sets, halo forecasting leverages cloud computing and machine learning to handle complex interactions among thousands of factors affecting sales.

The forecasting process begins with predicting in-store sales for a new location, using machine learning to model potential areas. GIS technology then assesses these areas' proximity to potential customers based on demographics and spending habits. This initial analysis is scaled to provide comprehensive forecasts for entire markets with accuracy often exceeding 90 percent.

The final step integrates digital sales into the forecast, offering an unparalleled view of how new store locations will impact both in-store and online revenues. With halo forecasting, retail executives gain a unique edge in business planning, enabling them to identify prime locations and collaborate effectively with real estate professionals.

Halo forecasting combines consumer demographics, retailer data, and geospatial intelligence to deliver insights that were previously out of reach. In a rapidly evolving retail landscape, the ability to predict business outcomes across multiple channels provides a significant competitive advantage.

Natural Resources

GeoAI is helping us get more effective outcomes in natural resources management as well. Foresters and landowners use GeoAI to give them knowledge about the volumes and species of trees without a time-consuming on-site inspection. The technology is also revolutionizing the precision agriculture market by aiding the automated detection of invasive species. Additionally, GeoAI is helping the oil and gas industry monitor assets through automated extraction of flares, new well pads, or field access roads.

As the above discussion unfolds, the applications of GeoAI are increasing day by day. The GeoAI industry is projected to grow significantly (~16% compound annual growth rate or $550 billion USD value by 2025) in the near future. The demand for GeoAI tools and techniques from all spatial information sectors, including education and research, will continue to increase as the benefits are visibly strong.

Generative AI: Taking GIS Potential Further

While traditional machine learning has already enabled AI to detect patterns and make predictions from vast datasets, GenAI takes it further by generating content, images, and natural language responses based on simple prompts. This advancement allows users to interact with complex systems like GIS software using intuitive commands, freeing technical experts to focus on tasks like quality assurance and data verification.

Integrating GenAI with GIS extends the benefits of location intelligence throughout an organization. For example, an employee could soon generate detailed maps of company assets, identify high-potential real estate opportunities, or pinpoint target demographic areas simply by describing their needs to AI-powered GIS software. Integrating GenAI into GIS allows even non-GIS specialists to quickly generate location-aware smart forms. Users can use natural-language prompts to modify descriptions, add or remove questions, and include maps or images. For instance, a business user can rapidly create a form for evaluating real estate properties or for homeowners filing insurance claims. The fusion of GenAI and GIS is set to improve communication and collaboration between professionals. **As GenAI becomes more integrated into GIS tools across enterprises, the potential for leveraging location intelligence to enhance business operations and empower employees will continue to expand. This integration promises to drive faster, more effective decision-making and improve overall efficiency in business processes.**

Fusion of GIS and IoT: Making the Future More Intelligent

As IoT and GIS adoption increases and their applications mature, the future is becoming increasingly intelligent and automated. GIS and IoT technologies are connecting systems and data in new ways, which is enabling the transformation of many organizational workflows. With a firm grasp of where IoT-connected assets are, executives are turning location intelligence into better business decisions. Companies in a range of industries are leveraging the where, when, and what of the IoT to boost profits, raise revenue, and enhance customer satisfaction.

With most e-commerce companies moving toward same-day delivery, traditional retailers face mounting pressure to deliver to customer expectations. For years, online retailers have had an edge when it comes to measuring consumer preferences. Websites closely track how visitors navigate online shopping experiences, and e-commerce companies use that knowledge to improve margins and customer satisfaction. That might mean adjusting airfares on a site in real-time, recommending similar products for a shopping cart, or allowing one-click purchases.

Brick-and-mortar retailers fell behind with such optimization because they lacked good data on where customers spent time in their stores. Now, through IoT and location technology, that's changing. **At the intersection of the Internet of Things and location, executives have found hidden reserves of business intelligence.** Esri's GeoEvent server helps executives connect and monitor real-time feeds and IoT data. ArcGIS Velocity is a managed SaaS for processing real-time IoT and big data analytics. It enables visualization, scalability, and spatial analytics.

GIS and VR/AR: Seeing What Others Can't

3D and augmented reality technologies are reshaping our interaction with spatial data. These innovations are crucial in urban planning and infrastructure development, offering immersive experiences and detailed insights.

As augmented reality (AR) becomes increasingly common in phone, tablet, and computer applications, more developers are expected to integrate GIS services and content to fulfill practical and real-world needs. **The fusion of GIS and AR makes GIS data and analytics more interactive, real-time, and user-friendly.** A prime example of this integration is Esri's AuGeo, which exemplifies the synergy between AR and GIS. AuGeo enables users to explore the possibilities of using ArcGIS data in an augmented reality environment. Esri envisions AR applications that leverage GIS data to assist professionals on-site by providing the most current and accurate information available via mobile devices.

For example, an ecologist might see real-time overlays of historical plant growth data while examining a forest, or a geologist could visualize underground mineral compositions without taking physical samples. This not only enhances the accuracy and efficiency of data collection but also provides immersive experiences.

Field workers can use their phone's camera to view the location and orientation of buried water pipes and electric cables. An AR app can cross-reference GIS data with their location, effectively giving them an x-ray vision to see the infrastructure beneath. In addition to visualizing hidden elements, you can have access to their attributes, view engineering diagrams, and connect to real-time sensor networks to check details like water pressure or electrical amperage. The augmented displays can also be synced with a GIS-enabled work order system for access by project managers and field crews. **The true excitement of combining AR with GIS lies not just in visualizing GIS content but in integrating that content seamlessly with other enterprise systems.** Traditional GIS maps and models, while detailed, often require specialized knowledge to interpret. AR transforms this by rendering GIS data in three dimensions and overlaying it onto our physical surroundings, making spatial information more interactive and tangible.

For instance, a city planner on a proposed development site can use AR to visualize underground utilities, potential skyscraper shadows, or historical data layers in real-time. This immersive perspective enhances decision-making and planning. Additionally, when AR is incorporated into public participatory GIS, it democratizes spatial planning. Residents can virtually experience proposed changes to their neighborhoods, leading to more informed discussions and collaborative urban planning.

AR is also revolutionizing disaster simulations for training and preparedness. Rather than relying on traditional drills or lengthy procedure manuals, first responders can engage in highly realistic AR-enhanced scenarios. Whether simulating the aftermath of an earthquake or practicing evacuation procedures during a flood, AR provides a more immersive experience.

AR and GIS seem to be a perfect match, not only for consumers but for professionals who rely on geographic information to make real-time decisions.

Orange County Public Works Using GIS and IoT to Innovate

Orange County Waste and Recycling is an agency that operates three landfills. These landfills are among the largest in California and receive more than four million tons of solid waste annually. A critical safety concern at landfills is monitoring and regulating waste stockpile temperatures. OC Public Works equipped drones with thermal imaging infrared cameras to test a way of detecting the surface temperature of stockpiles.

As the surface of stockpiles reached a specific heat threshold, staff would manually record the internal temperature of each stockpile to mitigate the risk of an internal fire that could quickly spread. Although this process helped landfill managers, it lacked real-time awareness and an active approach to internal temperature control.

The county was already familiar with pulling live data streams from its fleet vehicles into GIS to know when to provide preventative maintenance. The same concept was applied to waste stockpiles. County GIS staff inserted Raspberry Pi sensors into each stockpile, and the sensors would record the internal temperature automatically. Then, using ArcGIS Velocity, staff programmed the sensors to feed the data into a web map and show real-time temperatures within each stockpile.

"For about $40 per device, we can deploy several sensors in different locations within a stockpile and collect precise insights 24/7," explained Cameron Smith, GIS manager at OC Public Works. "Outsourcing this to a vendor would've cost the county tens of thousands of dollars yearly."

Using ArcGIS Velocity, staff quickly set up sensors to feed maps with real-time temperatures of stockpiles. The landfill staff can click across the interactive map and retrieve the real-time temperature of each stockpile. Staff can also push alerts when internal temperatures have passed a certain threshold, putting time-sensitive information into the hands of managers and landfill personnel. In the future, county staff can integrate other sensors—such as methane or moisture sensors—to enrich their data even further.

El Jebel, Colorado, Saves Thousands Using Augmented Reality and GIS

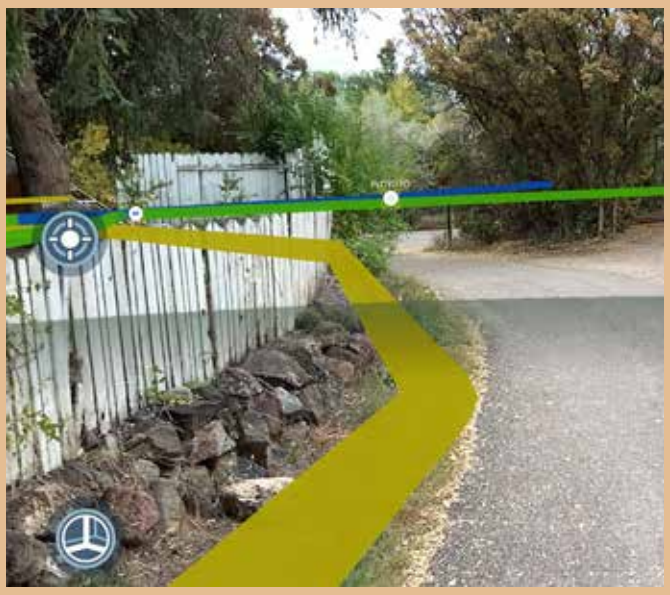
Crawford Properties, LLC, owns and manages a residential and commercial mobile home community in El Jebel, Colorado. The company is responsible for El Jebel's 5.4 square miles of underground assets, including water, sewer, gas, and electrical infrastructure, which are needed to support this growing community just outside of Aspen, Colorado. Crawford's staff needed a faster, more accurate way to record assets and their responses to 811 requests, reduce clerical errors, and mitigate any financial exposure due to inaccurate or slow response. Using the latest in geographic information system (GIS) and augmented reality (AR) technology, staff simplified how they locate assets and saved thousands in labor costs alone.

Crawford selected Argis Solutions to help solve the problem. Argis is a Denver, Colorado-based Esri partner

focused on integrating GIS with augmented reality and mixed reality. Argis's mobile app, the Argis Lens, translates ArcGIS feature services into augmented reality in real time. Crawford moved all its GIS data to ArcGIS Online—a cloud-based mapping system for creating, analyzing, and sharing maps—to consolidate information into one dynamic system of record. Whenever new assets are placed, Crawford's locating teams visit the site and record the asset's coordinates using ArcGIS Collector, a mobile data collection app, with a Global Navigation Satellite System (GNSS) receiver via a tablet. This data is then fed directly into ArcGIS Online onto a feature layer where it is maintained.

Using a tablet, mobile workers view the collected data, which ranges from sprinkler heads to electrical wires or sewer pipes. The Argis Lens allows them to verify the data's accuracy and record images near known points and landmarks. When location requests are submitted, the location team uses the Argis Lens and ARTMS, Argis's augmented reality 811 response system, to manage the entire location request on-site in one stop. ARTMS ingests Colorado 811 marking requests and shows 811 responses directly from the field within the application. Because ARTMS is an extension of ArcGIS Workforce, team managers can also use it to track workers and tickets. Combining ARTMS with the Argis Lens keeps mobile workers safer. They are armed with visual situational awareness of surrounding systems made visible on the AR map. If the ArcGIS data requires updating, the mobile worker uses the tablet and GNSS receiver to update the data directly at the work site.

This new workflow focuses on mobile worker empowerment. It allows all GIS locating and documentation to occur at the work site. Crawford Properties is reducing postprocessing activities by two hours a day, saving $7,500 yearly in labor alone in 2021. Data quality has improved, and data is more functional and accessible. With ARTMS, Crawford has excellent documentation for 811 location response requests, verifying the full record of information provided. Better documentation minimizes Crawford's loss exposure and protects the El Jebel community, allowing it to operate as seamlessly as possible.



Conclusion

The integration of GIS with cutting-edge technologies such as AI, IoT, Digital Twins, and AR/VR is shaping a brighter future for everyone. These advancements in GIS are leading to more sustainable decision-making and uncovering the best solutions to existing challenges. The transformative power of GIS technologies is driving progress and improving our world. Innovations like Machine Learning, Artificial Intelligence, Cloud GIS, and Augmented Reality are enhancing our lives and increasing convenience.

These developments create new opportunities and are expected to significantly boost the market value of GIS in the future. Various industries and sectors have already undergone a revolution due to the swift adoption of GIS technologies.

Looking ahead, GIS is poised for a promising future, with its significance set to grow as industries and educational institutions increasingly recognize its critical role and value. As GIS technology evolves, new methods for analyzing, visualizing, and managing spatial data will continue to emerge.