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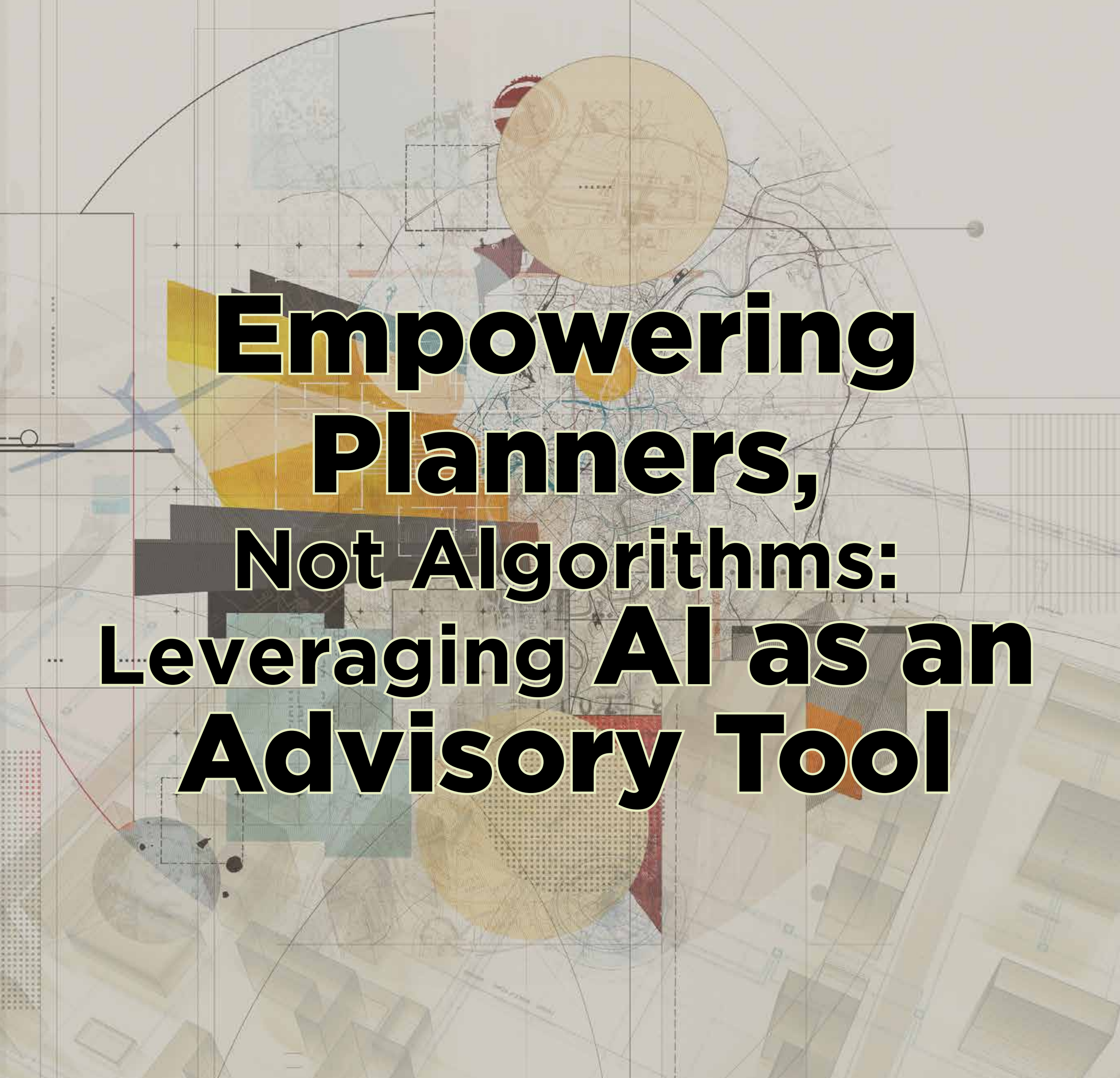
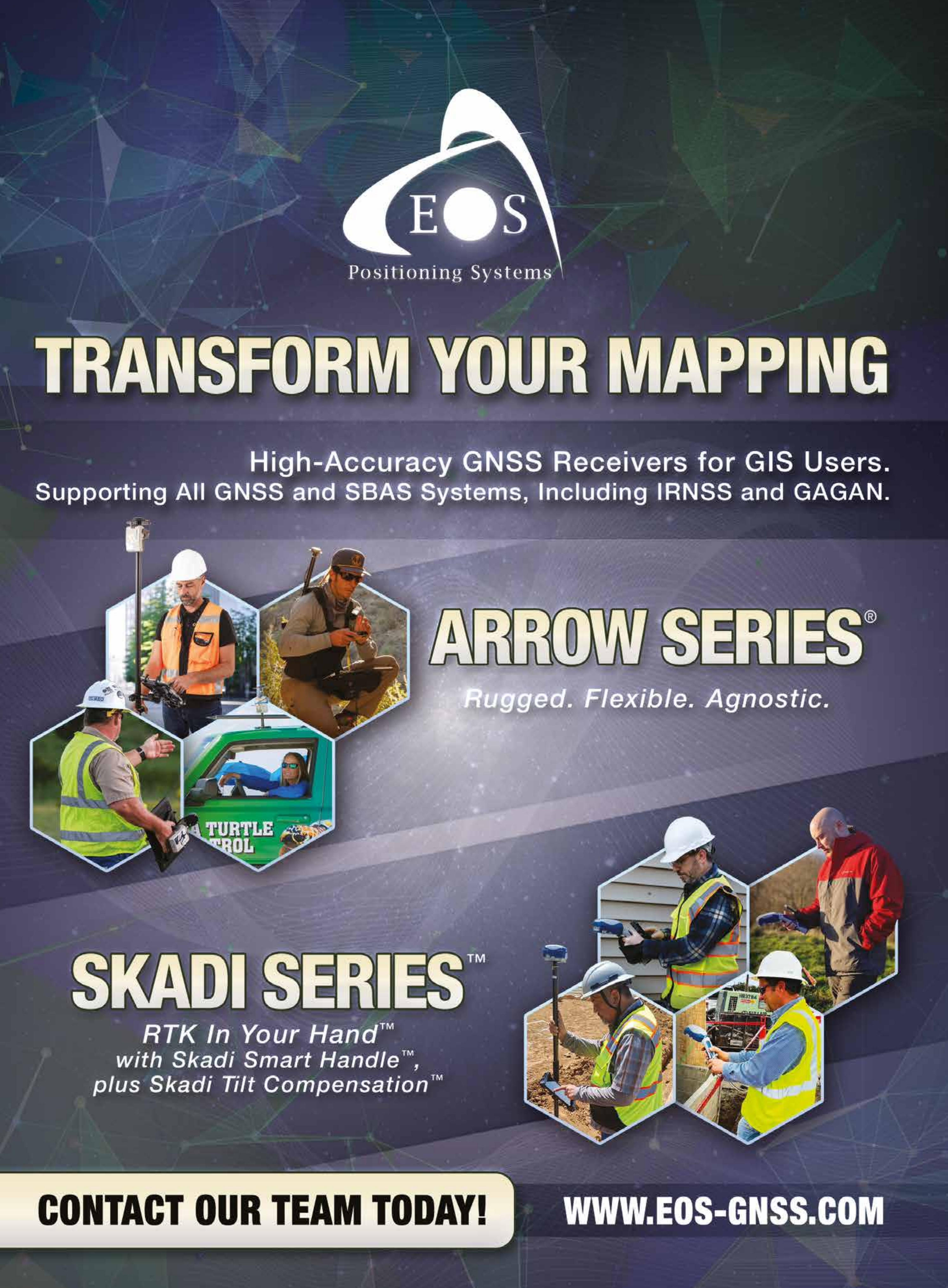


Empowering Planners, Not Algorithms: Leveraging AI as an Advisory Tool

The Power of Geospatial Intelligence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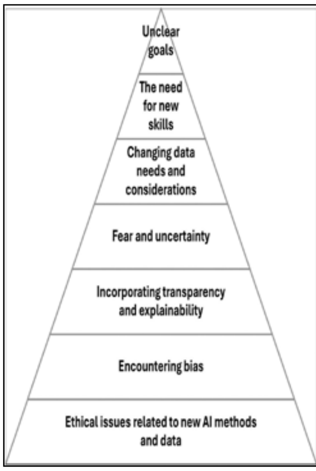

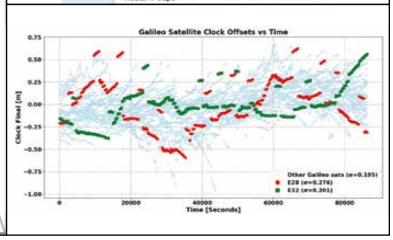

In this issue

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Articles

Columns

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Prof Dr. Mahavir, Narayan Dhital, Dr Prabh Bedi, Raymond Nkwenti and Tolulope Ayodeji Olatoye; EOS Positioning Systems, Riegl, SBG System, and many others.

Mailing Address
A 002, Mansara Apartments
C 9, Vasundhara Enclave
Delhi 110 096, India.
Phones +91 11 42153861, 98102 33422, 98107 24567

Email
[information] talktous@mycoordinates.org
[editorial] bal@mycoordinates.org
[advertising] sam@mycoordinates.org
[subscriptions] iwant@mycoordinates.org
Web www.mycoordinates.org

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Can AI plan a city?

AI can bring unprecedented speed to urban planning,

Making it possible to process vast volumes of spatial, environmental, demographic and infrastructural data.

But a city is not merely a collection of datasets.

It is a living and changing ecosystem of people, places, aspirations, conflicts and compromises.

In their interview with *Coordinates*, Prof. Dr. Mahavir and Dr. Prabh Bedi reflect on

what AI can do and more importantly, what it cannot.

AI may help planners see patterns that would otherwise remain invisible.

It may simulate alternatives, anticipate pressures and support more informed decisions.

But city is not merely a spatial problem waiting for an algorithmic solution.

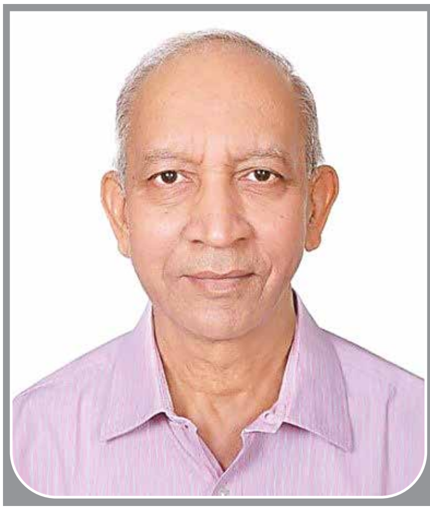
AI may help us design the city of tomorrow.

But whose tomorrow, that cannot be decided by AI alone.

Bal Krishna, Editor
bal@mycoordinates.org

Empowering Planners, Not Algorithms: Leveraging AI as an Advisory Tool

In an interview with Coordinates, Prof. Dr. Mahavir and Dr. Prabh Bedi explore how AI and geospatial technologies could reshape urban planning - from the conceptualisation of city plans and scenario generation to master-plan preparation, approval, public participation and the emergence of City Digital Twins. At the same time, they also caution against assuming that technology alone can solve the complexities of planning.



Prof. Dr. Mahavir

Was engaged in teaching at the School of Planning and Architecture (SPA), New Delhi (an Institution of National Importance under an Act of Parliament) for over 35 years. Planning Techniques, Geo-Informatics, Regional Planning and Environmental Planning have been his areas of interest. He holds degrees in Architecture, Urban and Regional Planning, PG Dip. in Remote Sensing and a Ph.D., jointly from ITC and the Utrecht University, the Netherlands. Besides teaching, Dr. Mahavir has held the positions of Dean (Academic) and has headed the Departments of Physical Planning, Environmental Planning, Regional Planning and Centre for Remote Sensing and GIS at the School. Recognising his contribution to education in the field of Geo-informatics, the School recently instituted an award in the name of Prof. Dr. Mahavir,

Dr. Mahavir has been on several committees of the Government of India related to Urban and Regional Planning and Geo-Informatics, notably on GIS-based Master Plans for AMRUT Cities. He was a Member of the Expert Committee - Comprehensive Development Strategy for the Entire State, including Capital - Andhra Pradesh, INDIA. Earlier, he was the Coordinator for the Institutional Consultancy Project on Feasibility Study for Locating Permanent Capital of Uttarakhand. He was also the Coordinator and Member (Urban Planner and Remote Sensing Expert), Planning Team for the Revision of the Master Plan for NOIDA-2011 and for the Preparation of the Master Plan for NOIDA – 2021. He has also been on several Committees related to the delineation and planning of the National Capital Region (NCR) of Delhi.

Besides being a Fellow Member of the Institute of Town Planners, India (ITPI), Dr. Mahavir is a Life Member of the Indian Society for Remote Sensing. His key research areas include Urban and Regional Planning; Geo-Spatial Technologies in Planning; Climate Change; Quality of Life, Urban Heat Islands, etc.

Dr. Mahavir is a regular contributor to Coordinates, besides several other National and International publications.

mahavir57@yahoo.com

Dr. Prabh Bedi

Is a geographer, regional planner and geospatial technology expert. She has been engaged in the field of planning and geospatial technologies both in industry and academics for nearly 30 years. She has published research on NUIS, Smart Cities, urban greens and urban hydrology. Her research interests include information systems, especially the ever-evolving geospatial technology, and its applications in urban planning.

Dr. Bedi is a regular contributor to Coordinates, besides several other National and International publications.

prabhb@gmail.com

Urban planning traditionally begins with analysing land use, infrastructure, demographics, and environmental constraints. With AI and geospatial intelligence now available, how do you see the conceptual stage of city planning evolving?

Well, not as simple as that! It starts with the formulation of goals and objectives, vision statements, demography, land availability, land features, thresholds, and regional considerations. It is a continuous, time oriented process where planning, implementation, monitoring, review and plan updating go on as a dynamic cycle (Fig. 1). Planning had become dynamic when computer-based GIS was integrated into it. Planning had transformed from a static and linear process into a dynamic system with the incorporation of RS and GIS into its fold; Geospatial Artificial Intelligence (GeoAI) shifts it further towards a continuous workflow. It also depends upon whether we are talking about planning for an existing city or a greenfield development. Further, at what scale of planning, i.e., a site, neighbourhood, zone/ sector, city or a region.

Planners can now instantly simulate thousands of scenarios across overlapping datasets like human mobility and climate constraints. Instead of preparing a single master plan, large Geospatial models allow planners to input specific textual requirements e.g., increase housing density or FAR or green spaces and instantly generate multiple viable alternative plans.

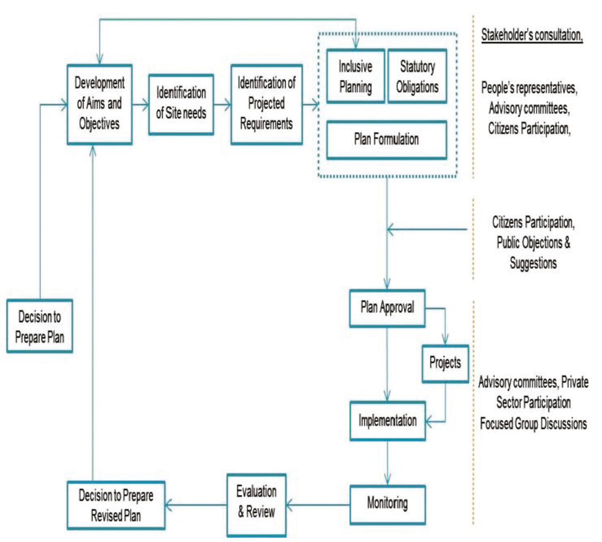


Fig. 1: General Process of Planning (Source: URDPFI Guidelines, 2015)

Rather than relying on periodic census surveys, which already have poor temporal resolution (as compared to urban dynamics) and can be further delayed, as is the case presently in India, the conceptual stage is now driven by indirect population indicators as real-time (validated) data, including GPS traces, IoT sensors, and mobile signals. This highlights actual functional flows and collective human behaviours. Geospatial AI platforms can process thousands of data layers (static and non-static) - topography, zoning, and market context - so planners can immediately evaluate which plans improve traffic, optimise infrastructure, or increase land value *before* the actual planning begins.

Core Geospatial technologies driving this shift are Generative Urban AI and Advanced Geospatial Analysis. Advanced computational models with hybrid intelligence architecture are now capable of analysing diverse data streams to interpret dynamic social behaviours. Systems are designed to encode multifaceted conditions into structured embeddings to guide generative models. This aspect is more attuned towards urban management, at least in the current space and time. To be able to incorporate it as a planning input, a continuous data stream aggregated over broader timelines (maybe 10 years at least for development plans) would be required.

Integration of Geographic Information Systems (GIS) with machine learning instantly models urban dynamics, anticipates urban sprawl, and optimises land uses. Some more quick applications that come to mind include resolution between conflicting and competing land uses while planning; identification of lands having potential for encroachments in future; predicting directions of growth; performing spatial SWOC analysis; detailing the spatial phasing of plans, etc.

You mentioned the levels and scales of planning. How can Geospatial AI help in providing a seamless transition between different scales and levels of (urban) planning in terms of data and plans?

Geospatial AI (GeoAI) acts as an analytical bridge in urban planning by continuously aggregating, downscaling and interpreting multi-source data. It resolves disconnects between macro-level regional policies and micro-level site designs, creating dynamic, data-driven planning frameworks. The transition between these scales can be achieved in several specific ways, such as Seamless Data Aggregation and Downscaling, Multi-Level Scenario Modelling and Digital Twins, Policy and Regulatory Translation, and Human-Centric Planning.

GeoAI resolves conflicting scales by utilising advanced deep learning models to convert macro-datasets (e.g., regional satellite imagery and census data) into hyper-local, block-level insights (e.g., predicting exact building uses and demographics at neighbourhood level). GeoAI integrates diverse layers - such as IoT sensor data, mobility traces, and socio-economic indices - so planners have a consistent foundation of real-world awareness, whether analysing an entire city or a small site. GeoAI can automatically extract unstructured data like building footprints and road networks from high-resolution aerial and LiDAR data, obtained through drones or otherwise, continuously updating local databases in real-time.

GeoAI can feed region-wide macro-economic and environmental forecasts into hyper-local models. This creates Urban Digital Twins, allowing planners to simulate how zoning changes at the city level impact micro-scale issues like urban local flooding, heat islands or traffic bottlenecks. Feeding broader goals (e.g., net-zero emission targets or mass-void ratios) into generative AI tools can instantly evaluate and generate thousands of localised 3D urban layouts compliant with those macro-level targets.

GeoAI can interpret complex, lengthy policy documents using Natural Language Processing (NLP) and vector search and overlay them onto 3D mapping environments. This allows planners and decision-makers as well to visualise whether region-wide master plans for density or environmental protection are feasible at the neighbourhood and lower levels. Agent-based models driven by Large Language Models (LLMs) that simulate human behaviour can be employed to evaluate proposed spaces from a micro-scale pedestrian perspective to test street vibrancy, walkability, and safety across the entire city's network. By decoding the spatial patterns of past land uses, GeoAI models can predict future developmental pressures and directions. Planners can dynamically adjust macro-zoning laws based on these forward-looking spatial models, avoiding the limitations of static, outdated master plans. Tools such as UrbanistAI allow citizens to easily visualise and propose local, street-level changes via prompts. Planners can seamlessly integrate these community inputs into larger, top-down policy configurations to ensure multi-scale stakeholder concerns.

Remote sensing and GIS have been important tools in planning for decades. With the rise of GeoAI, do you see a shift from analytical tools towards intelligent planning systems that can support or even anticipate planning decisions?

Absolutely. A basic paradigm shift from GIS as a system of record (which stores, displays, analyses and answers what currently exists) to GeoAI as a system of intelligence (which learns spatio-temporal dynamics to sketch, predict, and anticipate spatial planning outcomes).

Several key technological shifts are making this possible. Automating labour-intensive tasks through machine learning and computer vision instantly automates tedious workflows like land-use classification and building footprint extraction, freeing planners to focus on strategy and community engagement. Planners can now use tools like NASA's Prithvi geospatial foundation models and Esri's ArcGIS deep learning pipelines to automatically forecast urban sprawl, model traffic congestion, and simulate flood zones in near-real-time. Once popular simulation models like SimCity are now progressing to predictive simulation. By merging spatial data with IoT sensors and socio-economic variables, GeoAI can anticipate which utility assets (water and gas pipes, road networks) are most at risk of failing before it happens, optimising maintenance budgets and delays. Being predictive, GeoAI is likely to become a more enhanced and robust tool than existing RS and GIS, enabling planners to take more informed decisions. Since the output of GeoAI will be based on a varied set of data, rigorous analysis and faster response time, it will cause planners' decisions to be indicative and logical.

> Excessive reliance on AI can lead to technocratic planning, where opaque models and narrow performance metrics override human values. Over-reliance threatens human oversight, marginalises vital local knowledge, and can lead to automation bias.

One of the limitations of conventional master planning has been its static nature. Could GeoAI enable planners to simulate multiple urban futures and move towards dynamic or continuously self-evolving city plans? Can City Digital Twins be helpful? How can Geospatial AI help prepare and apply City Digital Twins?

GeoAI can actively revolutionise urban planning by replacing outdated, static master plans with dynamic, data-driven simulations. By leveraging city digital twins and advanced machine learning, planners can now continuously model multiple urban futures and create living city plans that evolve alongside socio-economic and environmental changes. Geospatial AI transforms static Master Plans into dynamic, self-evolving frameworks by integrating real-time data with predictive spatial modelling. GeoAI processes high-resolution satellite imagery and LiDAR to continuously monitor urban expansion and detect unauthorised constructions automatically. Planners gain instant visibility through spatial data-driven Real-Time Morphological Tracking, i.e., how a city is morphing rather than waiting for surveys. It shifts planning from rigid 20-year documents to responsive systems, continuously updated to adapt to urban growth, population shifts, and climate vulnerabilities. Self-evolution can help break the 20-year plan period into shorter periods, say 5-year plans. It is noteworthy that the shift from a 20-year plan to a 10-year (or lesser) plan is more a derivative of urban dynamics than GeoAI. GeoAI has the tools facilitating this shift. GeoAI can function as a core in the process of integration of plans at regional, sub-regional, urban area/ city, sub-city/ zone, neighbourhood and site levels, along with cross-functional plans like environmental, Transparency, accountability, and trust are very important. Human-in-the-loop (HITL) oversight requiring public algorithmic audits and adopting open-source civic tech prevent 'black box' decisions, combat systemic biases, and ensure that technology augments rather than replaces democratic decision-making.

transportation and traffic plans. However, its success remains in the purview of the planners through a functional institutional framework and adoption of GeoAI tools in the plan preparation. Planning has various cyclical stages, broadly: preparation, implementation, monitoring, feedback, and again plan preparation. Amongst these GeoAI will have a role to play in varying degrees, in some stages more than others. While projecting the future, these self-evolving plans will keep a connect with the past heritage, history and land uses and other planning policies in the case of plan preparation for existing cities.

GeoAI takes in real-time data from IoT sensors, mobility systems, and environmental monitors to build highly accurate virtual replicas of cities. These digital twins allow planners to test 'what-if' scenarios for traffic congestion, housing demands, and climate change in real time before building in the physical world. Advanced GeoAI allows planners to use 'generative agents' (Agent-Based Modelling) that simulate human-like behaviour, such as shopping, pedestrian movement, and commuting preferences.

As you rightly pointed out, one of the main criticisms of existing master plans is their rigid and static nature. Rather than a city plan being a rigid document that is updated typically every 20 years, GeoAI integrates a feedback loop where real-world outcomes continuously refine the simulation. As urban demographics and economic landscapes shift, the spatial-digital framework automatically adapts, allowing planning bodies to make proactive, evidence-based policy adjustments rather than reacting to crises. These spatial data-driven master plans rely on several core mechanisms, viz. predictive scenario modelling, dynamic spatial digital twins, and climate and vulnerability integration, etc.

City Digital Twins model environmental factors like the Urban Heat Island (UHI) effect, helping planners design green spaces that maximise cooling and reduce carbon footprints. Planners and private developers can model the full impact of new private residential townships (as in the case of Bengaluru) or zoning changes before it takes shape on the ground.

GeoAI transforms static 3D city models into dynamic city models by automating data preparation and powering predictive scenario simulations. It acts as the intelligent engine that turns raw data into functional urban planning ecosystems. The model analyses satellite and drone imagery and LiDAR scans to automatically identify and classify physical features such as roads, building footprints, trees and utilities. For instance, AI can process massive urban areas and model thousands of buildings in minutes. Huge amount of multi-source, spatial, attribute and aspatial data is then synthesised and stitched together into standard GIS layers.

AI algorithms infer properties about unmapped assets, adding semantic context (e.g., estimating the age, material, or function of a building) to the 3D models. Once prepared, GeoAI transitions the digital twin from a static 3D visualisation into a predictive tool for urban management. Besides planning, GeoAI can examine building permit applications against a city's zoning and other bylaws and instantly visualise the proposed building's shadow, height, and line-of-sight impacts on the digital twin. It can further visualise the impact on neighbourhood density or the overall built space, or on the infrastructure. It can also facilitate an urban designer to visualise the overall built form and scale it up or down at other levels of planning.

Cities today generate massive volumes of spatial data – from satellites, sensors, mobility platforms, and administrative databases. How can planners effectively integrate and interpret these diverse datasets at various stages of planning?

Planners integrate spatial data through Geospatial Digital Twins, which fuse real-time IoT sensors, satellite imagery, UAV-drones, and administrative databases into a single living model. This allows cities to shift from reactive planning to predictive, spatial data-driven management across all project phases. Planners can use AI algorithms combined with GIS spatial mapping to assess environmental risks (e.g., flood zones), proximity to transit, and land-use mix simultaneously. Mobility platforms and smart traffic cameras feed live data into predictive simulation models. Planners can virtually reroute traffic or trial new transit lines to measure impacts before real-world implementation. This can be particularly effective in deciding optimum stations for TOD.

Digital Twins at different levels can transform flat, static maps into immersive 3D/4D models. This visual context makes complex data much easier for community members and government leaders to understand, fostering public trust and collaborative and evolutionary decision-making.

It is reasonable to mention that this hi-tech situation in India exists in metropolitan cities or maybe Class I cities. The intent should be that the benefit of these tools is experienced by smaller towns as well, though their models will need to be adapted to their conditions using the data of these small towns. Achieving this will not be easy, especially considering funding, institutional and political issues, but it must be remembered that it can not be one (GeoAI) model fits all.

Can Geospatial AI reduce overall Master Plan preparation time in terms of data collection, data analysis and projections?

Planning is a team effort with planners from varied backgrounds, such as architecture, economics, geography, sociology, and environmental sciences, etc. So are the various fields from where data is fed into a master planning process. Geospatial AI (GeoAI) accelerates Master Plan preparation by integrating these data and fields, replacing manual, time-intensive tasks with automated workflows. It slashes months from traditional timelines through rapid data processing, intelligent pattern recognition, and scenario generation.

AI computer vision models can automate feature extraction by instantly extracting building footprints, road networks, green cover, and water bodies, etc. from satellite imagery and LiDAR, replacing months of extensive field surveys and manual digitisation. GeoAI can act as a ‘universal translator’, decoding fragmented, mismatched public data from various civic departments into uniform GIS layers, saving countless hours of data sieving and formatting. It can rapidly compare historical and current aerial imagery to identify urban sprawl, unauthorised developments, and land use changes over time.

GeoAI can literally reproduce and analyse all the spatial parameters (for example, those suggested by McHarg and many more) by quickly modelling machine-learned Land Suitability overlays with multiple variables -such as terrain, transport access, and proximity to utilities, etc. to instantly flag optimal areas for development versus high-risk environmental zones. Using historical mobility, demographic, and economic data, GeoAI runs predictive simulations to forecast spatial growth and predict future congestion hotspots. The ripple effects of proposed zoning changes or new infrastructure on population density can be developed in seconds, even before real-world rollout.

Can Geospatial AI reduce overall Master Plan approval time also, typically in India?

Yes, it’s not only the preparation time but also the overall time taken in the process of inviting and incorporating public opinions and objections, deciding upon and incorporating the valid and feasible ones, and the necessary approvals. Master Plan for Delhi – 2041, for example, though first notified in 2021 for inviting objections/ suggestions, has taken 5 years to finally approve and notify for the Perspective Year 2047 (MPD-2047). With better plan preparation, more alternatives, especially with ‘what if’ scenarios, Geospatial tools for better public participation and better vertical and horizontal integration, the overall time is bound to be reduced.

GeoAI can substantially reduce the Master Plan approval times by bypassing traditional bureaucratic bottlenecks and enabling instant, data-driven compliance reviews. Better reasoning supported with geospatial data (trends as well as current and projections), alternative plans with pros and cons of ‘what if’ scenarios, including feasibility and social-environmental-economic cost-benefits, help faster decision-making and the approval process. GeoAI evaluates environmental and infrastructure impacts, creating 3D visual models that allow authorities and stakeholders to assess proposals in a short period of time, streamlining both review and public consultation.

How can Geospatial AI help in generating alternative scenarios instead of just one Master Plan?

Traditionally, we have been creating just one Master Plan due to lack of time, real-time data, resources, and the very complex nature of considerations. This further delays the processes of public engagement and approvals, as the only option we offer is ‘take it’ or ‘leave it’. Yes, suggestions from the public and the decision makers are incorporated, but the base template remains the same. GeoAI transforms traditional planning by shifting from single, static, linear plans to more dynamic, ‘what-if’ simulations. Instead of delivering just one rigid master plan, GeoAI automates the iteration process to rapidly evaluate several alternative future scenarios based on real-time data and specific policy guidelines. Options offered with associated pros and cons strengthen the logic behind major proposals and hence make it easier for the decision maker to choose the most optimal. It also reduces biases on both the planners’ side as well as the decision maker’s side.

Planners input strict, non-negotiable rules (e.g., desired land use percentages, FAR constraints, density targets, zoning bylaws, etc.), and the GeoAI generates several plan proposals with related maps. Inputs from the supporting fields like Urban Design, Environment, Heritage, Landscape, Disaster Management, Social justice and equity can also be incorporated not as an appendix but as a foundation. Alternative infrastructure mappings can also be generated proactively. Stakeholders and citizens can interact with the system using simple prompts to instantly generate and visually compare alternative zoning or neighbourhood maps. Esri ArcGIS and Autodesk Forma are providing these GeoAI-driven capabilities. Planners can simulate a new metro line to see how it affects local land uses and property values, accessibility to jobs for low-income areas, and localised emissions simultaneously.

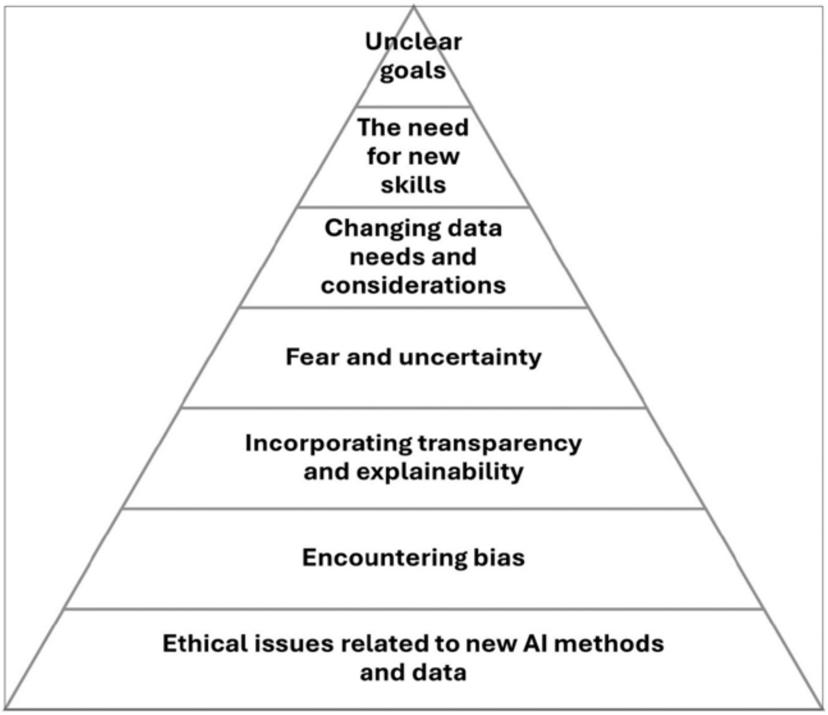


Fig. 2: AI Challenges for Urban Planners, Source: Sanchez, Brenman and Ye (2025)

How can Geospatial AI provide better integrity between different aspects of planning, like social, economic, environmental and infrastructure?

GeoAI breaks down data silos by synthesising massive, multi-dimensional datasets into a single, location-based intelligence platform. By adding geospatial context to machine learning algorithms, it solves the challenges of cross-sector evaluation, allowing planners to optimise complex trade-offs across social, economic, environmental, and infrastructure domains. Isolated datasets like census data, real estate prices, utility networks, and satellite images are anchored to precise geographic coordinates. This enables a unified, spatial database where actions in one sector are immediately evaluated against impacts in others. GeoAI also takes care of the spatial data available at different scales of mapping.

GeoAI models perform analysis on real-time IoT sensor networks and continuous satellite feeds to automatically identify and map urban heat islands, monitor air quality, and predict areas vulnerable to flooding. This pinpoints exact zones where expanding blue-green infrastructure will yield maximum results. The UN-Habitat GeoAI Toolkit provides methods for planners to integrate spatial analysis into their decision-making, ensuring social inclusiveness and climate resilience. Spatial analysis platforms like Esri Geospatial AI can be used to run automated land use mapping, monitor climate risk, and maintain up-to-date, digitised urban infrastructure inventories. More importantly, GeoAI can help bring the health and QoL aspects (Geddes, Howard, etc.) back into planning.

India is urbanising rapidly and faces challenges such as congestion, environmental stress, and informal growth. Could AI-enabled geospatial systems help planners address issues like climate resilience, flood risks, and urban sprawl more effectively?

Yes, AI-enabled geospatial systems are highly effective tools for managing India's rapid urbanisation. By integrating satellite imagery, IoT sensors, and local data, these systems provide planners with predictive models to tackle climate resilience, flood risks, and urban sprawl. However, besides the technology, the state needs to formulate and implement a National Urbanisation Policy, including counter-urbanisation in some areas, a population and migration policy and a strong directive for preparing regional plans not only for major cities but for regions defined based on political boundaries, if not geographical, social and economic entities.

GeoAI maps terrain, drainage networks, and historical weather data to run hyper-local flood simulations. One of the major problems in urban areas today is waterlogging due to intense rainfall, which can be addressed using predictive GeoAI models and tools to augment the infrastructure and be prepared with mitigative measures, such as identifying vulnerable neighbourhoods in flood-prone cities like Mumbai and Bengaluru before disasters strike. Algorithms evaluate optimal locations for Blue-Green Infrastructure like urban forests, wetlands, and permeable surfaces to reduce heat stress and mitigate urban flooding. Models process real-time data streams of satellite imagery to monitor city peripheries and sprawl. The same is true for informal settlements and conversions of agricultural land and green belts.

GeoAI-driven systems may increasingly shape urban policy and planning choices. How should planners ensure transparency, accountability, and trust in such technologies?

Transparency, accountability, and trust are very important. Human-in-the-loop (HITL) oversight requiring public algorithmic audits and adopting open-source civic tech prevent 'black box' decisions, combat systemic biases, and ensure that technology augments rather than replaces democratic decision-making. While GeoAI can interpret and structure data, final decisions must remain with professional, accountable, 'human planners' who understand local socio-political realities. Robust data privacy measures that adhere to global or ~~local~~ national data protection standards should be implemented, ensuring constituent data is anonymised and securely managed. Reasoning and arguments for developing and adopting a particular vision for planned development, or trends of population growth or spatial spread, though, can be relied upon various GeoAI models, must be owned and defended by 'human' planners and decision makers. As regards trust, we will repeat what Dr. Mukund Rao said, "Trust, but Verify" Rao, MK (2026).

Do you see any risks and challenges that excessive reliance on AI could lead to technocratic planning, where algorithms dominate human judgment and local knowledge?

Yes, the risk of shifting toward algorithmic governance is substantial. Excessive reliance on AI can lead to technocratic planning, where opaque models and narrow performance metrics override human values. Over-reliance threatens human oversight, marginalises vital local knowledge, and can lead to automation bias. Algorithms might fail to capture the nuanced realities, cultural subtleties, and specific context of local communities. There is a danger of decline in critical thinking skills and the atrophy of human expertise. AI systems should not be allowed to 'make' critical decisions; rather, they should aid in making a decision. Governance structures must enforce a human-centric approach to preserve human values, judgement and local knowledge. There are ethical and ownership issues as well. It must be acknowledged that the models may not be structured to reflect local conditions and nuances, which can be provided only through the intervention of the planners. A summary of challenges, as identified by Sanchez, Brenman and Ye (2025) is presented in Fig. 2.

How can Geospatial AI provide better horizontal and vertical integration between different levels of planning?

GeoAI provides better horizontal and vertical integration in planning by acting as a universal, spatial data translator. It enables cross-sector communication (horizontal) and connects local, urban, regional, and national goals (vertical) by transforming massive datasets into shared, predictive, and interactive planning models.

Planners can query unstructured administrative documents, policy guidelines, and spatial maps simultaneously using tools within enterprise ecosystems like ArcGIS, allowing domain experts without coding backgrounds to interact with multi-level datasets. By evaluating historical zoning, socio-economic layers, and development trends, GeoAI algorithms can accurately forecast where future infrastructure strain will occur, ensuring long-term city-level plans align with local neighbourhood or zonal level plans. Ideally, it is possible to seamlessly plan and flow through the local level plans to the city and regional level plans and vice-versa, typically like one would zoom in and out in Google Maps. In the same way, comparison and integration are possible between neighbouring wards or zones, etc.

How can Geospatial AI ensure better stakeholders' participation at each stage of Master Plan preparation – opinion and objections, plan preparation, and feedback?

Stakeholders' participation is an important stage in the planning process. But before the stakeholders can react, they must understand the plan proposals from the policy and layout perspectives. Gathering public input is traditionally hindered by technical jargon, complicated zoning maps, and overwhelming administrative data. Ideally, the stakeholders themselves should be able to generate 'what if' scenarios based on their suggestions. GeoAI transforms a Master Plan from a top-down techno-administrative process to an inclusive, data-driven and comprehendible framework. It bridges the gap between experts and citizens by making complex spatial data intuitive, automating public input analysis, and ensuring that community feedback is accurately reflected at every stage of the planning process. AI Natural Language Processing (NLP) translates dense techno-administrative planning text into simpler, local languages and accessible terminology, ensuring all residents understand how the plan proposals are going to affect their overall quality of life. When citizens submit feedback or drop location-based pins on maps (Public Participation GIS), GeoAI automatically analyses the text and categorises the data by specific themes like land use compatibility, congestion, green spaces or historical aspects. Instead of manually reading thousands of localised objections and suggestions, GeoAI tools immediately sort and summarise complex feedback to differentiate between localised voices and those at the city level.

> Urban planners were historically late in adopting technology, primarily because the profession originated in engineering, public health and architecture, focusing on physical aesthetics rather than empirical data. Early urban planning was treated as an artistic and spatial design process.

During the plan preparation stage, GeoAI acts as a real-time consensus and visualisation tool, bridging the gap between community needs and physical land use mapping. Complex 2D layers can be converted into 3D/4D visualisations, allowing all stakeholders to intuitively view how master plan proposals, new infrastructure, or changing building heights will look in their neighbourhood. Interactive GeoAI platforms enable planners to adjust draft plans live during community workshops. If residents request more parks, the system calculates the impact on connectivity and accessibility in real time, fostering an environment of co-creation rather than one-way communication. A similar process can be followed for periodic reviews and feedback.

The final check ensures the draft master plan accurately aligns with the thousands of opinions before it is finalised. GeoAI can facilitate consensus by grouping draft outcomes based on community preferences, ranking proposed solutions, and building automated dashboards that verify which public objections were integrated into the finalised master plan. Interactive mobile-based or internet-based apps can be developed to generate alternative scenarios for the suggestion being made. AI algorithms can segregate large volumes of unstructured public comments into organised, geo-referenced, quick-mappable solutions. These tools can expose structural inequalities and help evaluate whether the feedback captures a representative demographic group.

How can Geospatial AI help prepare app-based tools for public participation in the Master Plan preparation process?

App-based tools can ensure public participation in Master Plan preparation by automating data synthesis and making complex spatial data intuitive. It allows citizens to interact directly with urban planning data, analysis and plan proposals. AI-powered chatbots and Natural Language Processing (NLP) within apps can automatically translate complex, technical planning statements into simple, locally understood language for residents. Using 3D models and augmented reality, citizens can view and interact with proposed zoning (like mixed-use) or FAR and building height proposals in real-time, helping stakeholders easily grasp the impact of proposals. These models can also easily classify existing land use, creating a baseline map of current activities so the public can review spatial plans against current ground realities. Tools like UrbanistAI can help users to suggest public space designs on interactive maps using text prompts and visual generation. App dashboards can be used to model scenarios. GeoAI models can analyse proposals to show how close the citizens would be to public amenities, allowing them to spot and highlight service gaps at a neighbourhood or zonal level.

Urban Planners were late in adopting technology in general, especially the Systems Approach to Planning. Please elaborate.

Urban planners were historically late in adopting technology, primarily because the profession originated in engineering, public health and architecture, focusing on physical aesthetics rather than empirical data. Early urban planning was treated as an artistic and spatial design process. Planners mapped physical layouts and were slow to integrate the social, economic, and digital data required by a systems perspective. At the same time, planners lacked the mathematical and computational training to handle complex, cybernetic urban models. The Systems Approach conceptualised the city as a complex, interconnected organism - where transportation, housing, economics, and ecology influence one another. When technological tools and the Systems Approach emerged in the late '60s (Chadwick, Hall, McLoughlin), the profession resisted them, viewing these methods as overly technocratic and dismissive of human complexity. Gradually, cities were viewed as Generators of Economic Momentum (GEM; NCU) and Engines of Growth rather than a place to live with a certain Quality of Life. With the availability of raster-based satellite images and GIS, early attempts were made to predict growth and sprawl based on the fractal geometry of cities (Batty and Longley). Smart Cities Mission further pushed the technology aspect rather than the environment and quality aspect. However, the GeoAI technology of today can very efficiently merge statistical and spatial data, technical and humanistic considerations, environment and Quality of Life concerns, both for understanding the present and forecasting the future.

How can GeoAI and Agentic GIS help make better statistical and spatial projections and prepare better Master Plans for urban areas?

Geospatial AI (GeoAI) combines artificial intelligence with geographic information systems (GIS) to process satellite imagery, IoT sensors, and spatial data. Rather than estimating growth based solely on historical flat statistics, GeoAI combines demographic shifts, economic data, and satellite imagery to forecast population changes and map future demand for resources like land and infrastructure. Reasonably accurate estimates of population can be made in the absence of frequent or delayed census data. Not only the population in aggregate but also how the population is distributed over zones or wards, etc. It can automatically process drone and satellite imagery to map urban heat islands, calculate green cover loss, or predict flood zones and at-risk households. Geospatial AI (GeoAI) and Agentic GIS transform traditional urban planning by replacing static master plans with dynamic, data-driven systems. These technologies allow planners to automate complex workflows, predict urban growth, and analyse vast, multimodal spatial datasets in minutes rather than months. Also, self-evolving shorter-term plans can be prepared at various spatial levels.

Agentic GIS uses specialised AI agents that break down complex goals into smaller steps, autonomously fetch necessary geospatial data, analyse it against constraints, and output recommendations. Archivinci, CARTO and Mapbox are some of the tools that provide an Agentic GIS approach. GeoAI capabilities are directly connected to GIS workflows, offering assistive assistants and agentic systems for spatial analysis, geoprocessing, and geographic understanding.

GeoAI provides better horizontal and vertical integration in planning by acting as a universal, spatial data translator. It enables cross-sector communication (horizontal) and connects local, urban, regional, and national goals (vertical) by transforming massive datasets into shared, predictive, and interactive planning models.

Planners are expected to mainstream diverse fields like climate change, urban biodiversity, disaster prevention and management, socio-economic inclusion, equity, carbon emissions, urban heat islands, quality of life, etc. in one Master Plan document. Can Geospatial AI help achieve this?

Yes, GeoAI is highly capable of mainstreaming these complex, multi-disciplinary factors into a unified Master Plan. It serves as an analytical exoskeleton for planners, blending machine learning with spatial data to automate feature extraction, predict environmental vulnerabilities, and optimise infrastructure development.

First of all, GeoAI streamlines the massive task of preparing digitised basemaps and zoning, automatically extracting plot boundaries and estimating population density. This gives human planners the time and high-resolution data needed to focus on a qualitative, holistic plan. Through automated object detection on satellite and drone imagery, GeoAI inventories tree canopies, tracks green-space fragmentation, and calculates functional biodiversity connectivity. For disaster management, AI models analyse historical topography and hydrological data to accurately predict flood risks and landslide vulnerabilities. At a local level, individual structures can be identified which could be prone to fire hazard.

GeoAI maps Land Surface Temperature (LST) and micro-climates at the ward or street level. It correlates building density and surface reflectivity to pinpoint UHI hotspots, allowing planners to simulate how strategic tree-planting or cool roofs will lower ambient temperatures. It also models carbon footprints by assessing transportation networks and building energy usage. AI models overlay demographic profiles, income data, and spatial accessibility indices, revealing systemic disparities and allowing planners to prioritise equitable infrastructure investments.

As GeoAI becomes increasingly embedded in planning systems, what do you believe should remain fundamentally human in the process of planning and shaping cities?

Human oversight will always remain vital. The UN-Habitat GeoAI Toolkit for Urban Planners notes that while these tools give planners ‘digital superpowers’, they also risk inheriting human biases, violating data privacy, and overlooking community context if deployed without strict ethical frameworks. Therefore, GeoAI is not replacing urban planners; rather, it elevates them from basic spatial analysts into proactive, forward-looking strategists. The fundamentally human components of urban planning must remain grounded in values, empathy, and community consensus. GeoAI cannot replace human oversight; planners must blend these computational models with solid planning theory and public engagement to ensure algorithmic biases do not marginalise vulnerable communities. Human, planners’ oversight is crucial to audit these systems, ensuring they promote social justice and protect citizen privacy.

As I said in the very beginning, the planning activity starts with the formulation of goals and objectives and vision statements. This should and will remain planner-driven. Setting the philosophical direction - such as deciding whether a city prioritises sustainability or economic growth; whether it showcases itself as an educational hub or a religious node - is a planner’s responsibility. What built form should emerge will be decided by planners. Which parts of the city’s heritage should be conserved or taken up for redevelopment must be decided by planners. GeoAI can help achieve those goals and built form through the Development Plans. GeoAI cannot become a Planner by itself. GeoAI being only a tool, more sophisticated than GIS and RS, planners should continue to be the final thinkers and decision-makers, basing it all on first principles of planning. After all, it will be a city for humans and not for the machines!

Having spent decades teaching planning at the School of Planning and Architecture, New Delhi, how do you think planning education should evolve to prepare future planners for an AI-enabled planning environment?

We, at the School, were perhaps the first ones to start teaching Aerial Photography to the students of planning, way back in the early 80’s, in collaboration with the Indian Institute of Remote Sensing (then Indian Photo-Interpretation Institute). It was followed by establishing an Aerial Photography Lab, which was later transformed to a Remote Sensing and GIS Lab. From a small part of a subject on Planning Techniques, it expanded to a full subject on Remote Sensing and GIS. Today, besides offering compulsory courses on Geo-Informatics in Planning, the School is offering an Institutional Elective on Geospatial AI. We are also in the process of starting a GeoAI Lab. With its ties across various departments and institutions in the country, the School is best suited to function as a centre for building, generating and testing GeoAI models through capture of relevant data through its studio exercises, so that the future planners graduate with the skill of GeoAI while at the same time benefiting the institute and the involved cities and towns.

Our curriculum is designed to equip students with the skills to build predictive models for urban growth, utilise AI to optimise infrastructure, and apply generative design not only for aesthetic purposes but also for addressing complex social challenges. Several of our students continue their higher and doctoral studies in Geoinformatics at internationally renowned institutions like ITC and TU Delft, the Netherlands. They demonstrate a unique ability to think strategically and emerge not merely as analysts, but as future leaders and urban strategists.

Several other planning institutions now have full-fledged GIS labs and subjects related to GeoSpatial technologies. Several bachelor's, master's and doctoral theses have been completed on topics revolving around the GeoSpatial technologies either conceptually or used as a major tool. Several training programmes, short courses, Faculty Development Programmes and symposia are also organised from time to time.

Planning education at institutions like the School of Planning and Architecture, New Delhi must evolve by integrating computational thinking and data literacy into the core studio curriculum. Planners need to be trained to use AI for predictive modelling and real-time scenario planning while retaining the socio-cultural understanding of Indian cities. Students should learn to simulate the impacts of urban policies, zoning, and transit in real-time, leveraging tools like City Digital Twins. GeoAI tools must be used to address uniquely Indian urban challenges, such as informal settlements, high-density environments, mixed land uses and varied transit behaviours. Future planners must act as translators, communicating algorithmic outputs into actionable, human-centric plans. Ethical concerns like data privacy, algorithmic bias, and equitable resource distribution should remain one of the primary objectives.

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GNSS (SBAS) Constellation Specific Monthly Analysis Summary: July 2026

The analysis performed in this report is solely the author's work and his opinion.

Narayan Dhital
Actively involved to support international collaboration in GNSS-related activities. He has regularly supported and contributed to different workshops of the International Committee on GNSS (ICG), and the United Nations Office for Outer Space Affairs (UNOOSA). As a professional employee, the author is working as GNSS expert at the Galileo Control Center, DLR GfR mbH, Germany.

This article continues the monthly performance analysis of the GNSS/SBAS constellation. Readers are encouraged to refer to previous issues for foundational discussions and earlier results. The focus for this month's issue is the clock stability and precision of the latest operational satellites from the **Galileo** and **GPS** constellations—**Galileo E28**, **Galileo E32**, **GPS G20**, and **GPS G21**. Using the **IGS Final Clock Product** as a reference, the analysis evaluates the onboard atomic clock performance through **Modified Allan Deviation (MDEV)** and compares broadcast clock corrections against precise clock data.

Introduction

The most recent operational satellites in the Galileo and GPS constellations—Galileo E28 and E32, and GPS G20 and G21—mark a significant milestone in global navigation infrastructure. Galileo E28 and E32, corresponding to satellite vehicle numbers SAT 33 and SAT 34, were launched in December 2025 during the fourteenth Galileo launch campaign aboard Ariane 6 from French Guiana. They were declared operational in mid2026, completing the third orbital plane of the constellation. Each satellite carries a combination of Passive Hydrogen Maser (PHM) and Rubidium Atomic Frequency Standard (RAFS) clocks, designed to provide exceptional longterm stability. GPS satellites G20 and G21, part of the Block III series, were launched between 2024 and 2026 and declared operational shortly after commissioning by the U.S. Space Force. Operating in semisynchronous Medium Earth Orbit at approximately 20,200 km altitude, they are equipped with advanced Rubidium atomic clocks that offer improved shielding and thermal control compared to earlier generations. These satellites differ from their predecessors by incorporating enhanced clock technology, improved broadcast ephemeris accuracy, and refined signal designs, all of which contribute to greater timing reliability and interoperability across GNSS systems.

Analysis

The analysis was conducted using the IGS Final Clock Product as the reference truth for precision evaluation. Clock stability was assessed through the Modified Allan Deviation (MDEV), which quantifies frequency stability over varying averaging times and distinguishes shortterm noise from longterm drift. Accuracy was evaluated by comparing broadcast clock corrections from GPS and Galileo navigation messages against the IGS final clock product, allowing the determination of mean offsets, standard deviations, and RMS values. The results are visualized in three plots: the first showing Galileo clock offsets versus time, the second showing GPS clock offsets versus time, and the third presenting a comparative MDEV plot across the four satellites. These plots provide a clear picture of temporal variations, noise levels, and comparative stability. The randomly selected date is day of year 179, 2026.

Results and Interpretation

The Galileo results reveal that E28 and E32 perform consistently within the constellation, though with subtle differences. In Figure 1, E28 shows slightly higher scatter clock noise, with a standard deviation of approximately 0.276 m, suggesting minor shortterm fluctuations likely linked to orbital or thermal effects. E32, with a standard deviation of about 0.201 m, demonstrates smoother behavior and lower noise, confirming excellent stability. Other Galileo satellites cluster tightly around a mean offset with a standard deviation near 0.195 m, validating the robustness of the constellation's timing system. In the MDEV plot (Figure 3), both E28 and E32 maintain deviations below 10^{-13} for averaging times greater than 1000 s, confirming the superior longterm stability of their

PHM clocks. Their performance surpasses earlier satellites but well within the expected range among the FOC satelliets, reflecting improvements in clock conditioning and onboard management. Note that the scattered noise and jumps in Galileo satellites could also come from granularity of 10 minutes (whic is relatively freqeunt update of the broadcast clock data every10 minutes in comparison to 2 hours for GPS).

The GPS analysis (Figure 2) shows that G20 and G21 also deliver strong performance, though with distinct characteristics. G20, with a standard deviation of about 0.189 m, exhibits moderate variation and visible periodic trends, likely associated with orbital temperature cycles. G21, with a narrower standard deviation of 0.127 m, remains remarkably stable, forming a tight offset band around zero. Other GPS satellites show slightly higher dispersion, with a standard deviation near 0.158 m, consistent with the mixed aging of Block IIF and Block III units. In the MDEV

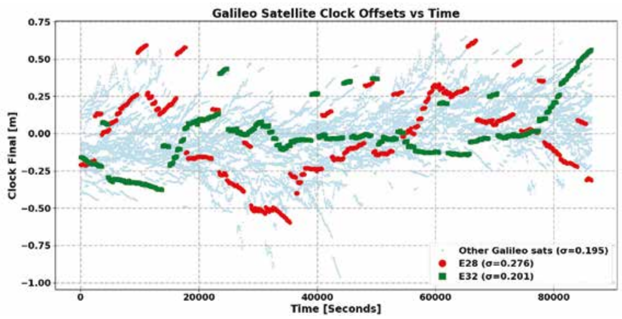

Figure 1: Clock accuracy analysis of Galileo satellites. The clocks are compared with MGEX-CODE final clocks and constellation and satellite specific bias are removed.

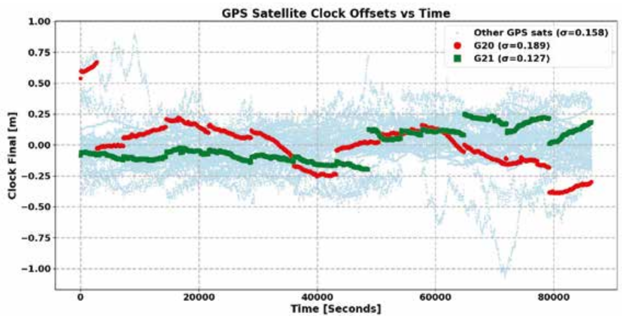

Figure 2: Clock accuracy analysis of GPS satellites. The clocks are compared with MGEX-CODE final clocks and constellation and satellite specific bias are removed.

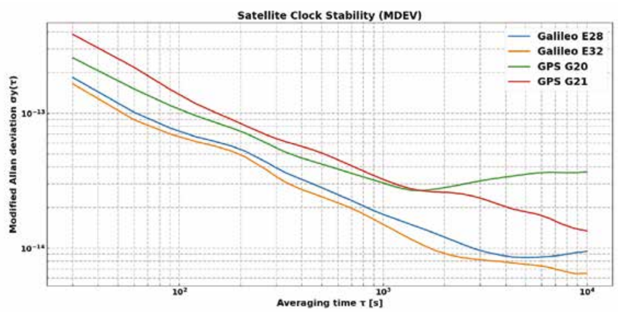

Figure 3: Clock stability analysis using the modified allan deviation. The clocks are used from MGEX CODE final 30 seconds sampled.

comparison, GPS clocks demonstrate deviations in the range of 10^{-13} to 10^{-14}, with G21 outperforming G20 at longer averaging times. This indicates excellent frequency stability, though still below the longterm performance of Galileo's PHM clocks.

Overall, the noise floor for all satellites lies within submeter clock offset levels, confirming the maturity of current GNSS timing systems. Orbital environment effects introduce small periodic modulations visible in the timeseries plots, but these remain well within operational tolerances.

(Note : in the monthly analysis series in coordinates (2024-2025) it was observed that Galileo satellite clocks were providing better constellation wide clock accuracy in comparions to GPS. Though GPS performance was gradually getting better from March 2024, this was reported in one of the monthly issues. In this specific analysis, GPS is slightly outperforming. It was reported in As monthly performance analysis for GPS and Galileo clocks have not been done in 2026, it is an interesting topic to be explored later.)

Conclusion

The analysis of Galileo satellites E28 and E32 alongside GPS satellites G20 and G21 demonstrates that both constellations continue to deliver exceptional timing performance, consistent with the high standards established by earlier generations. The results confirm that Galileo's Passive Hydrogen Maser clocks provide superior shortterm stability, with low noise and minimal drift across averaging times, while GPS Rubidium clocks remain highly reliable and predictable, particularly in their longterm behavior. Galileo clocks provide better performance in both short and long term. Although E28 and E32 do not represent a stepchange improvement over earlier Galileo FOC satellites, they reinforce the constellation's reputation for robust clock quality and operational consistency. Similarly, G20 and G21 show performance in line with the Block III generation, with G21 exhibiting particularly strong stability. Together, these satellites ensure continuity of precise timing across GNSS, supporting improved synchronization, positioning accuracy, and interoperability between Galileo and GPS.

Data sources and Tools:

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serenad-public.cnes.fr (SBAS data)

allantools, python

The Power of Geospatial Intelligence

A GIS-enhanced curriculum for sustainable planning and socio-economic transformation in northern cape, South Africa

Dr. Tolulope Ayodeji Olatoye
Lecturer and Post-Doctoral Research Fellow in Geography at Sol Plaatje University, Kimberley, South Africa.

Dr. Raymond Nkwenti Fru
Head of Department, Human Science Teaching at the Faculty of Education, Sol Plaatje University, Kimberley. South Africa

Abstract

The Northern Cape province of South Africa remains one of the most spatially marginalized and economically underdeveloped regions, plagued by low educational attainment, poor infrastructure, and unsustainable land use. This study investigates the transformative power of spatial intelligence through a GIS-enhanced curriculum aimed at fostering sustainable planning and socio-economic revitalization. Grounded in Place-Based Experiential Learning Pedagogical Framework, the research explored how geospatial technologies can be integrated into education to cultivate critical spatial reasoning, local agency, and sustainability-driven development. A systematic literature review methodology was employed to consolidate existing research on GIS in education, sustainable regional planning, and rural transformation. Scholarly databases such as Scopus, Web of Science, and ERIC were queried using a structured keyword strategy, yielding 67 peer-reviewed sources. Findings reveal that GIS-integrated education enhances learners' spatial awareness, problem-solving skills, and engagement with community development, but its effectiveness is hindered by digital divides, inadequate teacher training, and fragmented policy support. To harness its full potential, the study recommends the establishment of a state-of-the-art eco-tourism resort that leverages the province's unique ecological and cultural heritage, and the development of an additional public university dedicated to Social Sciences, Medicine, Law, Engineering, Built Environment and Veterinary Sciences. Future research could develop localized, multilingual GIS modules co-designed with indigenous knowledge holders and educators to assess culturally responsive applications of spatial intelligence in curriculum development. This approach would help address epistemic inequities in knowledge production and contribute to decolonial pedagogies in geospatial education.

Introduction

As elucidated by Gregory et al., Scott & Rajabifard, the 21st century has witnessed a paradigm shift in how knowledge systems, geospatial technologies, and sustainable development intersect, particularly in regions grappling with socio-economic marginalization and geographic vastness.[1] The Northern Cape, South Africa's largest and most sparsely populated province, remains paradoxically rich in natural resources yet impoverished in terms of human development, infrastructure equity, and access to spatially informed education.[2] Despite national efforts toward inclusive growth, the persistent disconnect between policy, pedagogy, and planning continues to impede meaningful transformation in this geographically complex landscape.

The Northern Cape, South Africa's largest province by geographic expanse, paradoxically remains one of the most economically disenfranchised regions in the country.[3] Despite its rich endowment of natural resources, unique ecological biomes, and cultural heritage, the province continues to grapple with entrenched poverty, youth unemployment, limited educational infrastructure, and uneven spatial development.[4] These challenges are symptomatic not merely of geographical isolation, but of deeper structural and epistemic deficits, most notably, the failure to integrate spatial intelligence into policy, planning, and education.[5] The marginalization of spatial reasoning skills, particularly those fostered through GIS, has resulted in a planning vacuum where decisions about land use, infrastructure, conservation, and economic development are often reactive, fragmented, or misaligned with local realities.[6] In the education sector, curricula remain largely static and disembodied from place-based knowledge systems.[7] This epistemological gap leaves learners ill-equipped to analyse spatial phenomena, participate in sustainable development discourses, or innovate context-responsive solutions. [8] Consequently, the province continues to be bypassed by the opportunities presented by the Fourth Industrial Revolution, exacerbating its peripheral status within South Africa's socio-economic landscape.[9] Hence, this study seeks to contribute to both pedagogical innovation and place-based development by repositioning spatial intelligence not merely as a technical skill, but as a powerful epistemic and civic tool for transforming peripheral geographies into nodes of socio-economic vitality and ecological resilience.

This study explores the transformative potential of spatial intelligence, operationalized through a Geographic Information Systems (GIS)-enhanced curriculum, as a catalyst for sustainable planning and socio-economic revitalization in the Northern Cape. Spatial intelligence, the cognitive capacity to reason, interpret, and act upon spatial data represents a critical yet underutilized asset in the reimagination of rural development, participatory governance, and future-ready education. When embedded within curriculum design and aligned with community-based geospatial needs, GIS education not only equips learners with powerful analytical tools but also cultivates a generation of spatially literate citizens capable of influencing developmental trajectories.[10] Framed within the broader discourse of spatial justice, decolonial education, and the Fourth Industrial Revolution, this research investigates how a GIS-integrated pedagogical model can bridge the gap between classroom learning and real-world spatial planning in a historically marginalized province. The study seeks to examine how the integration of geospatial intelligence through GIS in educational curricula can enhance learners' capacity for sustainable planning, spatial justice, and inclusive development in the Northern Cape. It further seeks to investigate how geospatial intelligence can be applied to determine optimal site selection for the establishment of a state-of-the-art international ecotourism resort and an additional public university in the Northern Cape. The study argues that empowering educators and learners with spatial tools is essential for unlocking the latent developmental potential of the Northern Cape and repositioning education as a driver of ecological resilience, infrastructural innovation, and socio-economic inclusion.[11] The following question underlies the study: How can a GIS-enhanced curriculum serve as a transformative tool for sustainable planning and socio-economic development in the Northern Cape province of South Africa?

According to Dold et al., the incorporation of geospatial intelligence (GIS) into education is increasingly recognized as a transformative pedagogical approach that aligns with the imperatives of the Fourth Industrial Revolution (4IR).[12] Scholars like Unangst and Beimers advocate for decolonized, contextually relevant, and socially just curricula, emphasizing GIS not simply as a technological tool but as a critical medium for disrupting dominant spatial narratives and empowering marginalized communities. [13] Rooted in critical geography and spatial justice, GIS fosters a critical spatial consciousness, enabling learners, especially in marginalized regions (like South Africa's Northern Cape), to engage with and transform their lived environments through mapping and analysis.[14] However, most research and implementation of GIS education have been concentrated in affluent, well-resourced settings, leaving a significant gap in the literature and practice regarding its use in historically disadvantaged areas.[15] In the Northern Cape, GIS adoption is limited by infrastructural deficits, inadequate teacher training, and a lack of localized learning materials.[16]

Place-based education offers a compelling framework for embedding GIS in context-sensitive curricula,[17] fostering experiential learning and socio-political empowerment.[18] Empirical evidence, such as, Tam, and Kholoshyn, from global initiatives demonstrates how GIS can act as a liberatory and developmental tool.[19] Yet in Africa (and the Northern Cape in specificity), GIS remains underutilized in both educational and policy domains despite its proven value in urban planning, environmental monitoring, and sustainable development.[20] Addressing these challenges calls for a curricular paradigm that aligns GIS with local knowledge systems, regional development goals, and socio-educational empowerment.[21] A GIS-integrated, place-based curriculum has the potential to cultivate spatially literate, critically conscious graduates who can drive sustainable change, making this study both timely and necessary.[22]

Theoretical framework

Place-Based Experiential Learning Pedagogical Framework (PBEL-PF)

The PBEL-PF emerges from the convergence of human geography, educational theory, and community development, positing that meaningful knowledge and transformative action are deeply embedded in the contextual realities of place.[23] At its core, PBEL-PF challenges abstract, universalist approaches to development and learning by insisting that spatial, cultural, ecological, and historical specificities must shape the design of policies, curricula, and socio-economic interventions.[24] Rather than treating place as a passive backdrop, PBEL-PF conceptualizes it as an active agent, laden with memory, identity, potential, and power.[25] PBEL-PF's philosophical foundations lie in the rejection of placelessness, technocratic uniformity, and the colonial logic of "development from above." [26] It calls for an epistemological realignment that privileges local knowledge systems, participatory engagement, and environmental responsiveness.[27] Education, in a place-based framework, becomes a vehicle for spatial justice, civic empowerment, and sustainable stewardship.[28] It emphasizes the co-production of knowledge between learners and their environments,[29] fostering an ethic of care and innovation rooted in lived geographies. In the context of this study, PBT provides a critical lens for reimagining the Northern Cape's developmental trajectory through a GIS-enhanced curriculum that is both spatially aware and socially embedded. The Northern Cape, often relegated to the peripheries of national development discourses, is not merely underdeveloped; it is under-recognized in terms of its place potential. Figure 1 depicts the Place-Based Experiential Learning Pedagogical Framework (PBEL-PF).

At its core, the PBEL-PF diagram depicted in Figure 1 situates experiential learning as the process of learning through direct engagement with phenomena within the spatial and cultural contexts of "place." This orientation is particularly significant for the Northern Cape, a province that is often misrepresented as void of opportunity, when in fact, it possesses immense ecological, cultural, and economic potential awaiting spatial reawakening. Critically, the PBEL-PF framework begins with concrete experience, the observation and reflection of real-world phenomena, and flows through reflective observation, abstract conceptualization, and active experimentation.[30] In this context, GIS serves not merely as a technical tool,[31] but as a medium through which students engage with their immediate geographies. Through hands-on spatial data collection, interpretation of satellite imagery, and digital cartography, learners come to "see" their world differently, thus initiating the journey from wonder to understanding and, ultimately, to action.[32] The framework foregrounds the idea that knowledge must be situated, not abstracted from, but embedded within, the ecological, social, and cultural narratives of local spaces.[33] This is vital for the Northern Cape, where traditional top-down development models have failed to produce sustainable or inclusive outcomes.[34]

A GIS-enhanced curriculum informed by this framework enables learners to interrogate and reconstruct their local geographies, cultivating a sense of civic responsibility, environmental stewardship, and spatial justice.[35] For instance, when learners analyse patterns of drought, land degradation, or socio-economic exclusion through GIS tools, they are not simply learning geography; they are engaging in critical place-based inquiry that has real-world implications for policy and planning.[36] The concentric circles of wonder, knowledge, understanding, responsibility, caring, and action (as depicted in Figure 1) reflect a deepening ethical engagement with place. This trajectory is crucial for transforming spatially marginalized learners into agents of transformation. The framework insists that civic efficacy and meaningful participation in development processes are contingent upon this deep connection to place, a connection that is currently underdeveloped in many educational contexts across the Northern Cape. Thus, GIS education becomes a form of spatial pedagogy, where data is not just analysed by employing this framework, but also ethically interpreted in light of local needs and aspirations.[37]

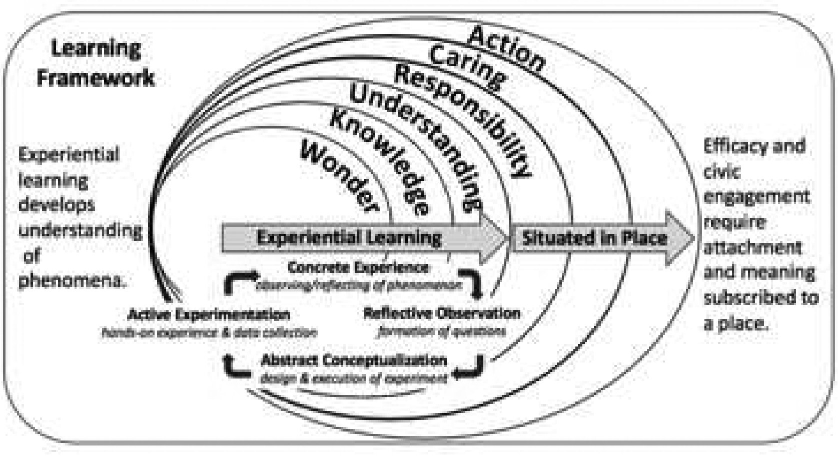

Figure 1. Schematic of Place-Based Experiential Learning Framework. (Adapted from The Journal of Sustainability Education (2019).

In practical terms, integrating PBELF into a GIS-enhanced curriculum supports the advocacy for the establishment of a state-of-the-art international ecotourism resort and an additional public university in the province.[38] These proposals emerge from a place-based recognition of the Northern Cape's rich biocultural assets and educational voids. Through experiential engagement, students could map potential ecotourism corridors, assess environmental impact zones, or design culturally resonant campus layouts using GIS. Such participatory and situated practices ensure that infrastructural recommendations are context-sensitive, inclusive, and grounded in lived realities.[39] It is on this premise that it is opined that PBEL-PF transforms the role of GIS in education from a technical skillset into a philosophy of situated knowledge and action.[40] It empowers learners to reclaim agency over their spatial futures by developing the capacity to read, critique, and reimagine the landscapes they inhabit.[41] This study, by aligning with PBEL-PF, not only contributes to spatial literacy but also advances a pedagogy of place that is urgently needed in South Africa's peripheral provinces.

Applying PBEL-PF to this research underscores the necessity of tailoring GIS education to the unique socio-ecological and economic context of the Northern Cape. Thus, PBEL-PF not only informs the theoretical grounding of this study but also elevates its practical implications. It demands that geospatial intelligence be tethered to ethical place-making where technology, pedagogy, and policy coalesce to honour, heal, and activate the dormant potential of marginal geographies.[42] The Northern Cape, seen through the lens of PBEL-PF, is not a void waiting for top-down interventions; it is a storied landscape of possibility awaiting place-based reawakening.

Methodology

Description of the Study Area

According to Mthombeni, the Northern Cape Province, covering about 372,889 km², is South Africa's largest but least populated province, encompassing semi-arid and arid zones with rich ecological and mineral resources.[43] Despite its vast natural wealth, including biodiversity hotspots and mineral deposits, the region remains marked by infrastructural underdevelopment and socio-spatial marginalization rooted in colonial and apartheid legacies.[44] Home to approximately 1.37 million people, mainly from historically disadvantaged groups, the province faces persistent inequalities, poor connectivity, and limited access to quality education and technology.[45] Educational institutions in the province often suffer from disconnection between policy goals and local realities, with scarce resources, low technological integration, and curricula detached from community needs and environmental contexts. These challenges perpetuate socio-spatial immobility and limit youth development opportunities.[46] The scarcity of higher education facilities exacerbates this marginalization.[47] The province's complex history and spatial dynamics, tied to land rights, environmental justice, and cultural identity, position it as a compelling site for deploying geospatial intelligence.[48] Hence, this study aimed to reframe the Northern Cape as a frontier for transformation, advocating for a justice-oriented, place-based approach to knowledge production, sustainable development, and inclusive growth by integrating GIS into education and spatial planning. Figure 2 presents the map of the study area.

This literature review adopted a systematic, interdisciplinary approach to explore the integration of Geographic Information Systems (GIS) in education, with a focus on marginalized contexts such as South Africa's Northern Cape. Using databases like Scopus, Web of Science, JSTOR, and Google Scholar, the study targeted literature from 2015–2025 on themes including GIS in education, spatial intelligence, place-based pedagogy, decolonizing curriculum, spatial justice, and ICT in rural education. Regional publications and policy documents were also included to ground the analysis in the local context. Inclusion criteria focused on peer-reviewed studies, theoretical works, and policy analyses addressing GIS in educational or spatial frameworks, especially in rural or under-resourced settings. Studies without educational relevance or focused solely on affluent urban areas were excluded unless they offered applicable insights. A qualitative thematic coding was applied across four main areas: (1) pedagogical frameworks for GIS integration, (2) spatial justice and decolonial theory, (3) challenges in marginalized contexts, and (4) links to regional development. This enabled a critical synthesis revealing gaps such as the underuse of GIS in rural South African education and the untapped potential of place-based approaches. To ensure depth, the review incorporated perspectives from education, human geography, environmental science, and development policy. Reflexivity was maintained by interrogating how colonial legacies and technological hierarchies shape curriculum and GIS use. Ultimately, the review positions GIS as a transformative pedagogical and epistemological tool, far beyond technical utility, capable of addressing spatial inequalities and advancing sustainable, locally grounded education in historically marginalized regions.

Presentation of results/ findings and discussion

Study objective 1: Integrating Geospatial Intelligence in Education for Advancing Sustainable Planning,

Figure 2: Map of the Province of Northern Cape, South Africa

Spatial Justice, and Inclusive Development in the Northern Cape

The study reveals both the transformative power and systemic challenges of integrating geospatial intelligence (GI) into education in South Africa's Northern Cape. Curriculum audits, interviews, focus groups, and policy analysis, carried out by Duarte and Hickman, show that GIS-based education enhances learners' spatial reasoning and their understanding of ecological, economic, and infrastructural issues.[49] Learners exposed to GIS began proposing context-specific development solutions, demonstrating increased civic awareness and engagement with spatial justice.[50] However, the study also highlights deep infrastructural and systemic disparities. Many schools, especially in rural and township areas, lack inadequate digital tools, trained educators, and curricular flexibility necessary for sustained GIS implementation. Educators face constraints from outdated syllabi and insufficient institutional support, while learners from historically marginalized backgrounds often experience digital alienation, which hinders their full participation in spatial learning. Despite these barriers, some schools, with support from municipalities, NGOs, and universities, piloted GIS projects that serve as models for scalable change. These initiatives empowered learners not just cognitively but politically, encouraging them to challenge spatial inequalities and contribute to sustainable development planning. [51] GIS also promotes interdisciplinary learning, allowing students to connect concepts across subjects and see sustainability as a tangible, locally relevant issue, thus leading to what the study terms a "spatial awakening", a departure from passive learning toward active, place-based engagement.[52] Thus, while GIS integration holds great promise for advancing spatial justice and inclusive development, its success hinges on dismantling systemic inequities, reforming rigid curricula, and closing the digital divide. A fundamental rethinking of education in peripheral regions is essential, one that centres agency, local relevance, and transformative spatial engagement.[53]

Study Objective 2: Applying Geospatial Intelligence for Optimal Site Selection of an International Ecotourism Resort and a Public University in the Northern Cape

The literature-informed phase of this study confirms the powerful role of geospatial intelligence (GI) as both a technical method and a strategic framework for regional development. Synthesizing insights across disciplines, the reviewed literature consistently highlights GIS as a key tool for site selection, [54] particularly where ecological sustainability and socio-economic inclusion intersect.[55] In the context of the Northern Cape, scholarly work on ecotourism informed the selection of locations for an international resort by emphasizing ecological sensitivity, biodiversity, and cultural uniqueness. Studies by Stone, Stephenson and Smith, respectively, from Costa Rica, Kerala, and Botswana reinforced the importance of aligning tourism development with conservation goals, guiding the study's focus on protected areas and indigenous zones.[56] Sustainability was further ensured through the incorporation of land fragility, erosion risks, and climate stress factors.[57] Parallel findings from studies by Benneworth and Ashik respectively, in the literature on higher education emphasized spatial equity, accessibility, and the developmental impact of strategically placed universities.[58] Case studies by Darvas, Goddard and Harris, respectively, from Canada, sub-Saharan Africa, and Australia highlighted how tertiary institutions can anchor growth in underserved areas.[59] These insights can shape the study's use of demographic mapping, transportation access, and youth population data to model a suitable location for an additional university, especially in the central-northern corridors of the province. Critically, the literature positions GIS not merely as a technical tool, but as an epistemic intervention aimed at correcting historical spatial injustices. This perspective informed the inclusion of vulnerability indices, deprivation data, and post-apartheid land exclusion patterns in the study's spatial analysis, leading to more ethically grounded and equitable site selection. Moreover, policy literature emphasized the developmental synergies of co-located infrastructure. The study followed this guidance by mapping areas where an ecotourism resort and a university could be spatially integrated, enabling mutual reinforcement through shared infrastructure, knowledge transfer, and local capacity building. In a nutshell, the literature validated the study's analytical choices and confirmed that when GI is applied within a justice-oriented, place-based framework, it can reshape the developmental prospects of marginalized regions like the Northern Cape. Site selection must thus be guided by a combination of spatial efficiency, ecological integrity, and social justice.

This study presents a transformative intervention at the intersection of spatial justice, educational reform, and sustainable development, using geospatial intelligence (GI), particularly through GIS tools, to address spatial inequality in South Africa's Northern Cape. Drawing from critical geography, place-based learning, and decolonial curriculum theory, it exposes how the integration of GIS can disrupt inherited legacies of apartheid-era marginalization and redirect development to historically overlooked regions. Key findings reveal that optimal sites for a new public university and an international ecotourism resort exist not in traditional urban centres but in ecologically rich and infrastructurally promising areas often excluded from mainstream development plans. This challenges dominant investment patterns and proposes a new spatial logic grounded in justice, local agency, and ecological sensitivity.

Pedagogically, the study advances GIS not just as a technical skill but as a critical epistemology, empowering learners, especially in marginalized communities, to analyze, question, and reimagine their lived spaces. This place-based approach to education aligns with global trends in sustainability learning but is distinctively localized to reflect postcolonial challenges and spatial injustices in under-resourced rural contexts. The study cautions, however, that the potential of GIS will remain unrealized without investment in infrastructure, teacher training, and policy reform. It highlights the co-locational power of higher education and ecotourism infrastructure as a catalyst for integrated, interdisciplinary regional growth, where universities can fuel conservation and innovation, and resorts can become sites of community learning and empowerment. From the foregoing, this study reframes GI as a justice-driven tool that democratizes spatial data, repositions education as emancipatory, and supports inclusive, equitable, and sustainable development planning. It calls for a shift in how peripheral regions like the Northern Cape are conceptualized, not as voids, but as frontiers of opportunity waiting to be reimagined through imagination, justice, and collective action.

Recommendations

This study proposes a bold, integrated strategy to advance spatial justice, educational transformation, and sustainable development in the Northern Cape. At the core of the recommendations are two interlinked infrastructure projects: a regionally responsive public university and a state-of-the-art ecotourism resort, strategically co-located to maximize impact.

Establishment of an Additional Public University: A new, context-sensitive, publicly funded university should be established in an underserved yet developmentally promising corridor identified through GIS analysis. This institution must go beyond traditional higher education models by emphasizing transdisciplinary learning, local knowledge, climate resilience, environmental stewardship, and community engagement. Its graduates should be equipped with spatial awareness and a deep connection to local socio-ecological dynamics.

Development of a World-Class Ecotourism Resort: A globally competitive ecotourism facility should be developed near biodiversity hotspots and culturally rich areas. The resort should emphasize ecological sustainability, architectural innovation, and community co-ownership, functioning not just as a leisure destination but as a site for environmental education, hospitality training, and indigenous knowledge preservation.

University–Resort Spatial Synergy: The co-location of the university and resort should be a deliberate regional development strategy, fostering mutual support. The university can offer academic programs aligned with the resort's needs (e.g., sustainable tourism, green economy), while the resort provides internship opportunities, research platforms, and community outreach spaces, thus creating a virtuous cycle of knowledge and development.

Policy Realignment and Institutional Collaboration: Realizing these projects requires policy reform and multi-sectoral coordination. The study recommends the creation of inter-ministerial task teams (across Higher Education, Tourism, Environment, and Rural Development) to coordinate spatial audits, public-private partnerships, and fast-track implementation.

Mainstreaming Geospatial Intelligence (GI): GI should be embedded into educational policy, teacher training, and planning frameworks. GIS must be introduced across school curricula and institutionalized in municipal and provincial governance, fostering a new generation of spatially literate and socially conscious learners and planners. In essence, these recommendations envision the Northern Cape not as a marginalized zone but as a crucible for innovation and place-based transformation. By fusing geospatial intelligence, education, and eco-tourism within a justice-oriented framework, the province can chart a new course toward inclusive and sustainable regional renewal.

Conclusion

This study has critically examined the integration of geospatial intelligence within educational curricula and regional development planning in the Northern Cape, revealing profound implications for sustainable planning, spatial justice, and inclusive growth. The findings demonstrate that embedding Geographic Information Systems (GIS) into education not only enhances learners' spatial cognition and interdisciplinary engagement but also serves as a transformative epistemic tool that challenges colonial legacies and spatial marginalization endemic to the province. Through the application of geospatial analysis, the study advocated for optimal sites for the establishment of an additional public university and a state-of-the-art ecotourism resort, both poised to act as catalytic infrastructure for socio-economic regeneration. These spatially informed interventions reflect a necessary alignment between education, environmental stewardship, and economic diversification, underscoring the critical role of place-based strategies in overcoming the Northern Cape's historic underdevelopment and infrastructural deficits. The study also illuminated systemic challenges, including infrastructural inequities, limited access to technology, and curricular disconnects from local realities, which must be addressed to fully realize GIS's potential as a democratizing and development-oriented tool. By situating geospatial intelligence at the nexus of pedagogy, policy, and planning, the research contributes a robust, context-sensitive framework for advancing equitable regional transformation. Hence, the study affirms that leveraging spatial intelligence through integrated educational and developmental approaches offers a compelling pathway to dismantle entrenched socio-spatial inequalities and foster a resilient, knowledge-driven Northern Cape. This conclusion not only advances scholarly discourse but also provides actionable insights for policymakers, educators, and community stakeholders committed to reimagining the province's future through innovation grounded in place.

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Leaf Space's first ground station in Canada

Leaf Space has announced the completion of its first ground station in Canada, built in partnership with Maritime Launch Services Inc at Spaceport Nova Scotia, near Canso, Nova Scotia. The newest ground station will support S- and X-band, high-speed data download for satellite operators worldwide, through efficient and mission-critical communication with their space assets from a strategic gateway on Canada's Atlantic coast. The antenna, radome and supporting electronics rack have been installed and activated on site, with the station now available for commercial satellite traffic, following regulatory clearance from Canadian authorities. *leaf.space*

Orbitworks ships UAE-built Altair-1 to US

Abu Dhabi-based satellite company Orbitworks has shipped Altair-1, the first satellite in its planned Altair constellation, to the United States for final launch preparations, marking a major milestone for the UAE's emerging commercial space industry.

Altair-1 is the UAE's first commercial AI-enabled Earth observation satellite and is the first of 10 spacecraft that will make up Orbitworks' Altair constellation. The satellite was developed, manufactured and integrated in the UAE before being transported to the US ahead of its planned launch in October 2026.

Long March 2C launches satellite for UAE

China launched a new batch of Guowang mega constellation satellites over the weekend, following up with a separate launch of a developmental satellite for the UAE. The launch of the Long March 12 notably came under a week after the failure of a Long March 7A rocket.

The Long March 12 lifted off at 12:10 a.m. Eastern (0410 UTC) Aug. 16 from pad 2 at the Hainan commercial space launch center, southern China. The China Aerospace Science and Technology Corporation (CASC) announced launch success, revealing the payload to be a new batch of satellites for the Guowang constellation. *spacenews.com*

Synspective's 10th SAR satellite successfully reaches target orbit

Synspective Inc. successfully deployed its 10th SAR satellite, StriX, the latest addition to its growing constellation. The satellite was launched into orbit by Rocket Lab's Electron rocket from Launch Complex 1 on New Zealand's Mahia Peninsula on June 26, 17:43 (UTC). Over the coming months, Synspective will conduct testing and commissioning to verify the satellite's observation capabilities before entering service. *www.synspective.com*

Uzbekistan-China satellite project advances with AI Module

Uzbek engineers are developing an onboard artificial intelligence module for a new Earth observation satellite being built in partnership with a Chinese aerospace company. The satellite, named Samarqand-2028, is being developed under an agreement between Uzbekistan's national space agency, Uzbekcosmos, and China's STAR.VISION Aerospace. The Chinese company is developing the satellite itself, while Uzbek specialists are working on an onboard AI system that will help process the information it collects. The spacecraft will use hyperspectral imaging, which can detect features invisible to the human eye. *timesca.com*

ISRO expands satellite-based Disaster Management across J&K

The Indian Space Research Organisation (ISRO) has implemented a range of satellite-based and space technology applications across Jammu and Kashmir, including landslide alerts, watershed monitoring, waterbody mapping, disaster management and decentralised planning. According to the Minister of State in the Prime Minister's Office Jitendra Singh, 12 operational communication satellites have coverage over Jammu and Kashmir. Among the major initiatives is the Satellite Integrated Landslide Assessment and Alert System (SILAAS) under ISRO's Disaster Management Support Programme, which is being used to map landslides and generate village-level alerts. ISRO has also undertaken landslide inventory mapping covering all districts of JK for the 2023 monsoon season. *kashmirlife.net*

Spire Global awarded $3.7 million NOAA contract

Spire Global has been awarded a $3.7 million contract by the National Oceanic and Atmospheric Administration (NOAA) for satellite weather data from Sept.18 through Dec. 1, 2026. Under the agreement, Spire will continue to deliver global navigation satellite system (GNSS) radio occultation (RO) data, including RO profiles with temporal resolution enhancements that provide a broader range of time sampling. *spire.com*

India plans BVLOS drone certification framework by end of 2026

India plans to introduce a refined certification framework enabling beyond visual line of sight (BVLOS) drone operations by the end of 2026, Civil Aviation Minister Kinjarapu Rammohan Naidu said at an Andhra Pradesh drone industry round table.

The AP Drone Industry CEO Round Table, hosted by the Drone Federation India (DFI) and the Government of Andhra Pradesh at Orvakal Drone City. Discussions focused on BVLOS operations, certification, testing and sandboxing, UAS traffic management (UTM), airspace access and domestic component development.

Industry representatives called for a risk-based certification framework, dedicated flight-testing environments and clear operating protocols to support the transition from experimental operations to commercially scalable drone networks. The discussions also highlighted the need for stronger UTM and live-tracking capabilities and more efficient mechanisms for drone operations in restricted and red zones. *www.dronefederation.in*

ISRO will not make any launch vehicle

India's space programme is preparing for one of its biggest structural transformations yet, with Indian Space Research Organisation (ISRO) set to gradually move away from manufacturing launch vehicles and routine satellites, handing these activities over to the private sector.

According to IN-SPACe Chairman Dr. Pawan Goenka, the transition is already underway and will allow ISRO to focus on research, advanced technologies, scientific missions and infrastructure that private companies may not be able to build on their own.

The shift has already begun with the Small Satellite Launch Vehicle, or SSLV, whose technology and production rights have been transferred to Hindustan Aeronautics Limited following a bidding process.

The next phase could be even more significant. Goenka said the Polar Satellite Launch Vehicle (PSLV) and the Launch Vehicle Mark-3 (LVM3), India's most powerful operational rocket, are also headed towards privatisation. Unlike the SSLV process, public sector companies will not be allowed to participate in the upcoming transfer process, leaving private industry to take charge. *www.indiatoday.in*

NASA invites ISRO to join its ambitious Moon Base programme

India and the United States are set to strengthen their cooperation in space exploration, with NASA inviting ISRO to join its ambitious Moon Base program, building on the two countries' partnership under the Artemis Accords.

During the 9th meeting of the India-US Civil Space Joint Working Group (CSJWG), hosted by India on 5-6 August 2026 at the headquarters of the Indian Space Research Organisation (ISRO) in Bengaluru, the two sides also agreed to advance discussions for cooperation on open scientific data sharing under the Accords.

India and the United States advanced their discussions on civil and commercial space cooperation and also focused on pursuing future science and human space flight technology partnerships, according to the US Embassy press release. *https://ddindia.co.in*

MCD's drone-based property survey pilot project to kick off soon

The Municipal Corporation of Delhi (MCD) is set to begin a pilot project using drones and other advanced mapping technologies to improve property tax assessment.

According to officials, the exercise is expected to help identify unassessed and under-assessed properties and plug revenue leakages.

The pilot follows memorandums of understanding (MoUs) signed by the civic body on June 2 with four agencies under its "Pilot Drone-based Geospatial Survey and Digital Twin Initiative".

Under the project, the agencies will independently conduct surveys using drone-based aerial imaging, LiDAR mapping, GIS-based asset mapping, Digital Twin technology, 3D city modelling and advanced data analytics. The MCD will not incur any expenditure on the pilot exercise, officials said. *www.ptinews.com*

Indonesia targets commercial drone operations by end of 2026

Indonesia's Ministry of Transportation is targeting commercial drones, or Advanced Air Mobility (AAM), to be operational by the end of 2026.

According to the reports, the ministry is currently drafting regulations and preparing infrastructure to support the new form of air transportation. To date, the ministry has registered around 5,000 small drones and issued over 11,000 remote pilot certificates. *https://english.news.cn*

Drone mapping project for digital governance in Ho Chi Minh

Ho Chi Minh City is implementing a project that uses unmanned aerial vehicles (UAVs) to survey local areas, create digital maps, and collect data to support government management across the city's 168 wards, communes, and special zones.

Tru Van Tho Commune is the first locality in Ho Chi Minh City and in Vietnam to partner with the Ho Chi Minh City Department of Science and Technology in a pilot project using UAVs to document local conditions, collect aerial imagery, and build spatial data layers for local administration.

After being selected for the pilot program, the commune began aerial surveys in June. Data collected by UAVs is providing the foundation for a visual, integrated database that can be updated regularly to support more effective local management.

Following Tru Van Tho Commune, the communes of Bau Bang, Tan Vinh Loc, Ben Cat, Can Gio, and Hung Long have also begun implementing the project. *https://en.sggp.org.vn*

Drone Survey for TMCP Work at Amelia North Coal Mine

Central Mine Planning & Design Institute Limited (CMPDI) successfully carried out a drone survey recently at the Amelia North Coal Mine of Jaiprakash Power Ventures Limited (JPVL) for Temporary Mine Closure Work (TMCP). The survey was conducted using a drone equipped with a high-resolution photogrammetry camera. The mine area, Coal Handling Plant (CHP), residential colony, and office premises were comprehensively surveyed to generate a high-resolution orthophoto mosaic.

OS donate survey kits to Bahamas

Ordnance Survey (OS) has donated 170 field survey kits to the Bahamas to help with strengthening geospatial learning and mapping capacity.

The donation will enhance practical training and support the continued advancement of surveying, mapping, environmental management, infrastructure planning, disaster resilience, and sustainable national development across the Bahamas. The donation grew out of a technical exchange visit by Bahamas National Geographic Information Systems (BNGIS) officials to the UK last year when a need for high-quality survey instruments was identified. *www.ordnancesurvey.co.uk*

Korea to build 3D 'New National Map'

The Korean government will shift its spatial information system, currently centered on 2-D maps, to a 3D spatial information foundation that artificial intelligence (AI) can utilize, and will foster the related industry. The Ministry of Land, Infrastructure and Transport (MOLIT) had confirmed the "Fourth Basic Plan for Spatial Information Industry Promotion (2026-2030)" following deliberation by the National Spatial Data Infrastructure Committee.

The basic plan consists of three strategic initiatives and 12 detailed tasks. First, the government will build spatial information, a core infrastructure of the AI era, from multiple angles. MOLIT plans to build six types of high-precision three-dimensional core spatial information that will serve as the foundation for an AI highway. Moving away from 2D maps centered on a 1:5,000 scale, the plan is to newly build the entire national territory into a high-precision 3D map, dubbed the "new Daedongyeojido" (Great Map of Korea), to achieve digital transformation, while also expanding the scope of 1:1,000 scale mapping.

The high-precision 3D spatial information secured in this way will also be used as AI training data. Based on this, MOLIT will pursue the development of a "GeoAI foundation model" that analyzes space to support decision-making, and will increase related research and development (R&D) investment. Plans to expand satellite infrastructure also stand out. In addition to the currently operating National Land Satellites 1 and 2, the ministry will introduce additional units 3 and 4, and will newly introduce a radar satellite (SAR) capable of constant observation.

First, it will overhaul regulations that hinder the use of spatial information. It will revise disclosure restriction standards to fit reality, and establish a basis for private companies to distribute spatial information they produce themselves after security processing.

The digital twin national territory model, used for disaster prediction and response, will also be expanded to various fields. GeoAI-based services such as a "land development permit pre-diagnosis service" and a "factory permit service" will be increased to support citizens' lives and corporate activities. Through the overhaul of data standards and quality management systems, the government will enhance interoperability among spatial information and support convergence with new technologies such as AI. *en.sedaily.com*

Nagaland GIS Centre boosts evidence-based planning

The Nagaland GIS and Remote Sensing Centre (NGISRSC) has significantly strengthened evidence-based planning and sustainable development in the state through the extensive use of geospatial technologies. According to senior project director of the NGISRSC, the Centre's key initiatives, including statewide Village Resource Mapping, assessment of hydropower potential, urban mapping down to the building-footprint level, landslide hazard zonation, aquatic resource mapping, traffic studies, and several other thematic geospatial projects. *https://theshillongtimes.com*

HydroGNSS data open for new insights into Earth's water

The European Space Agency's (ESA's) two-satellite HydroGNSS Scout mission has completed commissioning and is now in full scientific operations.

Following extensive testing and validation of the satellites, instruments and ground segment, HydroGNSS data are now freely available to users worldwide, opening new opportunities to advance our understanding of water availability and the impacts of climate change on Earth's water cycle.

Launched in November 2025, the HydroGNSS satellites use Global Navigation Satellite System Reflectometry (GNSS-R) to observe key hydrological variables from space.

The mission captures L-band signals transmitted by navigation satellites such as GPS and Galileo after they have reflected off Earth's surface. By comparing these reflected signals with those received directly from the navigation satellites, HydroGNSS can derive information on soil moisture, inundation and wetlands, freeze–thaw dynamics, and above-ground biomass, helping scientists better understand the processes shaping our changing planet. *www.esa.int*

H3 launches navigation satellite

The H3's upper stage deployed Michibiki 7 into its target orbit 29 minutes later, eliciting cheers from the folks in mission control.

The two-stage H3 is the successor to Japan's workhorse H-2A rocket, which retired last year after a total of 50 flights.

The H3 — which stands 187 feet or 207 feet (57 or 63 meters) tall, depending on what type of payload fairing it employs — debuted in March 2023 and had eight liftoffs under its belt. Michibiki 7 will be part of Japan's Quasi-Zenith Satellite System (QZSS), a homegrown navigation system that operates high above Earth in geosynchronous orbit. *www.space.com*

System testing against GNSS jamming by NATO

NATO's Communications and Information Agency (NCIA), together with the Finnish Border Guard and the Finnish Defence Forces, has carried out new operational tests of technology designed to detect GNSS jamming and strengthen navigation capability under electronic interference. The trials took place from 6 to 9 July 2026 aboard the offshore patrol vessel Turva and an H215 Super Puma helicopter.

GANDALF-4 is described by NATO as a prototype sensor developed by experts at the NATO Communications and Information Agency (NCIA). The system is designed to detect, classify and locate deliberate attempts to jam or manipulate Global Navigation Satellite System (GNSS) signals, including jamming and deceptive signal manipulation, known as spoofing.

The latest campaign builds on flight tests conducted together with the Finnish Defence Forces aboard an NH90 helicopter during 2025. Through the trials with the Turva and the H215 Super Puma, the evaluation was extended to additional maritime and airborne platforms.

Alongside GANDALF, NCIA also evaluated its latest Controlled Reception Pattern Antenna (CRPA) technology. The technology is designed to help navigation systems continue functioning when satellite navigation signals are subjected to jamming. *https://nordicdefencesector.com*

NVS-03 ready for launch in September by ISRO

The Indian Space Research Organisation (ISRO) is finally ready to fly its next space mission. The space agency is preparing to launch its NVS-03 mission – part of India's navigational satellite series NavIC – in the first week of September, senior officials from ISRO said. The final date will be announced soon.

Recently, Mr. Jitendra Singh, Union Minister of Science and Technology and Space, also confirmed that NVS-03 was ready for launch. The minister also said that after the third of the NavIC series, ISRO will also be launching its subsequent satellites, NVS-04 and NVS-05, in close succession.

The official also confirmed that ISRO will also be launching GISAT-1A or EOS-05 satellite, which is an advanced geo-imaging technology capable of real time monitoring of the Indian territory, in a few weeks after NVS-03.

NavIC, which was planned to be India's version of the US's GPS, Russia's Glonass, Europe's Galileo and China's BeiDou, is currently dysfunctional because of ageing satellites and ISRO's failure to replace them with new ones. *https://theprint.in*

Decimeter-level accuracy with 3GPP-based GNSS RTK

Ericsson and MediaTek have successfully completed a world-first end-to-end (e2e) test of high-precision outdoor positioning. Utilizing standardized 3GPP technology for Global Navigation Satellite System (GNSS) Real-Time Kinematic (RTK), the partners demonstrated positioning accuracy down to a ten-of-centimeters directly over a commercial 5G network.

This test marks a breakthrough for industrial and autonomous applications where precise location data is essential for mission-critical applications. By integrating RTK correction data into the 5G infrastructure via the LTE Positioning Protocol (LPP), the solution eliminates the need for proprietary systems or complex external hardware to achieve centimeter-level precision. *www.ericsson.com*

Canada's first Quantum Defence Innovation Secure Hub

The Quantum Defence Innovation Secure Hub (DISH) under the Bureau of Research, Engineering and Advanced Leadership in Innovation and Science (BOREALIS) was launched early this month in Calgary, Alberta.

Quantum technologies are expected to transform defence and security through advances in sensing, secure communications, navigation, computing, and decision support. The Quantum DISH will provide a secure environment where government, industry, academia, and innovators can collaborate to rapidly develop, test, validate, and transition these technologies into operational capabilities for the Canadian Armed Forces. The hub will strengthen Canada's technological advantage, improve operational effectiveness, and reduce vulnerabilities in contested environments, including threats such as GPS spoofing. A University of Calgary-led consortium will receive $20.3 million over two years to establish and operate the Quantum DISH in Calgary. *www.canada.ca*

5G-powered PNT interoperability by NextNav and Safran

NextNav has entered an agreement with Safran Electronics & Defense to integrate and demonstrate interoperability between NextNav's terrestrial 5G positioning, navigation and timing (PNT) network in Santa Clara County, California, and Safran's timing and navigation receiver. The collaboration will evaluate how terrestrial 5G-powered PNT capabilities can complement existing technologies and contribute to more resilient PNT solutions including drones, autonomous systems etc. *nextnav.com*

Quantum timing trial with UK Royal Navy

Saab UK, Aquark Technologies and the Royal Navy Disruptive Capabilities and Technologies Office (DCTO) have successfully completed a UK trial showing how a military radar network can continue operating without GPS timing. The trial integrated Saab's Giraffe 1X radar capability with Aquark's AQlock quantum technology and is believed to be a the first demonstration of a distributed high-performance military radar network maintaining a coherent operational picture using independent quantum timing sources. *www.saab.com*

JAVAD GNSS introduces GNSS+INS product line

JAVAD GNSS, announced the introduction of its GNSS+INS product line: a family of tightly integrated GNSS and inertial navigation solutions now available for evaluation and integration by qualified users. The line pairs JAVAD's multi-constellation GNSS receivers with proven commercial and defense IMU modules through a purpose-built interface board, giving OEMs a prime navigation system that produces PVT solutions with attitude when satellite signals may be jammed, spoofed, or blocked.

Operators in aviation, maritime, and unmanned systems now encounter jamming and spoofing worldwide, and the platforms most affected (e.g., small UAS, autonomous ground and marine systems) require small compact integrated systems which would allow them to endure navigation gaps.The JAVAD GNSS+INS configuration ships as a pre-assembled stack-up that an integrator can deploy as delivered, or separate and mount to suit the mechanical constraints of the host platform. The interface board handles the electrical connection, time synchronization, and data path between receiver and IMU, removing the cabling, timing alignment, and sensor calibration work previously required by the integrator. *www.javad.com/products/ins*

Quantum Universal Positioning System to be built by Dirac Labs

Dirac Labs has announced its $1.8M pre-seed funding to prototype its quantum sensors and conduct field trials to further refine its technology to provide universal positioning where GPS is unavailable. Quantum sensing offers a resilient, alternative method of positioning by measuring features of Earth's magnetic field, which remains present in environments where GPS signals cannot reach.

TitletownTech, a venture capital firm formed out of a partnership between Microsoft and the NFL's Green Bay Packers, participated in the funding along with Automotive Ventures, Riceberg Ventures, quantumEDGE Ventures, Jude Gomila and Balaji Srinivasan. *www.diraclabs.com*

Microchip advances space-grade timing

Microchip Technology has expanded its atomic clock portfolio with the radiation-tolerant Space CSAC-SA65, a Chip Scale Atomic Clock designed to deliver precise timing for space systems. The device provides a compact, low-power alternative to traditional radiation-hardened timing solutions, helping developers reduce size, weight, power and cost while maintaining accuracy. The Space CSAC-SA65 extends radiation tolerance to at least 30 kRad and operates in extended temperature ranges from –40°C to +80°C. Consuming less than 120 mW and occupying less than 17 cc of volume, the device is optimized for size-, weight- and power-constrained satellite designs. *ir.microchip.com*

Emlid Reach receivers add RTK corrections

Emlid Reach receivers now come with built-in RTK corrections powered by the Point One Navigation network. Emlid Corrections is a professional RTK correction service designed to eliminate the biggest barrier to high-accuracy work — configuring external correction sources. *https://emlid.com*

Xpanner launches X1 Shake-Out

Xpanner has introduced Shake-Out, a GNSS-guided pile distribution application designed for utility-scale solar projects. It replaces manual survey marking and pin hunting with real-time, on-screen guidance, enabling crews to place piles accurately without a dedicated marking team. It addresses several long-standing bottlenecks in solar pile distribution. Survey pins can be difficult to locate or may be missing, while operators traditionally calculate bundle positions, pile counts and colours manually. Progress is also often tracked through phone calls, spreadsheets and end-of-day reports. With Shake-Out, operators follow GNSS-guided target points using visual and audio cues, while configurable distance and angle tolerances allow placement accuracy to be tailored to each project. *xpanner.com*

Trimble Introduces Trimble Arc Agent

Trimble has introduced Arc Agent, a purpose-built artificial intelligence (AI) agent designed to automate office work and eliminate manual processes for transportation and logistics organizations. By reducing reliance on multiple agents, Trimble Arc Agent frees teams to focus on high-level strategy where human decision-making matters most. Offered as a subscription-based software-as-a-service (SaaS) solution, it connects directly to existing transportation management systems (TMS) and third-party applications like Gmail and Outlook. By securely extracting and validating data from unstructured channels — such as emails, PDFs and spreadsheets — it allows teams to turn real-world inputs into actionable, system-of-record data. It bridges the gap between the physical supply chain and digital back-office systems by automating the flow of information. *https://news.trimble.com*

IHI Corporation and Kuva Space partnership

IHI Corporation, Japan's and Kuva Space of Finland have signed a memorandum of understanding (MoU) to expand their cooperation on hyperspectral satellite data and services. Both the companies will evaluate Kuva Space's constellation capacity, define requirements for a Japanese sovereign hyperspectral constellation, and explore business structures to build and operate that capability in Japan, including potential domestic satellite manufacturing. The agreement comes amid a wider shift from individual satellite missions toward persistent, multi-sensor intelligence built with commercial providers. For IHI, the MoU will assess how hyperspectral sensing could be integrated at constellation scale into the sovereign Earth-observation

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September 2026

Intergeo 2026
15 - 17, September
Munich, Germany
https://dvw.de/intergeo/en

21st International 3D GeoInfo Conference
28 - 29 September
Sofia, Bulagria
https://gdmc.nl/3DCadastres/workshop2026

October 2026

14th International FIG Workshop on the Land Administration Domain Model & 3D Land Administration
1 - 2 October
Sofia, Bulagria
https://gdmc.nl/3DCadastres/workshop2026

ICL-GNSS 2026,
6 - 8 October
Rome, Italy
https://events.tuni.fi

3rd Annual International Geotechnical Innovation Conference
12 - 13 October
Jeddah, Saudi Arabia
https://geotechnicalinnovationconference.com

47th Asian Conference on Remote Sensing
12 - 16 October 2026
New Delhi, India
https://acrs2026.in

GoGeomatics Expo 2026
26 - 28 October
Calgary, Alberta, Canada
https://gogeomaticsexpo.com

ICRSGISA-26
30 - 31 October
Barcelona, Spain
https://iser.org.in

November 2026

United Nations World Geospatial Information Congress (3rd UNWGIC)
16 - 19 November
Jeddah, Saudi Arabia
https://ggim.un.org/3UNWGIC

Geoworld
23 - 26 November
Dubai, UAE
https://www.geoworldevent.com

Pacific Islands GIS & Remote Sensing User Conference
30 November - 4 December 2026
Suva, Fiji
https://pgrsc.org

December 2026

IEEE India Geoscience & Remote Sensing Symposium
01 – 04 December 2026, Hyderabad, India
https://ingarss2026.co.in

system it is building for Japan, alongside optical, radar, infrared, radio-frequency and VDES (next generation of AIS) capabilities. *https://kuvaspace.com*

BEL and Esri India sign MoU

Bharat Electronics Limited (BEL), a Navratna Defence Public Sector Undertaking signed a Memorandum of Understanding (MoU) with Esri India on August 3rd 2026, aimed for Cooperation in Surge Deployment for BEL/Defence Services.

The MoU will help to leverage the opportunities in the defence sector by combining BEL's deep domain expertise in defence electronics and systems integration with Esri India's GIS, location intelligence and GeoAI capabilities.

Esri India will also extend training support to BEL to help them build in-house capability in GIS and GeoAI on its 'Indo ArcGIS' platform. *https://bel-india.in*

Intermap acquires PCI Geomatics

Intermap Technologies has entered into a definitive arrangement agreement with PCI Geomatics Group Inc. and Grenadier Investments Limited, a major shareholder of PCI. Intermap will acquire all of the issued and outstanding shares in the capital of PCI not already owned by Intermap by way of an arrangement under the Canada Business Corporations Act Intermap will use $11 million of cash to complete the transaction. *www.intermap.com*

BAE Systems and Tualcom collaboration

BAE Systems, UK has signed an MoU with Türkiye-based Tualcom to explore collaboration on technologies that will enable the next generation of autonomous air capabilities to thrive in the modern battlespace. Both the companies will investigate opportunities to integrate resilient navigation, advanced communications and electronic warfare technologies into future autonomous platforms. *www.baesystems.com*

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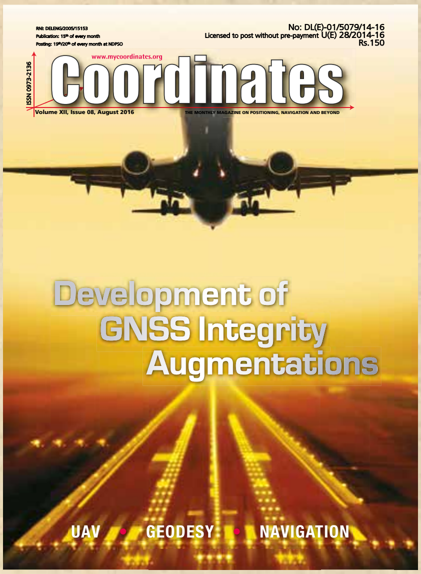

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Lessons Learned from the Development of GNSS Integrity Augmentations

Sam Pullen, Stanford University Stanford, USA

This paper describes lessons learned from my experience in the development of safety-critical GNSS applications for civil aviation. They show how the challenges to integrity and continuity design and verification differ from maximizing performance in typical GNSS environments. While GPS satellite failures that threaten integrity have historically been rare, the limited number of observed failures makes it difficult to build models that can be assured to bound worst-case failure events with certainty.

Comprehension of the Eye of the Navigator

LtCdr Odd Sveinung Hareide, Royal Norwegian Naval Academy, Navigation Competence Centre, Norway
Dr Runar Ostnes, Associate Professor, Norwegian University of Science and Technology, Department for Advanced Maritime Operations, Norway

The use of Eye Tracking equipment as a tool to develop maritime navigation has a clear potential. Data from Eye Tracking can be analyzed to identify pros and cons concerning bridge layout and GUI to identify visual attention thieves.

The integration of UAVs into the civilian airspace will open up a new market

Siddappaji B, Scientist E, ADE, Defence Research and Development Organization (DRDO), India

As UAVs are making significant contributions in the commercial sector, the integration of UAVs is one of the challenging task to policymakers as there are no comprehensive policy and regulations, which are need to be formulated immediately to reap the benefits of UAVs. Military, Research organizations are allowed to use the airspace for UAVs, but commercial organizations are not permitted to put UAVs in to the sky.

Indoor Maps – the new frontier of mapmaking

Joseph Leigh, Head of Venue Maps, HERE
Stefan Gimeson, PM Venue Maps Platform, HERE

Over the past five years, mapmaking has soared beyond the boundaries of walls of buildings, penetrating deep inside complexes with multi-floor, room-level maps becoming available for shopping centers, airports, train stations and even hospitals and office buildings.

The wider potential market is still waiting for solutions

Matteo Faggin, GiPStech Srl

We constantly face has to do with the lack of a standard in the field. Most of IPS provider communication and consequently of prospective customer attention focuses on precision of localization, while this is only one metric (although important) that influences the outcome of a good implementation: stability, responsiveness, lag time and computation power required are some of the other important factors that should be considered in determining what is the best solution to the specific use case.